Asian Cities Climate Resilience

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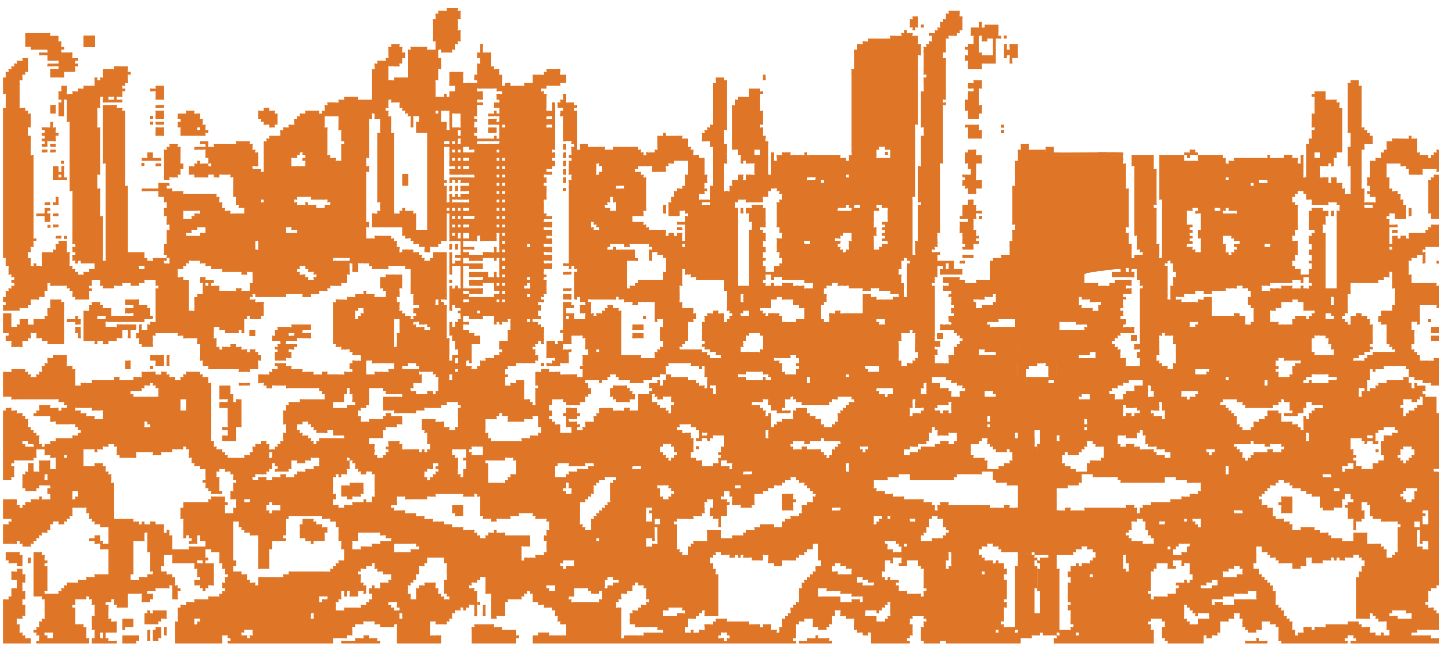
The impact of urban heat islands

Assessing vulnerability in Indonesia

BY TUMIAR KATARINA MANIK AND SYARIFAH SYAUKAT



About the authors

Tumiar Katarina Manik (Universitas Lampung, Perhimpi Lampung) and Syarifah Syaukat (Pusat Studi Geografi Terapan Universitas Indonesia)

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Abstract

The impacts of global change can be felt by local communities during both short-term events such as intense storms and long-term changes such as rising temperatures and changing rainfall patterns. Natural disasters related to hydrometeorology are likely to increase in severity, while in coastal areas sea-level rises require serious attention. At city scale, with high levels of urbanisation, local rising temperatures can affect the quality of life of communities. Urban heat islands (UHI) reflect the magnitude of the difference in observed ambient air temperature between cities and their surrounding rural regions. This study aims to identify whether the urban heat island phenomena is occurring two cities in Indonesia: Jakarta, a large metropolitan city with a business and industrial background, and Bandar Lampung, a growing city with an agricultural background. The aim is to identify community vulnerability to UHI impacts and community adaptation efforts related to UHI.

The results show that UHI is present in both Jakarta and Bandar Lampung. The UHI was clearly evident in morning temperatures in Bandar Lampung, showing that the area surrounding the city had more air moisture due to vegetation land cover, compared to the city area. In Jakarta the UHI effect was clearly visible in the afternoon, and the highest temperature was in high density settlement areas compared to the business and industrial area. Communities in both Bandar Lampung and Jakarta were assessed to have average (moderate) vulnerability levels. Bandar Lampung's moderate vulnerability level is due to low levels of community knowledge of climate change impacts and public facilities, but there were indications of adaptation in the form of natural spontaneous adaptation. Jakarta faces rising temperatures but has low adaptation levels which could be due to low participation in community programmes in general.

1 Introduction

Urbanisation is occurring across Indonesia. The World Bank projects that between 2010 and 2025 the population of 11 big cities in Indonesia (including Jakarta and Bandar Lampung) will increase by an average of 309,000 people per year (World Bank, 2012). By 2025, approximately 67.5 per cent of Indonesia's population will live in urban areas (ibid). In terms of urban growth rates, Indonesia and China have urbanised most rapidly in percentage terms in the period from 1970 to 2010. The trends indicate that Indonesia is likely to continue to urbanise at relatively high rates for the next decade. Java is the most urbanised region, with almost 50 per cent of its population living in urban areas, followed by Kalimantan and Sumatra with 36.3 and 34.0 per cent respectively (World Bank, 2012).

Alongside this urbanisation, the impacts of climate change are being felt increasingly. Air temperatures are slowly rising as one consequence of global climate change, with adverse effects including melting Arctic sea ice, rising sea levels, increased frequency and intensity of tropical storms, changes in the air circulation pattern and alterations in seasonal patterns (IPCC, 2007.

At the local scale, especially in urban areas, waste heat produced by human activities, including heat generated by vehicle combustion and industrial processes, the conduction of heat through building walls or emitted directly into the atmosphere by air-conditioning systems, and the metabolic heat produced by humans all combine to cause local air temperatures to rise, especially in urban areas. This phenomenon is known as 'urban heat islands' (UHI) (Allen *et al*., 2010).

Elevated global temperatures may thus be compounded by the additional stress resulting from the urban heat island phenomenon. As a result, it is expected that the effects of climate change on rising temperatures will be felt most severely in the world's cities or urban areas (Watkins *et al*., 2013).

This study seeks to carry out an assessment of the UHI phenomena, alongside a vulnerability assessment of the effects of UHI, in two Indonesian cities of differing size, Jakarta and Bandar Lampung. This will enable an identification of priority areas for action in UHI adaptation programmes that are adequately tailored for a given community. The study assesses the existence of UHI by measuring local air temperature. It applies the Intergovernmental Panel on Climate Change (IPCC) definition of vulnerability to measure the exposure, sensitivity and adaptive capacity of the population in the urban area. This study is important in a context of increasing urban development in Indonesia, in which a growing population will be exposed to the effects of UHI in addition to other climate change impacts.

The study will achieve the above aims by examining the urban heat island phenomena in Jakarta, a metropolitan city which function as the political, business and industrial centre for Indonesia, and Bandar Lampung, a growing city with an agricultural background. The study will identify community vulnerability to UHI impacts and community adaptation efforts related to UHI. The findings will enable targeted responses in terms of building awareness of potential UHI impacts in at-risk areas, as well as offering possible pathways in terms of adaptation of urban planning and development processes in Indonesian cities.

1.1 What are urban heat islands?

The urban heat island (UHI) effect is the magnitude of the difference in observed ambient air temperature between cities and their surrounding rural regions (Landsberg, 1981 in Wengha *et al*., 2004). The magnitudes of the differences can be quite large at times depending on weather conditions, urban thermophysical and geometrical characteristics, and anthropogenic moisture and heat sources present in the area.

The UHI is created primarily by dense concentrations of heat-absorbing, impervious building materials that trap more heat during the day and release it more slowly at night than natural ground cover, such as soil and vegetation (Voogt, 2002 in Harlan, *et al*., 2006).

At the regional scale, land-use patterns and land cover are the strongest drivers of urban temperatures. Urbanisation replaces vegetated surfaces – which provide shading, evaporative cooling and rainwater interception, storage and infiltration functions – with impervious built surfaces (Whitford *et al*., 2001). Currently, 54 per cent of the world's population lives in urban areas, of which nearly half live in smaller settlements of fewer than 500,000 inhabitants (United Nations, 2014). Population growth and continued urbanisation are expected to add another 2.5 billion urban dwellers by 2050, and 90 per cent of this increase is expected to be in Africa and Asia (ibid, 2014). In this context, it is important to understand the potential for UHI effects to manifest themselves, and how urban populations can adapt to these effects to minimise the risks to their lives.

There are a number of existing city-level studies of UHI effects and their relation to land cover and other causes. Quantitative analysis in Bandung, Indonesia from 1994 to 2002 showed that the area with high air temperatures of 30–35^{0}C became wider following an increase in housing and industrial areas with the rate of 4.47 per cent per year (about 12,606 ha) (Tursilowati, 2011). The same results were found in other big cities in Indonesia such as Semarang with rate of 8.4 per cent (12,174 ha) and Surabaya with the rate 4.8 per cent (1,512 ha) (ibid).

Wenga (2004) examined land surface temperature patterns and their relationship with land cover in Guangzhou and in urban clusters in the Zhujiang Delta, China and concluded from a remote sensing investigation that vegetation abundance is one of the most influential factors in controlling land surface temperatures.

In the UK the largest heat island is found in London with night-time temperatures up to 7°C warmer than rural temperatures 20 km away. Notably the greatest urban heat island intensity in London is experienced overnight with the lowest increased urban temperature being in the early afternoon (Watkins *et al.,* 2013).

The monthly mean maximum UHI intensity in Chiang Mai and Songkhla in Thailand were the greatest in April (2.73°C and 2.70°C), during the Thai hot season, while the weakest mean maximum UHI intensity in Chiang Mai was found in August, and in Songkhla was found in July, corresponding to the rainy season. Many previous studies have indicated that the UHI intensity was related to local meteorological conditions (Jongtanom *et al*., 2011). In Seoul, Korea, the most prominent occurrence of the maximum UHI intensity has a peak at 4.5°C when there is zero cloud cover (Kim and Baik, 2002).

The spatial variability in temperatures measured traversed across the urban area of Portland on hot days showed that temperatures varied by 5.5°C across the area measured. Annual mean temperatures at stations in populated areas of 10,000 people or more were 0.1°C warmer than nearby stations located in rural areas with a population of 2,999 (Hart and Sailor, 2009). In the city of Szeged, Hungary, seasonal mean temperature differences between urban and suburban areas on calm and cloudless days ranged from 1.5–2°C; while in Alaska, urban areas were 2.20C warmer than rural areas. In Poland, under favourable weather conditions, the highest temperature difference between urban and rural stations reached 80°C (Bulut *et al*., 2008).

These observations show that temperature rises and the UHI effect is evident in urban areas, though there is scope for further research in understanding the vulnerability of local populations to UHIs. As this could affect the quality of life for urban residents, this study seeks to fill this research gap for Jakarta, the capital city of Indonesia, and Bandar Lampung, a medium-sized city.

1.2 What are the impacts of urban heat islands?

Urban heat islands (UHIs) have the potential to become one of the largest problems associated with the urbanisation and industrialisation of human civilisation, as the increased temperatures associated with UHIs tend to exacerbate the threats to human health posed by thermal stress. As a result, the UHI has been a central theme among climatologists, and is well documented in many metropolitan areas around the world (Tan, *et al*., 2010).

The IPCC reports that incidences of heatwaves increased towards the end of the 20th Century and are projected to continue to increase in frequency, intensity and duration worldwide (IPCC, 2007). The actual impacts of urban climate change and heat islands depend on the characteristics of local climates. Exposure to excessively warm weather is a global threat to human health and well-being. Most UHI impact studies relate UHI impacts on human health on hot days. Heat-related illness includes: heat stress, heat cramps, heat syncope, heat edema, heat exhaustion and heat stroke (California Department of Health, 2007).

Studies of heatwaves and mortality in Shanghai, China (Tan *et al*., 2010) and in the USA (Chestnut *et al.,* 1998 in Reid *et al*., 2009; Harlan *et al*., 2006; Klinenberg, 2001) demonstrate that days with increased temperatures or periods of extended high temperatures have increased heat-related mortality. More deaths are attributed to heat in temperate climates than in warm climates because people in temperate zones are less acclimatised to high temperatures (Kalkstein and Davis, 1989; Kalkstein and Greene, 1997). Climatically diverse cities, such as Toronto, Canada and Sao Paolo, Brazil report excess mortality attributable to extreme heat (Patz *et al*., 2005; Smoyer *et al*., 2000). Notable recent events include the heatwaves of 2003, which killed an estimated 35,000 Europeans in two weeks (Larsen, 2003) and more than 1,900 people in India (IFRC, 2003 in Harlan *et al*., 2006).

UHI also has impacts on water availability and safety, as lower water levels and warmer water temperatures in a drinking water source can increase the risk of contamination. Since higher water temperatures decrease the dissolved oxygen level, water will require additional treatment to be used as drinking water. Because urban development often involves expanding paved or concrete areas at the expense of green space, it can result in increased flooding and run-off during a storm. Increased run-off can carry contaminants such as oil, chemicals and microbes into drinking water sources, with implications for public health. Additionally, the development of homes using individual groundwater wells and septic tanks can potentially result in an increase in nutrients in surface water or contamination of groundwater due to septic effluent.

The direct impact of climate change on water resources concerns the availability of water supply due to increasing temperature and precipitation variability. Warmer temperatures may lead to increased demand by water utility customers while the water supply is limited. Moreover, increased water temperature affects water quality due to the increased use of disinfectant for killing germs (Rayburn, 2008).

Projections show that the heat differential between urban centres and surrounding areas will grow wider in the future, increasing the relative health risks for poor and vulnerable populations who reside in cities. Analysing the risks and understanding the spatial variations in vulnerability, as this study does, will allow policymakers to develop adaptation responses tailored to the needs of certain communities and different sorts of risk.

1.3 Vulnerability assessments of urban heat island impacts

Vulnerability assessments are needed to assess the extent to which communities are vulnerable to changing environmental conditions, and thus identify what steps they should take to adapt to these changes. In this study, the vulnerability assessment tries to bridge the gap between the social, natural and physical sciences, and by doing so aims to contribute new methodologies which could be applied in other urban areas. Whilst there are a variety of approaches to carrying out vulnerability assessments, many of the methods rely heavily on the IPCC working definition of vulnerability as a function of exposure, sensitivity and adaptive capacity (Hahn *et al*., 2009). Vulnerability hence assesses the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes and in the context of this study, the vulnerability of urban residents is the focus. Within the hazards literature, vulnerability has many different connotations, depending on the research orientation and perspective. Physical vulnerabilities are the amount of potential damage that can be caused to a system by a particular hazard (Allen, 2003). Social vulnerability on the other hand is determined by factors such as poverty, inequality, marginalisation, access to health and housing quality (Blaikie *et al*., 1994). Vulnerability defines the extent to which people are susceptible to harm from or unable to cope with a particular hazard (Kazmierczak *et al.,* 2010).

1.4 Approaches to assessing vulnerability

The vulnerability assessment process can include a diverse set of methods used to systematically integrate and examine interactions between humans and their physical and social surroundings.

The IPCC definition can be expressed as:

vulnerability = function [exposure (+); sensitivity (+); adaptive capacity (–)]

(IPCC, 2007).

Exposure refers to the degree to which a system is exposed to significant climatic variations. Sensitivity refers to the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli, whilst adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007).

Different regions and groups will respond to the same event differently. The way in which an impact of climate change is felt will be a combination of the degree to which a system is exposed and the degree to which a system is sensitive to changes in climate variables. When a region or a system is exposed to changes in climate, sensitivity determines the extent to which various receptors in the system are affected positively or negatively.

A common approach to assessing vulnerability goes through the following steps: selection of adequate indicators (e.g. statistical data about the population being studied) and geographic information system (*GIS*) and remote sensing (RS) (geodata, administrative units, and thermal data) for calculating the exposed area. Sensitivity is calculated using indicators such as age and unemployment. The data is then normalised, weighted and aggregated in a composite indicator (Welle, 2011).

Klein (2004) concluded that while several vulnerability indices have been developed, all have been criticised, and none have been widely used. An index that focuses on one type of impact in one region is likely to be more informative and useful, whilst retaining the multiple dimensions of vulnerability. In short, the development of vulnerability indices continues to present an academic challenge. Vulnerability assessments require different information, methodologies and spatial and temporal scale depending their objectives, and the appropriate indicators can be elicited by feedback from expert meetings and interviews with public officials (Koh, 2010).

In this study, the vulnerability index approach based on the IPCC definition was chosen as the most widely used index. However, as a vulnerability study specific to UHI is new both in Bandar Lampung and Jakarta, there is no existing UHI vulnerability index in these areas. Therefore, two approaches are used in this index. The first is comprised of the livelihood vulnerability index (LVI) as a composite index comprised of major components, while the second aggregates the major components into the three contributing factors to vulnerability: exposure, sensitivity and adaptive capacity (Hahn, *et al*.,2008). The LVI uses a balanced weighted average method where each sub-component contributes equally to the overall index even though each major component is comprised of a different number of sub-components. LVI is intended as an assessment tool accessible to diverse users in resource-poor settings.

LVI-IPCC is an alternative method for calculating the LVI that incorporates the IPCC vulnerability definitions: exposure, sensitivity and adaptive capacity. Both of these indices can be constructed from primary data from household surveys, which is beneficial in areas where secondary data might not available such as Bandar Lampung. As this approach does not require a complicated model, it could be easily replicated in other Indonesian cities.

2 Studying urban heat islands in Jakarta and Bandar Lampung

This research was conducted in Jakarta and Bandar Lampung to investigate the urban heat island effect in two different types of city: a metropolitan city and a developing medium-sized city. Besides these different characteristics, they were chosen because both provinces had previously conducted another vulnerability study related to hydrometeorological disaster under the API Perubahan (Adaptation to climate change and resilience to disaster risk) project. The API Perubahan project (2009–2013) was supported by USAID and conducted by Mercy Corps Indonesia together with Masyarakat Penanggulangan Bencana Indonesia (MPBI, Indonesian Community of Disaster Relief), and implemented by several stakeholders in targeted provinces: Jakarta, Bandar Lampung, West Sumatra and Maluku. Bandar Lampung is also participating in the Asian Cities Climate Change Resilience Network (ACCCRN) initiative, which included a community-based vulnerability assessment process. As part of the ACCCRN process, Bandar Lampung developed a city climate change resilience strategy for 2011–2030. This study of UHI impacts will complement and add to the existing climate vulnerability studies in both cities.

2.1 Background: Bandar Lampung and Jakarta

As stated above, the UHI effect is created primarily by dense concentrations of heat-absorbing, impervious building materials that trap more heat during the day and release it more slowly at night than natural ground cover, such as soil and vegetation (Voogt, 2002 in Harlan, *et al*., 2006). At the regional scale, land-use patterns and land cover are the strongest drivers of urban temperatures. Sarkar (2004) noted that the UHI phenomenon is the warming in the city area due to unexpected changes in landcover and population density. For these reasons, this study included secondary data on land use, population, roads and vehicles and industrial development of each city, which may serve as explanatory factors for the UHI phenomena in the cities.

2.1.1 Administration

Jakarta is the Indonesian capital city, covering 66,233 ha of land area and 6,977 ha (2,694 square miles) of sea area with a population of 10.18 million as of November 2011. It is a metropolitan city with intense business and industrial activities (1,699 large and medium enterprises) (Biro Pusat Statistik Jakarta, 2013). As growing numbers of buildings and roads are developed, the land area for open and green spaces is declining. Dokumen Perencanaan Kota Jakarta (2010) mentioned that 16,955 ha is occupied by buildings for business, government and industries while 33,182 ha is for housing, and only 7,169 ha is green open space.

Bandar Lampung on the other hand is a medium-sized city. Its position as the gateway province from Jakarta to Sumatra Island attracts people and investors. With an area of 19,722 ha and a population of just over 900,000 (2012) Bandar Lampung has 147 large industries. Compared to Jakarta, Bandar Lampung still has 9,963.58 ha of agricultural land and 532.62 ha of forest. It has 1,392.36 ha of industrial areas; 6,640.58 ha of residential areas; and 51.13 ha of abandoned open space (Badan Pusat Statistik Lampung, 2013).

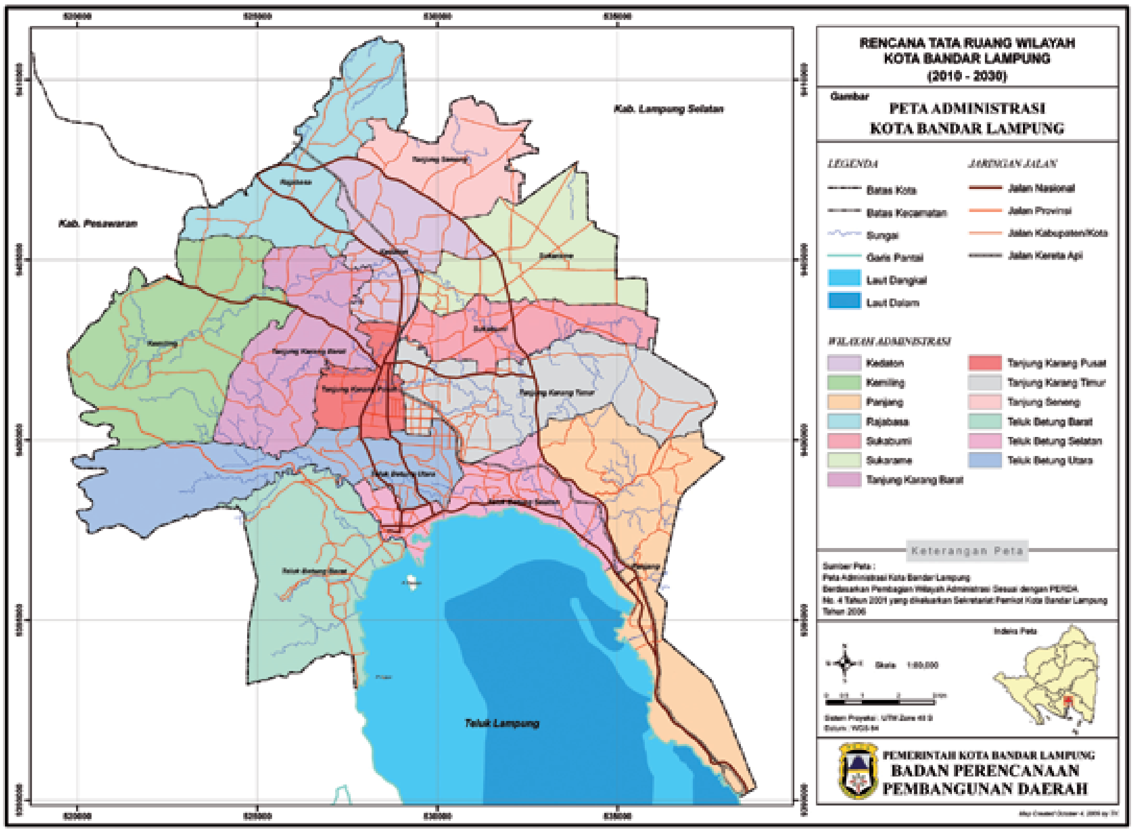
Jakarta is divided into six administrative areas while Bandar Lampung is divided into 13 districts. (see Table 1 and Figure 1).

Table 1. Administration division of Jakarta and Bandar Lampung

Jakarta	**Area (ha)**	**Bandar Lampung**	**Area (ha)**
Seribu Islands	870	Teluk Betung Barat	2,099
South Jakarta	14,127	Teluk Betung Selatan	1,007
East Jakarta	18,803	Panjang	2,116
Central Jakarta	4,813	Tanjung Karang Timur	2,111
West Jakarta	12,954	Teluk Betung Utara	1,038
North Jakarta	14,666	Tanjung Karang Pusat	668
		Tanjung Karang Barat	1,514
		Kemiling	2,765
		Kedaton	1,088
		Rajabasa	1,302
		Tanjung Seneng	1,163
		Sukarame	1,687
		Sukabumi	1,164
Total	66,233	**Total**	19,722

Source: BPS Provinsi Jakarta (2013) and BPS kota Bandar Lampung (2013)

Figure 1. Administration maps of (a) Bandar Lampung and (b) Jakarta



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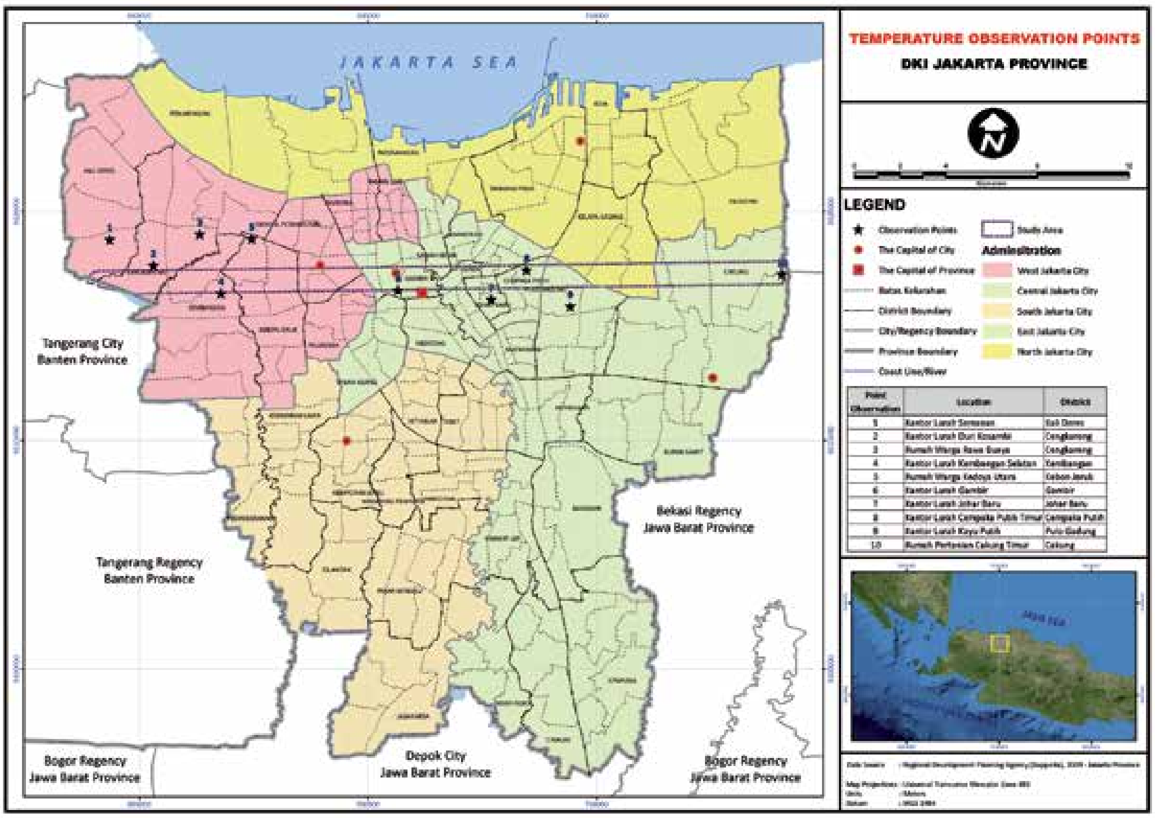

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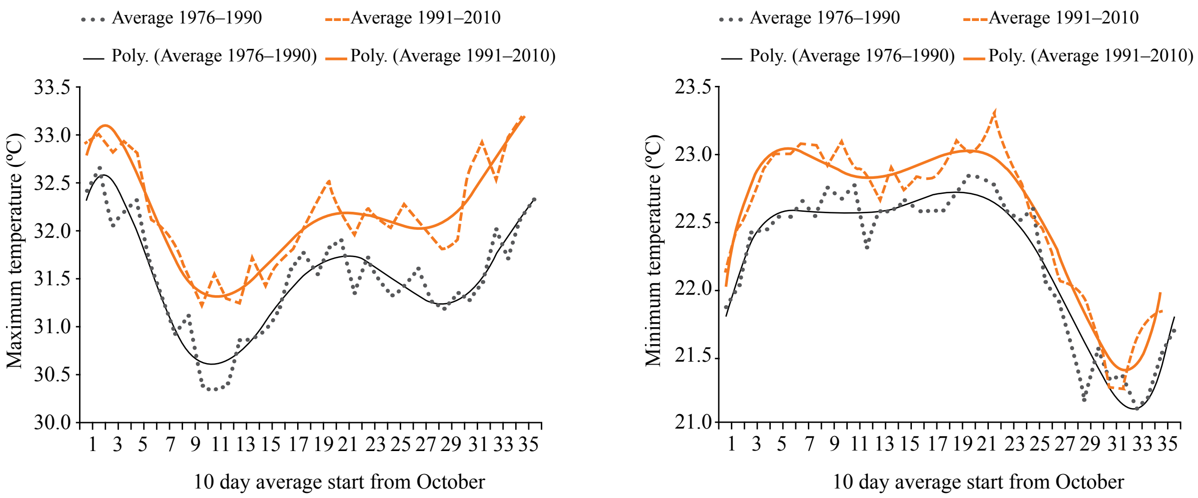
Sources: BAPPEDA Provinsi DKI Jakarta (2013) and BAPPEDA kota Bandar Lampung (2013)

2.2 Tracking global warming through long-term air temperature trends

2.2.1 Air temperature trends in Bandar Lampung

Figure 2 shows average air temperatures in Bandar Lampung in 1976–1990 and 1991–2010; both maximum and minimum temperatures in the latter period were higher than the former. The average rise was 0.7ºC for maximum temperatures and 0.32ºC for minimum temperatures while the difference between maximum and minimum temperatures rose on average by 0.4ºC.

Figure 2. Maximum and minimum air temperature trends comparing 1976–1990 and 1991–2010

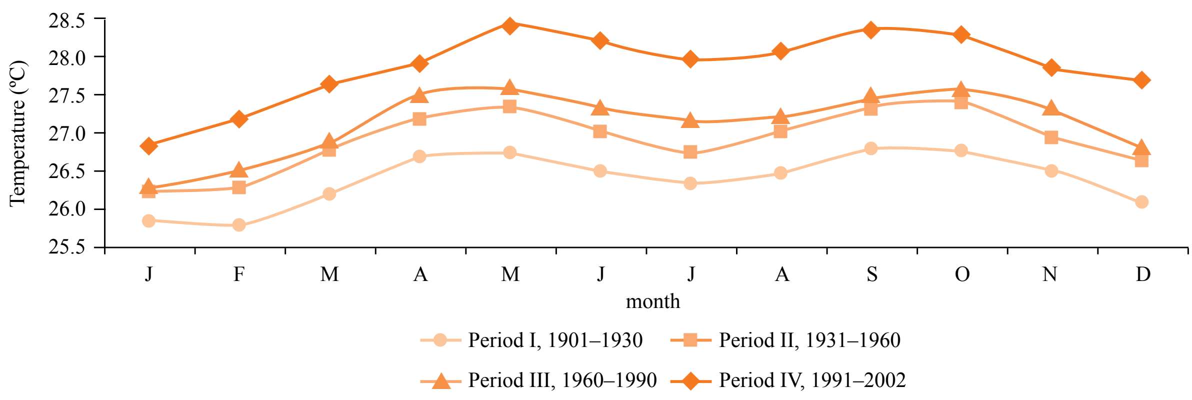


Source: Manik (2013).

2.2.2 Air temperature trends in Jakarta

Figure 3 shows the temperature trends from 1901–2002 divided into four periods. During the first period (1901–1930), the average air temperature of Jakarta was 26.4ºC while in the second period (1931–1960) temperatures rose by 0.018ºC/year and in the third period (1961–1990) by 0.025ºC/year. The fourth and most recent period (1991–2002) saw the largest temperature rise of 0.124ºC/year.

Figure 3. Air temperature trends in Jakarta 1901–2002



Source: BAPPEDA Provinsi DKI Jakarta (2013)

2.3 Land use in Jakarta and Bandar Lampung

Bandar Lampung land use is still predominantly agriculture and other open spaces (50.52 per cent) followed by residential (33.67 per cent). Only a small portion is used for industry (2.84 per cent). In comparison, almost 59 per cent of the land area in Jakarta is residential, about 10.31 per cent is industrial and business related, and about 7.89 per cent is covered by vegetation (including agricultural activities).

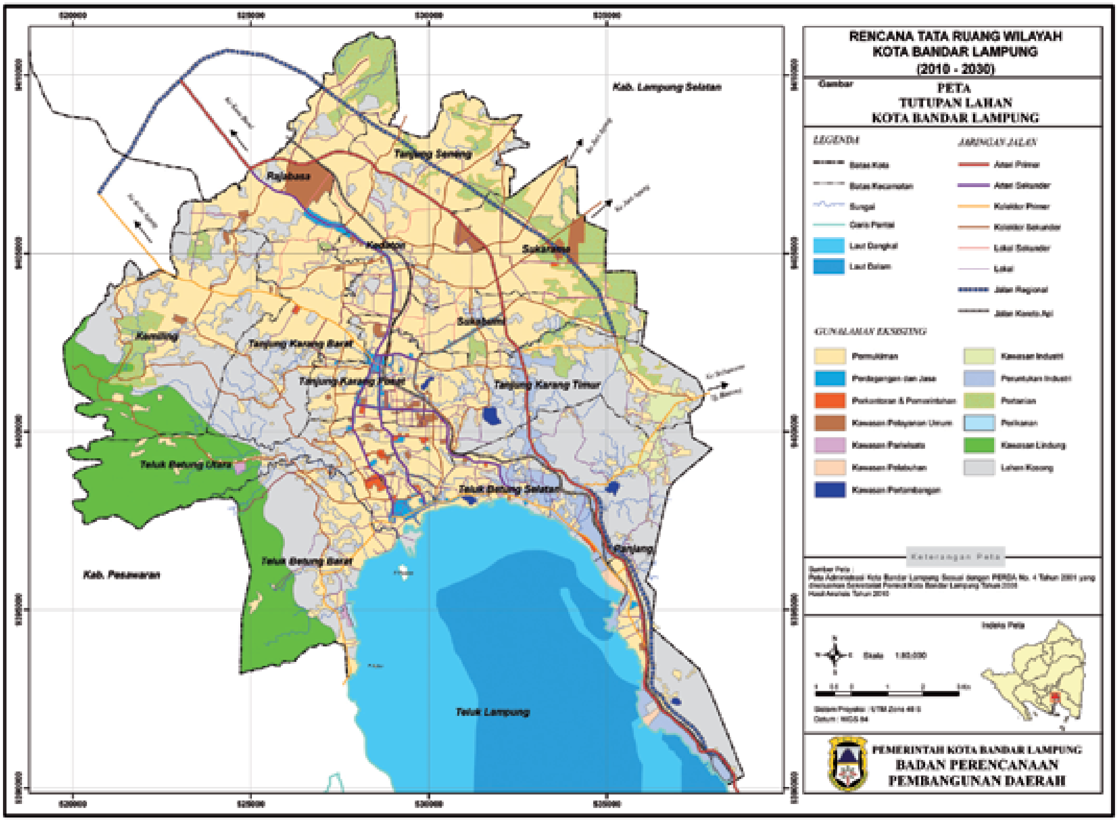
In 2013, Jakarta land use was still predominantly residential because of the high population density. Figure 4, Table 2 and Table 3 describe the land use in Bandar Lampung and Jakarta.

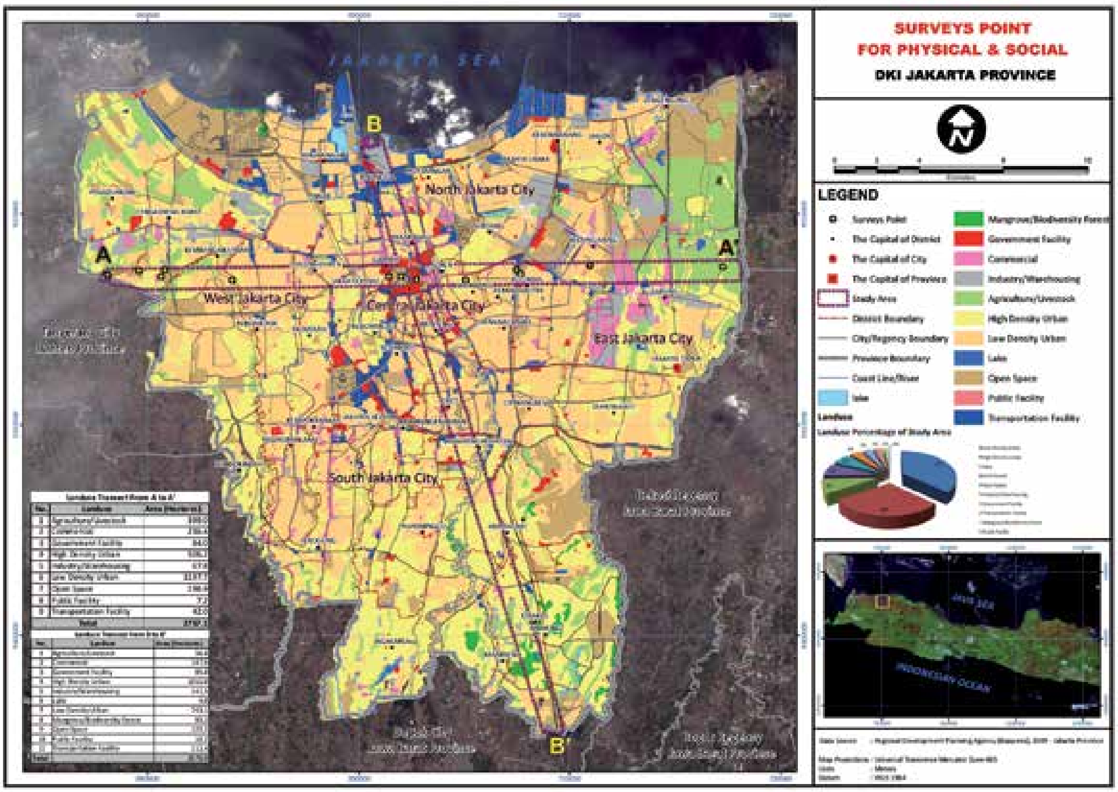
Table 2. Land-use distribution in Bandar Lampung from 2008–2012

Land use (km^2)	2008	2009	2010	2011	2012	Percentage (2012)
Residential	6,209.79	6,251.19	6,325.19	6,335.19	6,640.58	33.67
Agriculture	10,810.55	10,522.94	10,448.49	10,435.44	9,963.58	50.52
Forest	452.82	532.62	532.62	532.62	532.62	2.70
Swamp	9.75	5.50	5.50	5.50	5.50	0.03
Business	352.14	312.76	312.76	312.76	333.92	1.69
Industrial	268.20	488.20	488.93	488.93	560.19	2.84
Services	384.05	438.20	438.20	441.41	498.25	2.53
Other	1,195.58	1,150.64	1,150.64	1,150.64	1,136.23	5.76
Abandoned	39.12	19.72	19.72	19.72	51.13	0.26
Total	**19,722.00**	**19,721.77**	**19,722.05**	**19,722.21**	**19,722.00**	**100.00**

Source: Badan Pusat Statiktik Bandar Lampung (2013)

Figure 4. Maps showing land-use in Bandar Lampung and Jakarta: a possible reason for UHI?





Source: Sources: BAPPEDA Provinsi DKI Jakarta (2013) and BAPPEDA kota Bandar Lampung (2013)

Table 3. Land-use distribution of Jakarta

Land use	Total area (ha)	Percentage
Low-density settlements	21,302.50	32.16
High-density settlements	17,670.70	26.68
Business/commercial premises	1,728.70	2.61
Government facilities	1,187.20	1.79
Industrial warehouses	1,006.70	1.52
Markets	980.00	1.48
Industrial plants	787.80	1.19
Workshops	781.90	1.18
Warehousing	587.50	0.89
Fisheries	3,883.50	0.06
Wet agriculture	770.80	0.01
Dry agriculture	498.10	0.01
Livestock	71.90	0.00
Open spaces	4883.10	0.07
Cemeteries	339.10	0.01
Education facilities	313.10	0.00
Transport facilities	161.70	0.00
Public facilities	100.00	0.00
Other	9178.70	0.14
Total	**66233.00**	**69.80**

Source: BAPPEDA Provinsi DKI Jakarta (2013)

2.4 Population statistics

As a city's population grows there is a need to expand the area for housing, the capacity of existing water resources and public facilities. Table 4 and Table 5 describe the population in Bandar Lampung and Jakarta. Population growth caused by urbanisation is the main problem for big cities, especially Jakarta. The 2010 census showed that population density in Jakarta was 147.38 people/ha compared to Bandar Lampung 44.60 people/ha. The population of Jakarta in 2012 was 9.7 million, so therefore the growth rate in Jakarta can be calculated as x 1.41/year. The population of Bandar Lampung in 2012 was 934,964 therefore its growth rate can be calculated as x 0.06/year for 2000–2010.

Table 4. Bandar Lampung population in 2010

Districts	Area (ha)	Number of population			Distribution (%)	Density (person/ha)
		Male	Female	Total		
Teluk Betung Barat	2,099	30,785	28,850	59,635	6.78	28.41
Teluk Betung Selatan	1,007	46,642	44,613	91,255	10.37	90.62
Panjang	2,116	32,358	30,896	63,254	7.19	29.89
Tanjung Karang Timur	2,111	44,430	44,045	88,475	10.06	41.91
Teluk Betung Utara	1,038	31,391	30,899	62,290	7.08	60.01
Tanjung Karang Pusat	668	35,870	36,797	72,667	8.26	108.78
Tanjung Karang Barat	1,514	32,141	31,307	63,448	7.21	41.91
Kemiling	2,765	35,427	35,287	70,714	8.04	25.57
Kedaton	1,088	43,714	43,673	87,387	9.93	80.32
Rajabasa	1,302	23,076	21,592	44,668	5.08	34.31
Tanjung Seneng	1,163	20,682	20,509	41,191	4.68	35.42
Sukarame	1,687	35,524	35,355	70,879	8.06	42.01
Sukabumi	1,164	32,333	31,455	63,788	7.25	54.80
Total	**19,722**	**444,373**	**435,278**	**879,651**	**100.00**	**44.60**

Source: BAPPEDA Provinsi DKI Jakarta (2013) and BAPPEDA kota Bandar Lampung (2013)

Table 5. Jakarta population in 2012

Cities	Area (ha)	Number of population			Distribution (%)	Density (person/ha)
		Male	Female	Total		
Seribu Islands	870	11,854	11,275	23,129	0.24	26.59
South Jakarta	14,127	1,054,501	998,144	2,052,645	21.03	145.30
East Jakarta	18,803	1,423,261	1,341,603	2,764,864	28.32	147.04
Central Jakarta	4,813	542,784	518,555	1,061,339	10.87	220.52
West Jakarta	12,954	1,144,264	1,070,137	2,214,401	22.69	170.94
North Jakarta	14,666	849,725	795,304	1,645,029	16.85	112.17
Total	**66,233**	**5,026,389**	**4,735,018**	**9,761,407**	**100.00**	**147.38**

Source: Badan Pusar Statistik Jakarta (2013)

2.5 Industrial statistics

The main industries that support the economy of Bandar Lampung are listed in Table 6, with non-oil and gas manufacturers and transportation representing the biggest shares. The main industries in Jakarta (Table 7) are finance, real estate and hotels and restaurant, processing industries and construction. Logically, these types of business in Jakarta need space for buildings and large developments.

Table 6. Type of industries that mainly support the Bandar Lampung economy

Type of Industries	IDR Million	Percentage	Growth rate
Agriculture	1,418,138	8.93	2.06
Mining	204,450	1.29	3.47
Non-oil and gas manufacturers	5,590,237	35.2	5.93
Trade, hotels, restaurants	3,325,722	20.94	4.13
Transport and communications	5,343,852	33.65	7.22
Scale of industries			**Number**
Large to medium			147
Small			2175
Household level			7010

Source: Badan Pusat Statistik Bandar Lampung (2013).

Table 7. Industrial development in Jakarta

Type of business	GDP basis of prevailing prices		Percentage	Rate
	2009	2012		
Farming	762,980	968,424	0.16	0.27
Mining	3,155,761	5,182,086	0.86	0.64
Processing Industry	118,163,190	172,371,172	28.72	0.46
Electricity, Gas & Water	8,294,308	10,244,236	1.71	0.24
Construction	86,646,985	126,272,409	21.04	0.46
Commercial, Hotel & Retaurant	156,084,326	228,042,609	38	0.46
Forwarder & Communication	74,970,893	114,228,509	19.03	0.52
Finance, Real Estate & Business	213,437,911	305,617,626	50.92	0.43
Business	96,180,239	140,810,529	23.46	0.46
GDP	**757,696,594**	**1,103,737,592**		
Non oil/Gas	**754,540,833**	**1,098,555,505**		

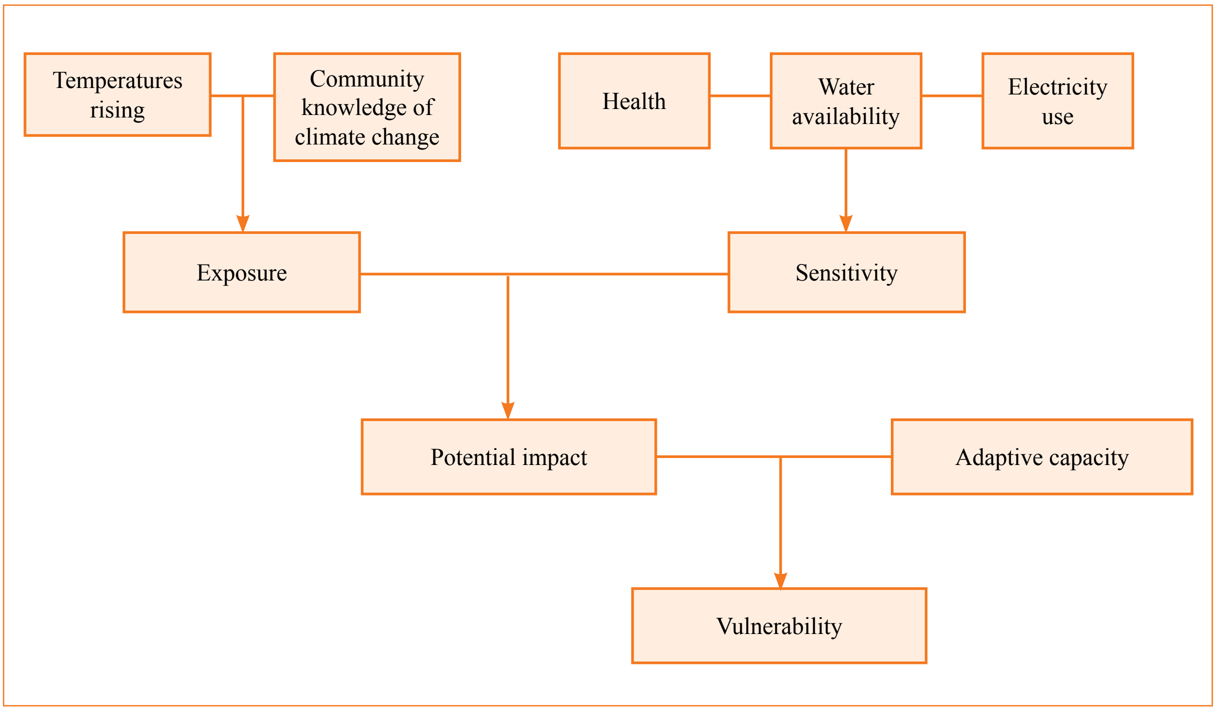
Source: Badan Pusat Statistik Jakarta (2013).

3 Investigating urban heat islands in Bandar Lampung and Jakarta

3.1 Methodology

UHI studies have traditionally been conducted for isolated locations and with in situ measurements of air temperatures. The advent of satellite remote-sensing technology has made it possible to study UHI both remotely and on continental or global scales (Streutker, 2002). This study used direct air temperature measurements and also used satellite observation results to identify UHI phenomena in both cities. The framework in Figure 5 is presented in order to explain the components of the vulnerability index (exposure, sensitivity and adaptive capacity).

Figure 5. Framework for index to assess communities' vulnerability



In the context of this study on UHI, exposure, the degree to which a system is exposed to significant climatic variations, was assessed in relation to air temperature. When one area has a higher temperature than its average it was considered as an area more exposed to the possible impact. Since this was a study of vulnerability at the community-level, community knowledge of climate change was also added as a sub-factor. This was based on the assumption that when a community is aware of the impacts of climate change in terms of rising temperatures the community would be less exposed to the impact as they would take measures to address it.

Sensitivity means the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. As previous studies have mentioned (Tan *et al*., 2010; California Department of Health, 2007) rising air temperatures will seriously affect human health; rising temperatures will also affect water availability (Rayburn, 2008). Since it is expected that on hot days air-conditioner use would increase, electricity usage would increase as well. Therefore, three factors were chosen – general health, water availability and electricity demand –to determine the level of the sensitivity.

Sensitivity together with exposure will determine the level of potential impact. When an area is highly exposed but has adequate facilities for health, water and electricity then the impact will be lessened than if all those facilities were limited.

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences (Hudeková, 2011). Communities have some ability to adapt to a changing environment including rising temperatures for example by planting trees, increasing the size of their windows or more recently by installing air conditioning. Adaptive capacity could be spontaneous but also could be as a result of local government programmes. Higher levels of adaptive capacity will lower the level of vulnerability even if the area faces a high potential impact.

The spatial distribution of air temperature, to assess the existence of urban heat island, was measured through these steps:

1. Temperature data in the chosen study area was collected at different points using air thermometer measurements.
2. Thermometers were distributed to the communities in each survey area (9 locations in Bandar Lampung and 8 in Jakarta). In each location, temperature measurements were measured by two people who would be available to do the measurements three times a day. The air temperature was measured daily at 7am, 1pm and 5pm (a manual for taking measurements was provided with a short on-the-spot training on how to read the scale on the thermometer).
3. The temperature data was reported to the researchers via mobile phone daily.
4. The average from all observation data in each location, together with its geographic position, was used in Kriging spatial analysis (see below for an explanation) to attain spatial temperature distribution.

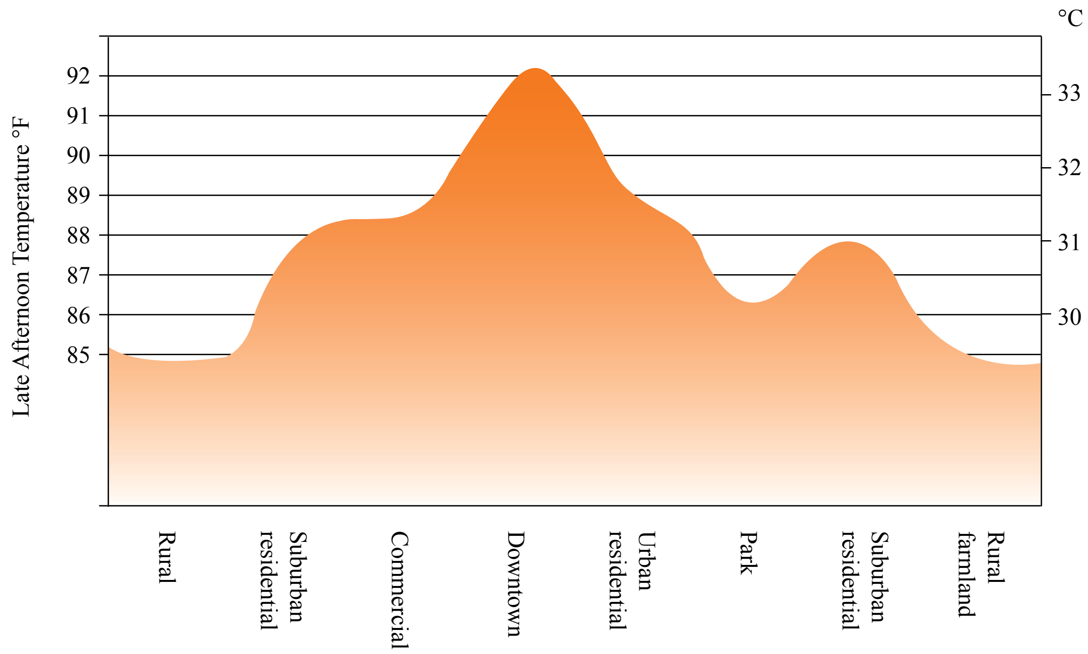
Temperature measurements were carried out from September to November 2013. This short period of temperature measurement was not intended to describe the cities' temperature as part of the cities' climate records. The measurements were done 1.2 m above the ground only in the dry season to observe air temperature difference in different land cover, on the assumption that the UHI phenomena is more obvious in the dry season. This type of temperature measurement follows the same procedures used by weather stations for observation of surface air temperature. Since station-based observations are sparse and unevenly distributed, using satellite imagery is an advanced option for evaluating temperature ranges. However, satellite recordings of temperature are only available on days with clear weather conditions so there is a difference in temperature ranges observed by stations. Evapotranspiration from land vegetation and the effects of water vapour radiative forcing are the major reasons for the temperature difference (Sun *et al*., 2006).

Kriging analysis is an optimal interpolation based on regression against observed z values of surrounding data points, weighed according to spatial covariance values. As the air temperature was measured only in some spots, using the Kriging method in an ESRI Arcmap programme, the temperature in surrounding unmeasured locations could be estimated. This method was intended to give a possible spatial view of the temperature distribution, though depending on topographic variability the predicted maps might not exactly represent the physical situation. A greater number of points might be needed where the temperature is measured (Bezzi and Vitti, 2005). Recognising these limitations and the fact that temperature measurements collected by local residents may not be always accurate, the method was used to supplement the collected data.

3.2 Study areas: Bandar Lampung and Jakarta

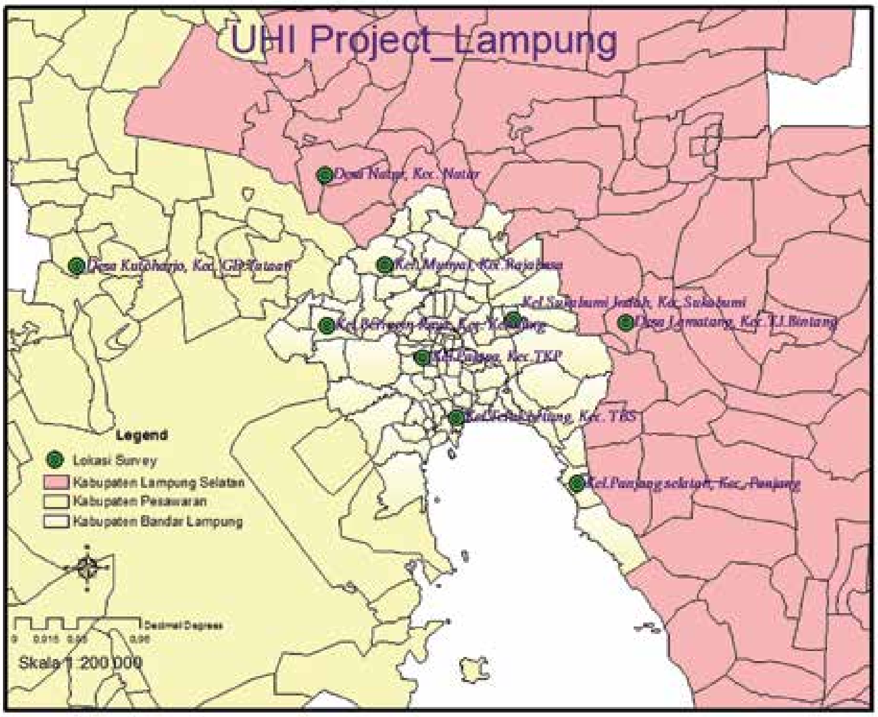
In each city, certain locations were chosen for the UHI vulnerability assessment, locations which represent rural or green areas, residential areas, business areas and the commercial centre of each city, in order to offer points of comparison across land-use types (Table 7). It is expected that UHI trends may reflect those illustrated in Figure 3, showing an urban heat profile according to land use. Based on the different land-use types profiled in Figure 6, a selection of locations were chosen to investigate the UHI phenomenon in Bandar Lampung and Jakarta (Table 8, 9 and Figure 7).

Figure 6. Urban heat island unit profile



Source: Heat Island Group, Lawrence Berkeley National Laboratory in Sailor (2002).

Figure 7. Survey area locations in Bandar Lampung and Jakarta



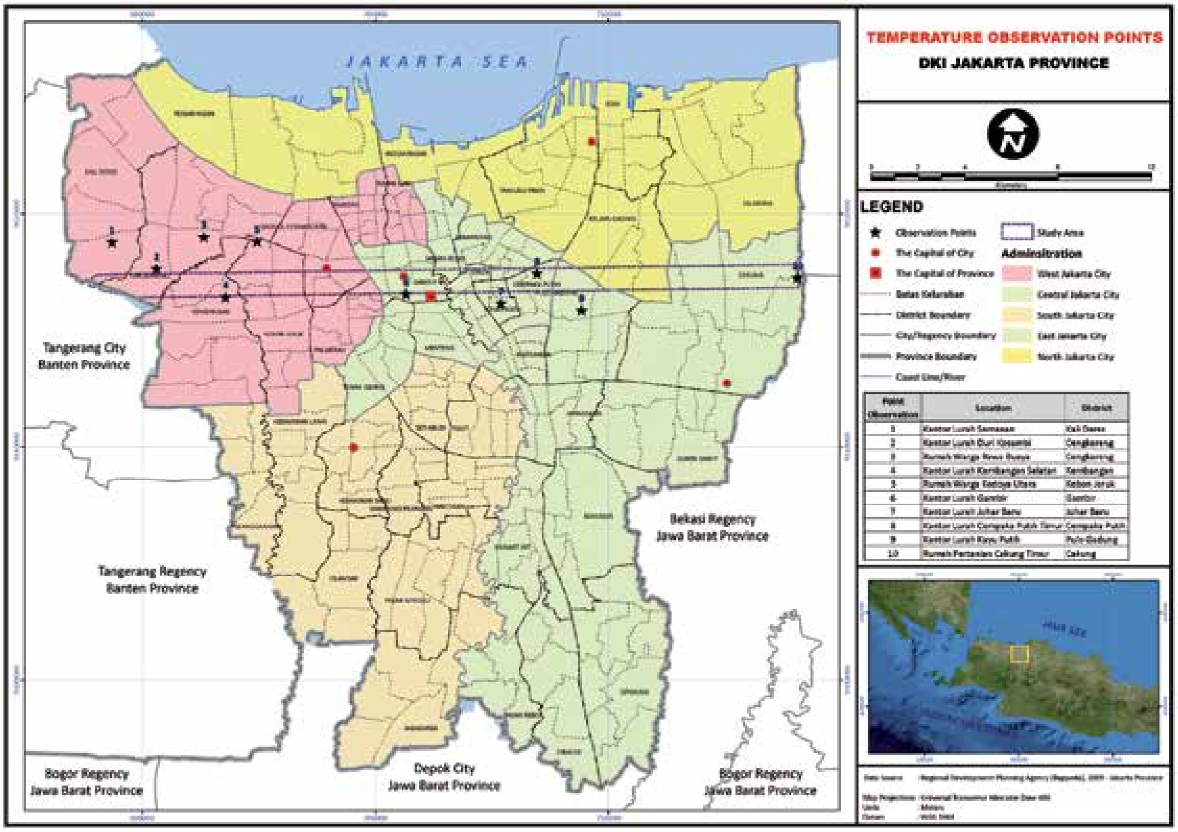


Table 8. Description of survey area in Bandar Lampung

Area	Area description	Population	Public facilities	Type of area
Sindang Sari, Natar	105.21E; 5.33 S 21,380ha 100m above sea level (ASL) 11km from city centre 11 villages	90,311 male 86,539 female Population density: 8,250 people/ha	2 schools 1 public health centre 1 public health sub-centre 30 children's healthcare groups	Agricultural Rubber plantations
Kutoarjo, Gedong Tataan	105.09 E; 5.37 S 1,010ha 200m ASL 12.7km from city centre 15 villages with 30 community clusters	14,070 male 13,420 female Population density: 3,800 people/ha	1 public health centre 1 public health sub-centre 30 children's healthcare groups	Agricultural Paddy fields
Nunyai, Rajabasa	105.23 E; 5.37 S 1,353ha 50m ASL 11.2km from city centre 7 villages with 101 community clusters	23,712 male 22,136 female Population density: 3,521 people/ha	15 schools 11 housing complexes 1 hospital 1 public health centre 5 public health sub-centres 30 children's healthcare groups	Residential
Sukabumi Indah	105.30 E; 5.40 S 2,360h 118m ASL 9.3km from city centre 7 villages	33,234 male 32,294 female Population density: 5,625 people/ha	22 schools 17 housing complexes 1 public health centre public health sub-centres 4 maternity hospitals 1 clinic 30 children's healthcare groups	Residential and industrial
Beringin Raya, Kemiling	105.26 E; 5.40 S 242.2h 263m ASL 10.4km from city centre 9 villages with 264 community clusters	36,403 male 36,178 female Population density: 2,625 people/ha	30 schools 8 housing complexes 1 hospital 3 public health centre 4 public health sub-centres 1 clinic 40 children's healthcare groups	Residential

Area	Area description	Population	Public facilities	Type of area
Lematang, Tanjung Bintang	105.35 E; 5.42 S 12,972ha 130m ASL 30km from city centre 16 villages	36,010 male 34,144 female Population density: 5,429 people/ha	2 schools 1 public health centre 1 public health sub-centre 30 children's healthcare groups	Industrial
Palapa, Tanjung Karang Pusat	105.25 E; 5.42 S 40,500ha 130m ASL 3.3km from city centre 7 villages with 257 community clusters	36,859 male 37,728 female Population density: 1,167 people/ha	13 schools 2 housing complexes 5 hospitals 3 public health centres 2 public health sub-centres 3 clinics 57 children's healthcare groups	Business and commercial
Teluk Betung Selatan	105.27 E; 5.45 S 379ha 50m ASL 2.9km from city centre 6 villages with 313 community clusters	47,927 male 45,736 female Population density: 9,301 people/ha	13 schools 3 housing complexes 2 public health centres 3 public health sub-centres 1 clinic 22 children's healthcare groups	Business
Panjang Selatan	105.33 E; 5.48 S 1,575ha 28m ASL 12.1km from city centre 8 villages with 211 community clusters	33,250 male 31,675 female Population density: 3,068 people/ha	2 public health centres, 3 public health sub-centres 2 maternity hospitals 48 children's healthcare groups	Coastal

Table 9. Description of survey area in Jakarta

Area	Area description	Population	Public facilities	Type of area
Semanan, Kalideres	106.71E;6.16 S 38,940ha	39,378 male 37,316 female	52 schools 2 maternity hospitals 7 polyclinics 2 community health centres with 30 health officials	Agricultural
Duri Kosambi, Cengkareng	106.72E; 6.17 S 30, 940ha	44,459 male 42,112 female	51 schools 1maternity hospital 2 polyclinics 2 community health centres with 16 health officials	Commercial, industrial and warehousing
Kembangan Selatan	106.75 E; 6.18 S 15,030ha	16,024 male 16,724 female	1 hospital 1maternity hospital 2 polyclinics 1 community health centre with 4 health officials	Low-density urban area
Kedoya Utara, Kebon Jeruk	106.76 E; 6.16 S 3,820ha	30,470 male 29,765 female	45 schools 3maternity hospitals 5 polyclinics 1 community health centre with 2 health officials	High-density urban area
Johar Baru	106.87 E; 6.17 S 2,590ha	18,654 male 18,985 female	2 maternity hospitals 4 polyclinics 3 community health centres with 8 health officials	High-density urban area
Cempaka Putih Timur	106.87 E; 6.17 S 5,450ha	11,388 male 12,516 female	2 hospitals 1maternity hospital 2 polyclinics 1 community health centre with 8 health officials	Commercial and industrial
Kayu Putih, Pulo Gadung	106.89 E; 6.19 S 5,250ha	22,894 male 23,945 female	2 hospitals 1maternity hospital 3 polyclinics 1 community health centre with 5 health officials	Low-density urban area
Gambir	106.82 E; 6.18 S 11,630ha	1,337 male 1,379 female	6 schools 1 maternity hospital	Government offices and buildings

4 Results: identifying urban heat islands

4.1 Field observations

4.1.1 Bandar Lampung

Temperature measurements by local residents were taken from 9 September to 7 November 2013. The average measured temperatures are presented in Figures 8–11 for Bandar Lampung and Figures 15–18 for Jakarta. The spatial distribution of the observations are presented in Figures 12–14.

Figure 8. Air temperature profiles (morning) Bandar Lampung: (a) east–west and (b) north–south

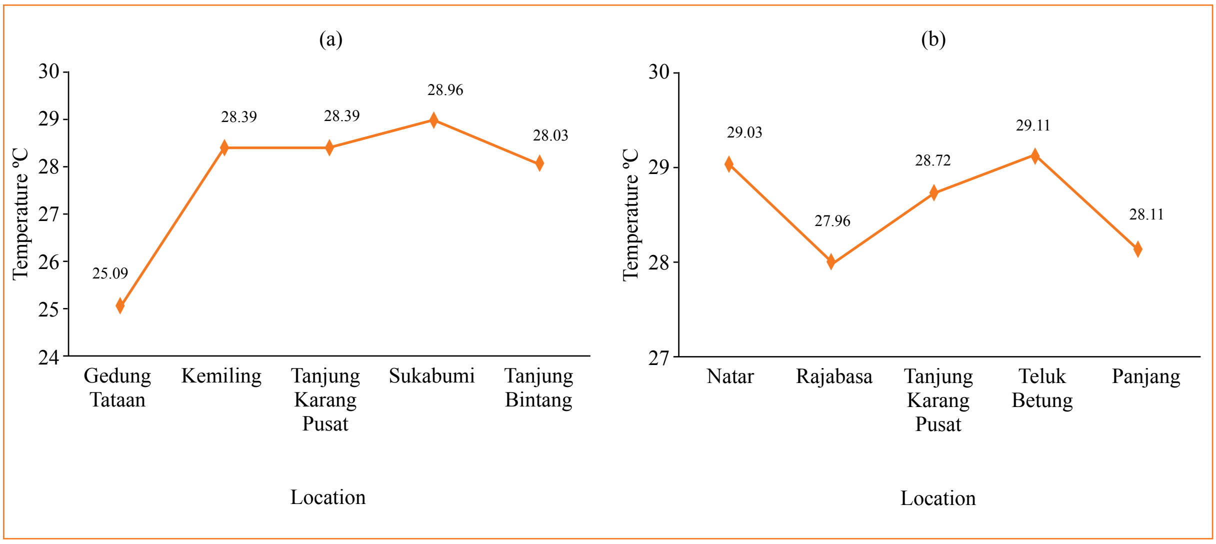


Figure 9. Air temperature profile (afternoon) in Bandar Lampung: (a) east–west and (b) north–south

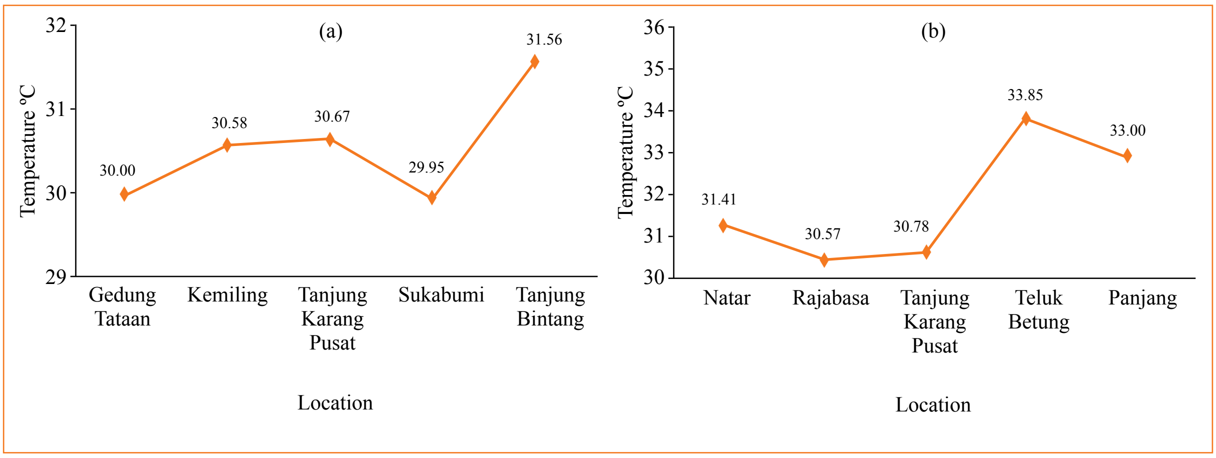


Figure 10. Air temperature profile (evening) in Bandar Lampung: (a) east–west and (b) north–south

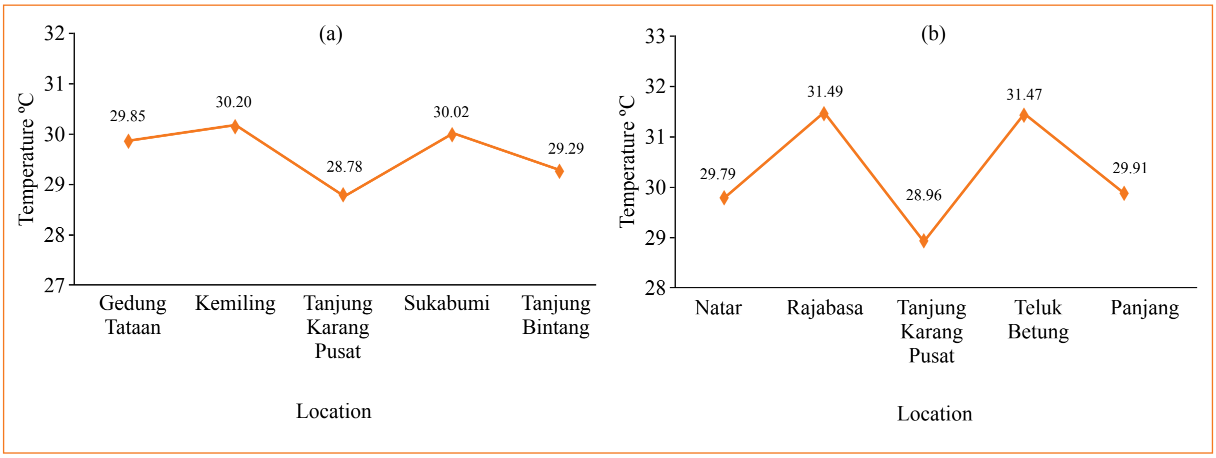


Figure 11. Average air temperature profile in Bandar Lampung: (a) east–west and (b) north–south

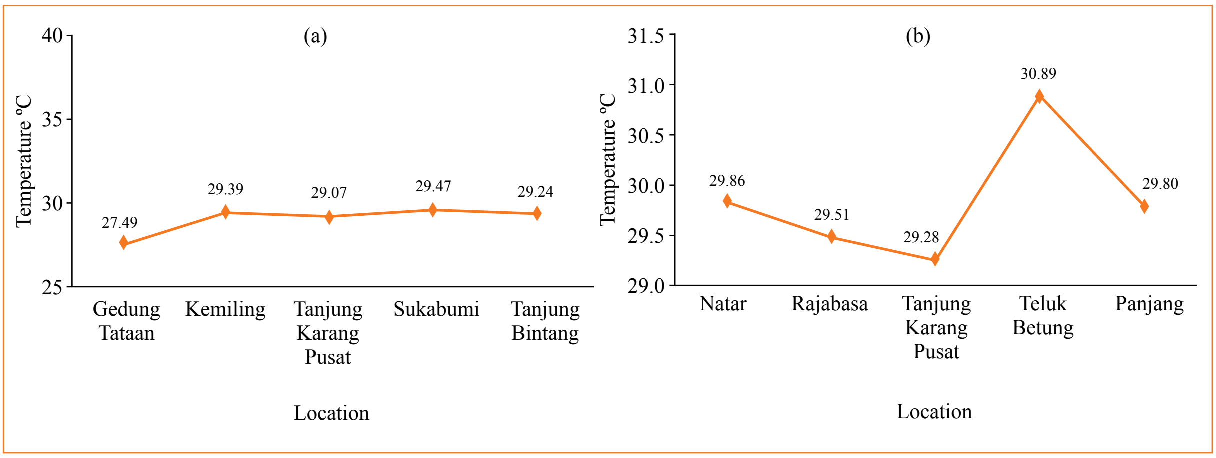


Figure 12. Spatial distribution of observed morning air temperature in Bandar Lampung

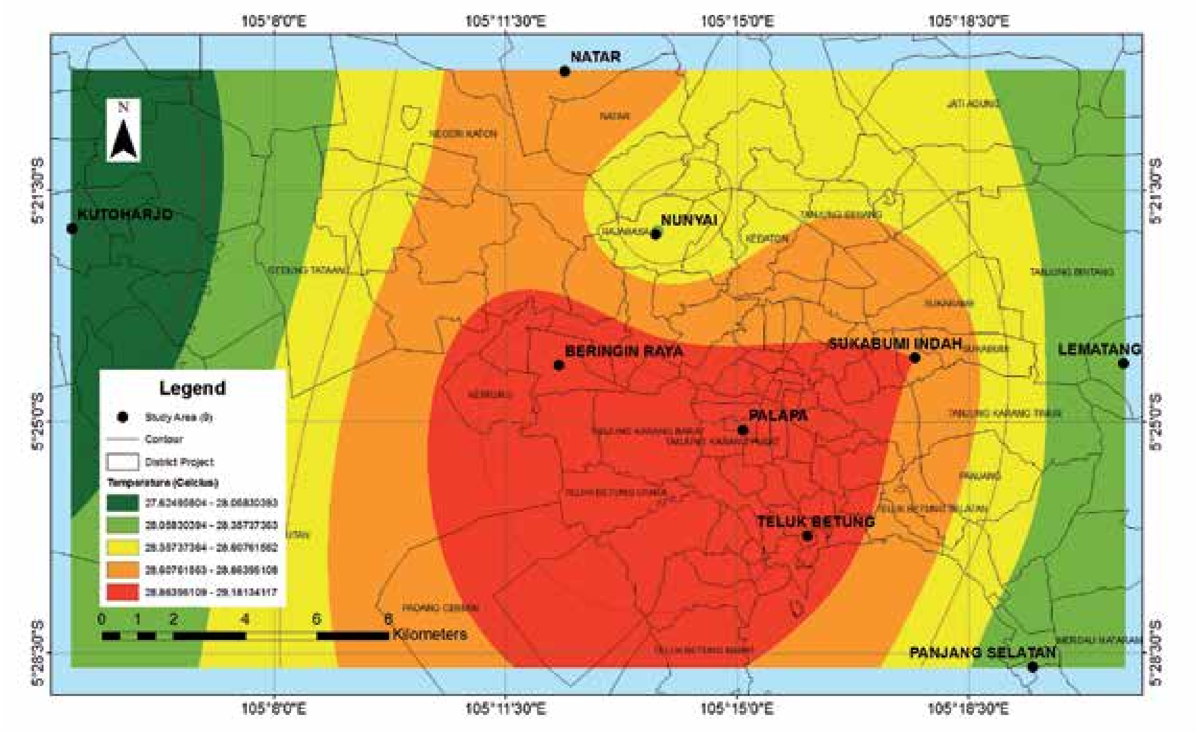


Figure 13. Spatial distribution of observed afternoon air temperature in Bandar Lampung

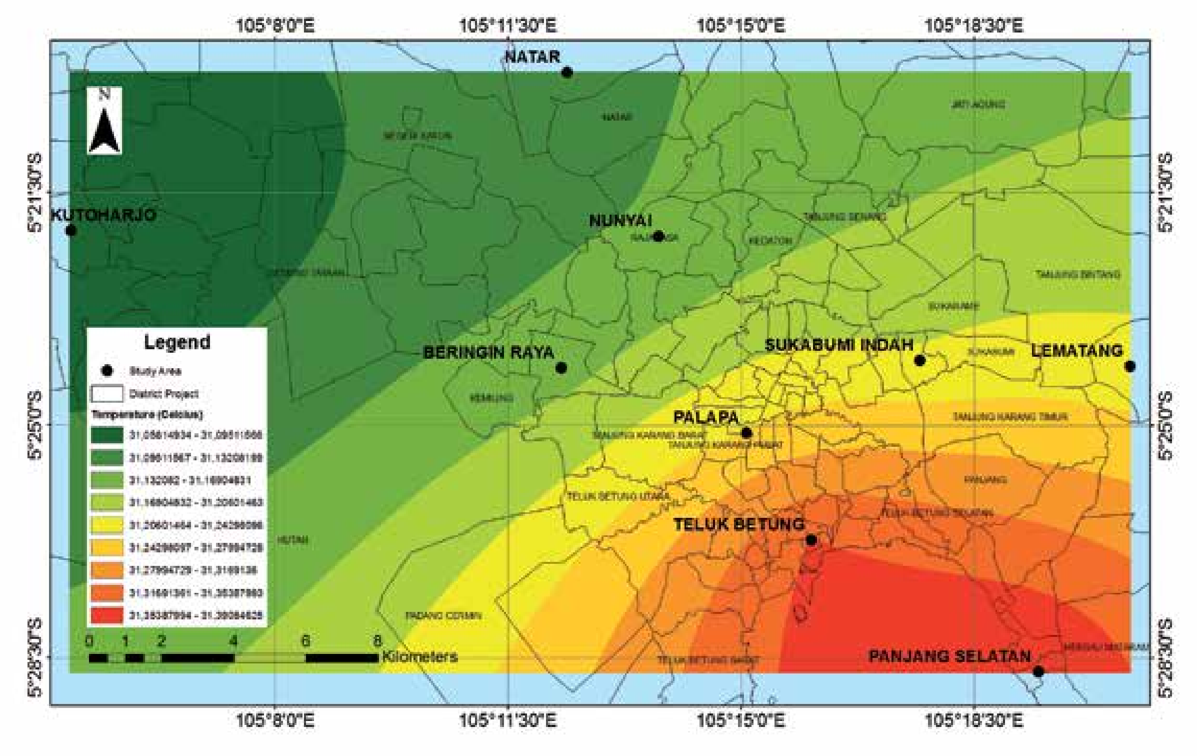
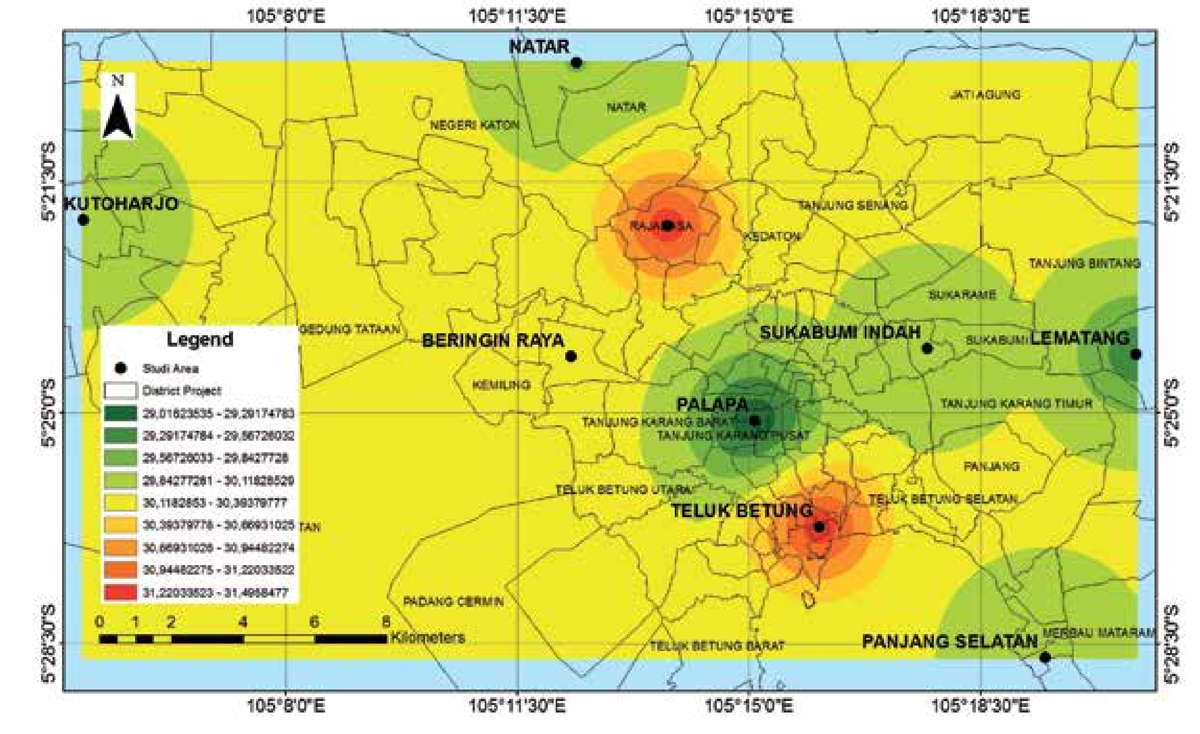


Figure 14. Spatial distribution of observed evening air temperature in Bandar Lampung



In Bandar Lampung, the morning air temperature profile (Figures 8 and 12) shows that the air temperature tended to rise closer to the city centre (Tanjung Karang Pusat, Teluk Betung Selatan) and at its maximum the temperature difference could be 4˚C. Residential areas have a similar (28ºC) air temperature to the city centre, since the centre in Bandar Lampung is not occupied with tall buildings and still has open space. Gedong Tataan –an agricultural area – had the lowest temperature (25ºC) as expected; however Natar– a palm oil plantation area – had high temperatures similar to the city centre. Palm oil tends to use soil water making this area dry, combined with the fact that this area has a lot of bare land because of new areas of plantation.

In the afternoon (Figures 9 and 13) the agricultural, residential and business/government areas in the city centre shared similar temperatures (30–31ºC). High temperatures (33–34ºC) were found closer to the commercial and industrial areas near the coast (Teluk Betung and Panjang). As in the morning, the maximum temperature difference between areas reached 4ºC.

In the evening (Figures 10 and 14) air temperature did not show a specific profile as it was almost flat (29–30ºC). Some high temperature spots (>31ºC) were found in Rajabasa residential area, probably caused by an open land area still emitting radiation into the atmosphere, and Teluk Betung (a business area near the coast). On average, the air temperature in Bandar Lampung was 29ºC. The coolest area was Gedong Tataan, which has agricultural land cover, and the hottest was Teluk Betung.

4.1.2 Jakarta

The morning temperature profile of Jakarta (Figures15 and 19) shows that most areas in Jakarta had similar temperatures of about 29°C, though some places had higher temperatures: Johar Baru (29.6ºC) and Cempaka Putih (31.1ºC).Johar Baru is an area of high-density settlement while Cempaka Putih is an area occupied with commercial/business buildings and high-density settlements. Densely packed houses and buildings appear to have caused higher air temperatures compared to other areas.

Figure 15. Air temperature profiles (morning) in Jakarta

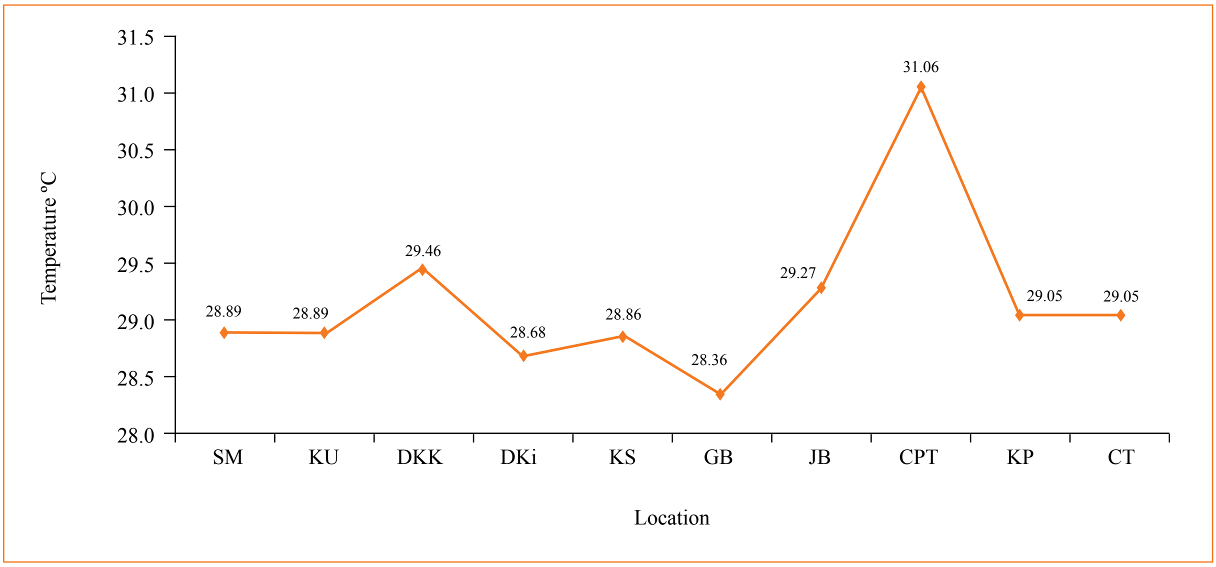
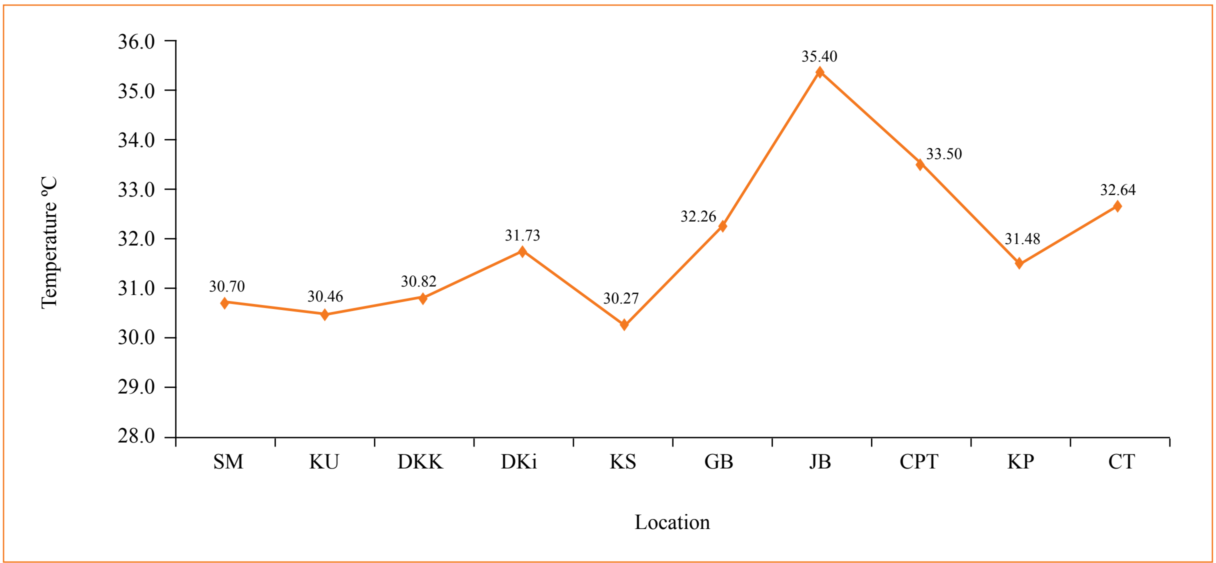


Figure 16. Air temperature profiles (afternoon) in Jakarta



The afternoon temperature profile (Figures 16 and 20) shows that UHI was identified in Jakarta with a temperature difference of about 5ºC. The area of Semanan (dominated by agriculture), Kedoya Utara (residential), Duri Kosambi (a commercial and industrial area) had higher temperature (31.7ºC). The temperature rose to 32ºC in Gambir (government buildings area) to the highest (35.4ºC) in Johar Baru and Cempaka Putih (33.5ºC) which are both high-density residential areas, and decreased to 31.5ºC in Kayu Putih, which is a lower-density area.

Figure 17. Air temperature profiles (evening) in Jakarta

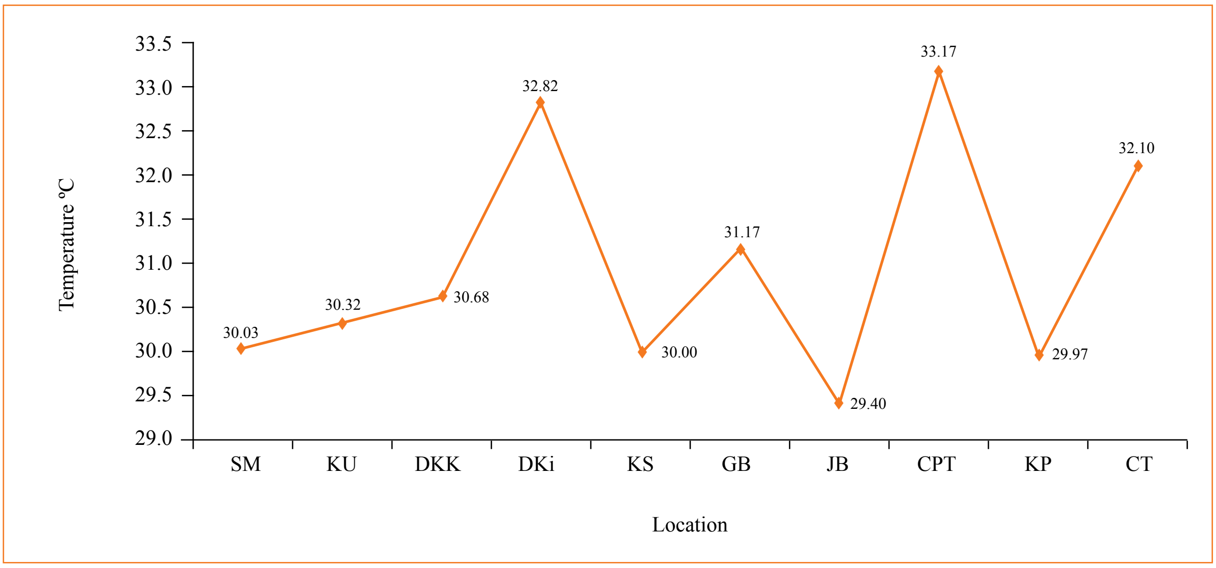


Figure 18. Average air temperature profiles in Jakarta

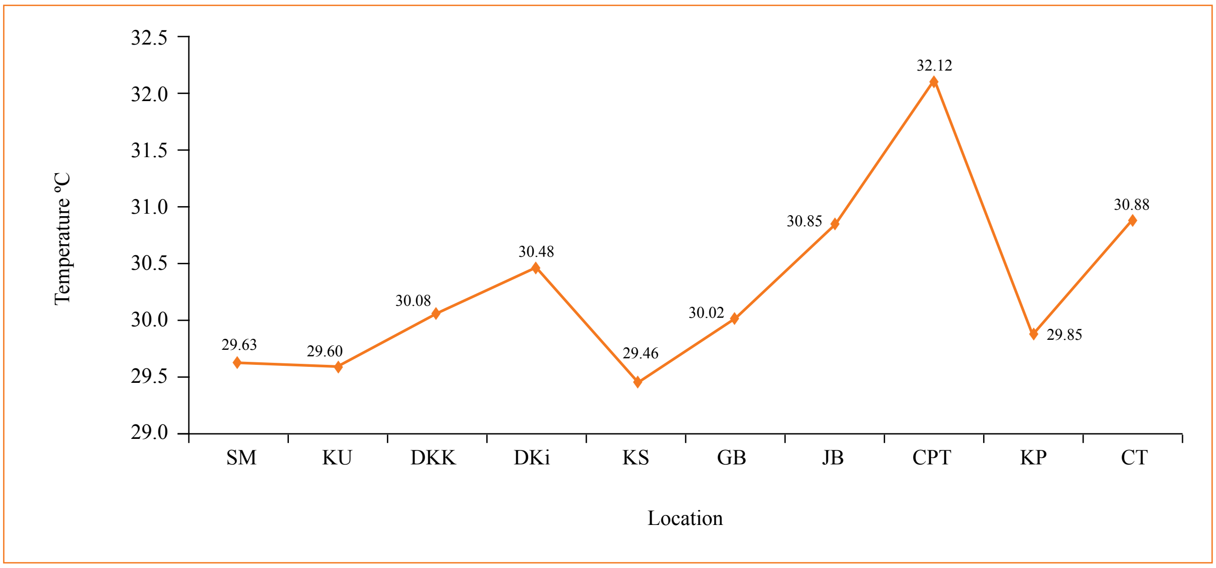


Figure 19. Spatial distribution of observed morning air temperature in Jakarta

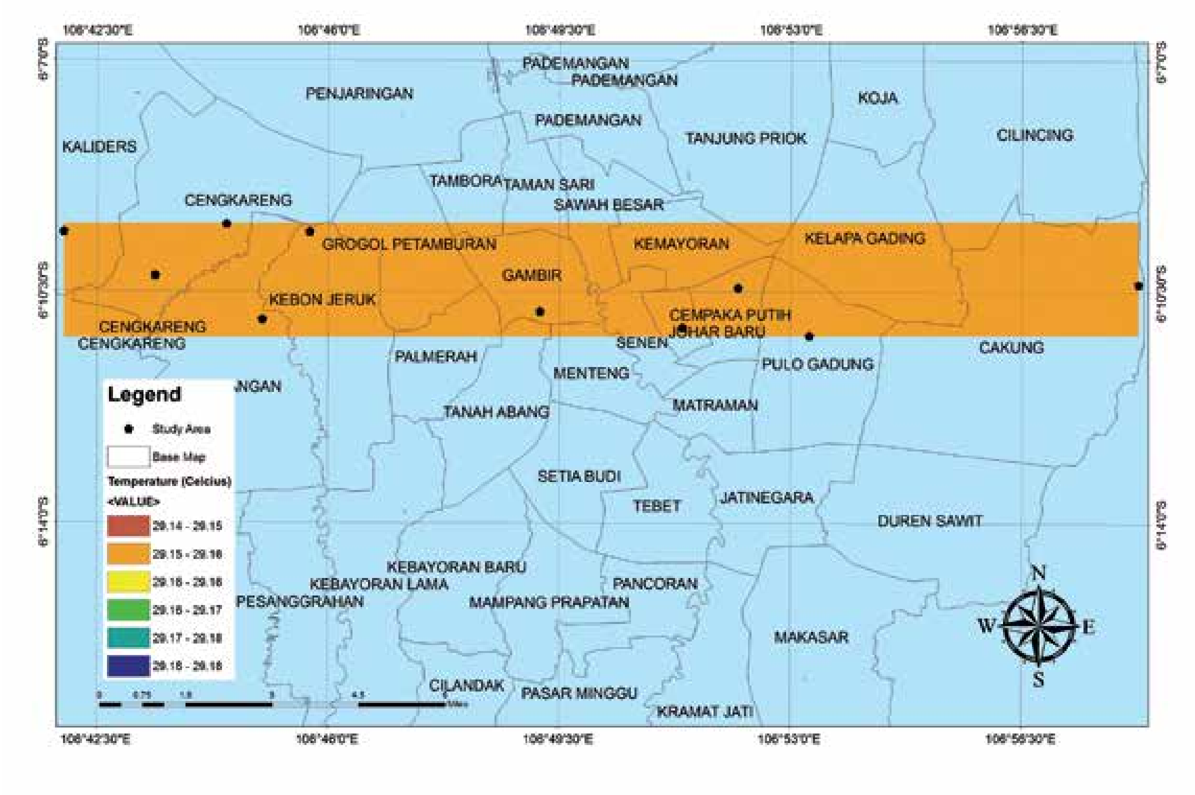


Figure 20. Spatial distribution of observed afternoon air temperature in Jakarta

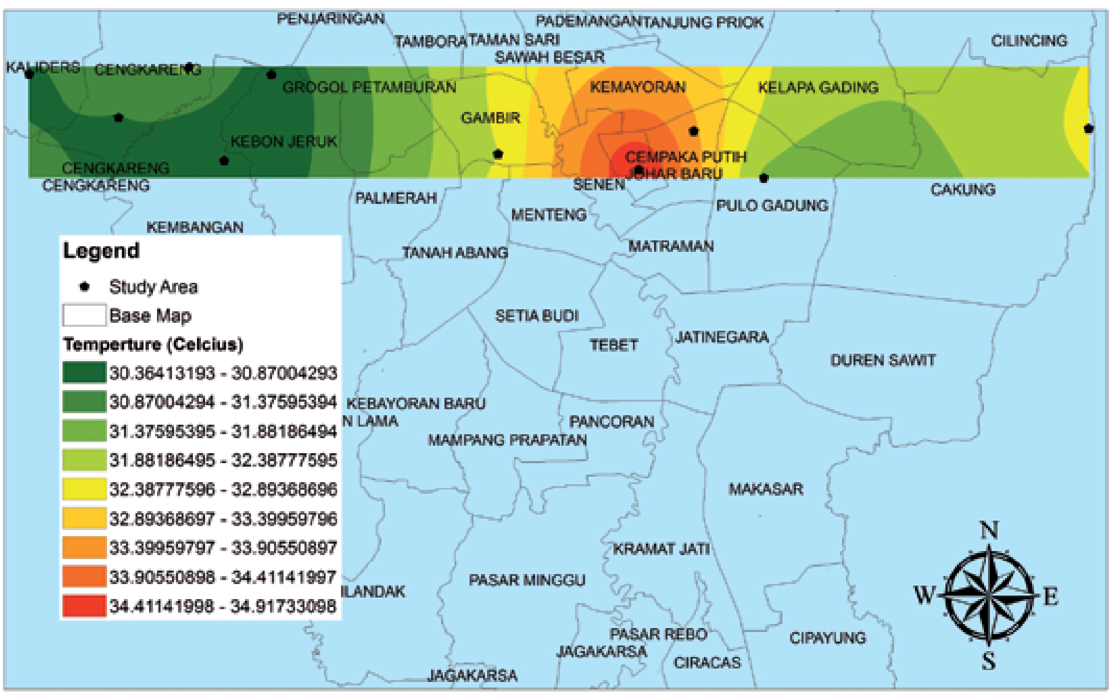
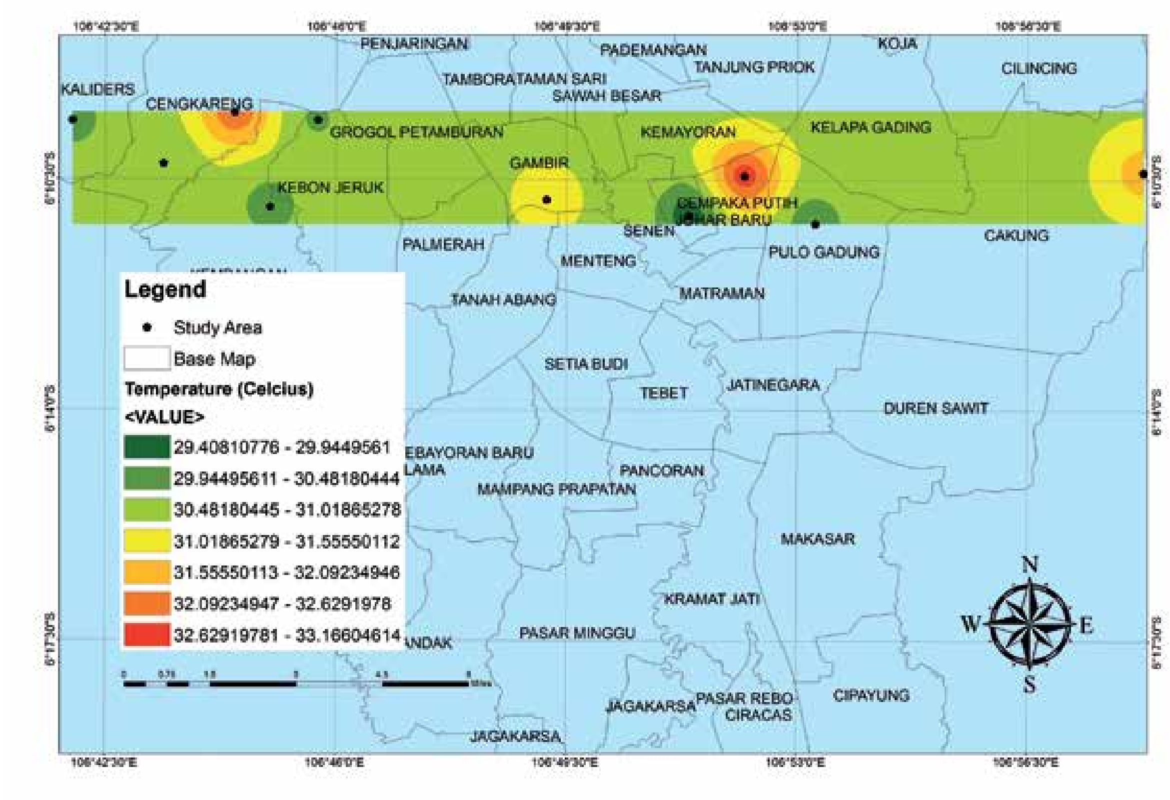


Figure 21. Spatial distribution of observed evening air temperature in Jakarta



However, the evening temperature profile (Figures 17 and 21) did not show a UHI pattern. The highest temperature area was still the high-density residential area of Cempaka Putih (33.2ºC) and the industrial area of Duri Kosambi (32.8ºC). On average, the Jakarta temperature profile (Figure 18) identified a UHI pattern, with air temperatures rising nearer to the central industrial area.

4.2 Satellite observations

Satellite observations on 8 September 2013 (Figure 22) identified UHI in Bandar Lampung. Gedung Tataan and Natar (agricultural areas, 27–29ºC), Kemiling and Rajabasa (residential areas) and Tanjung Bintang (industrial area) have a slightly higher temperature (29–32ºC) and Tanjung Karang Pusat (city centre), Teluk Betung (business area) and Panjang (coastal area) had the highest temperatures (32–34ºC).

However, it seems that when solar radiation was higher and therefore air temperatures were higher, the UHI profile was not as clear. The satellite observations on 19 October 2013 (Figure 23) showed that Gedong Tataan, Natar, Kemiling, Tanjung Bintang (agricultural and residential areas) had similar temperatures of about 31ºC; while Rajabasa, Tanjung Karang Pusat, Teluk Betung Selatan and Panjang had similar temperatures of about 34ºC. On the hotter day of 28 October 2013 (Figure 24) all Bandar Lampung areas had air temperatures of about 32–34ºC.

In Jakarta, from satellite observations the urban heat island effect was apparent on both on the very hot day (8 July 2013, 31–34ºC) (Figure 25) and when it was cooler (15 July 2013, 28ºC) (Figure 26). The areas which tend to have a lower temperature are in North Jakarta.

Figure 22. Surface temperature in Bandar Lampung, 8 September 2013

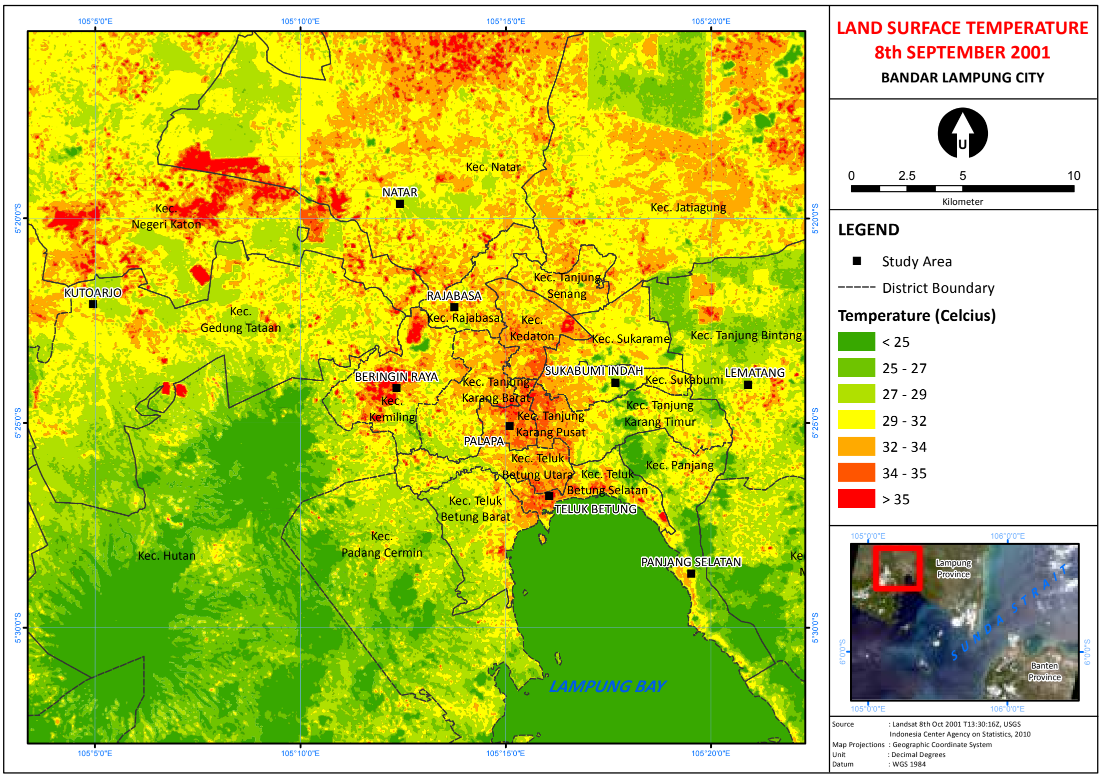


Figure 23. Surface temperature in Bandar Lampung, 19 October 2013

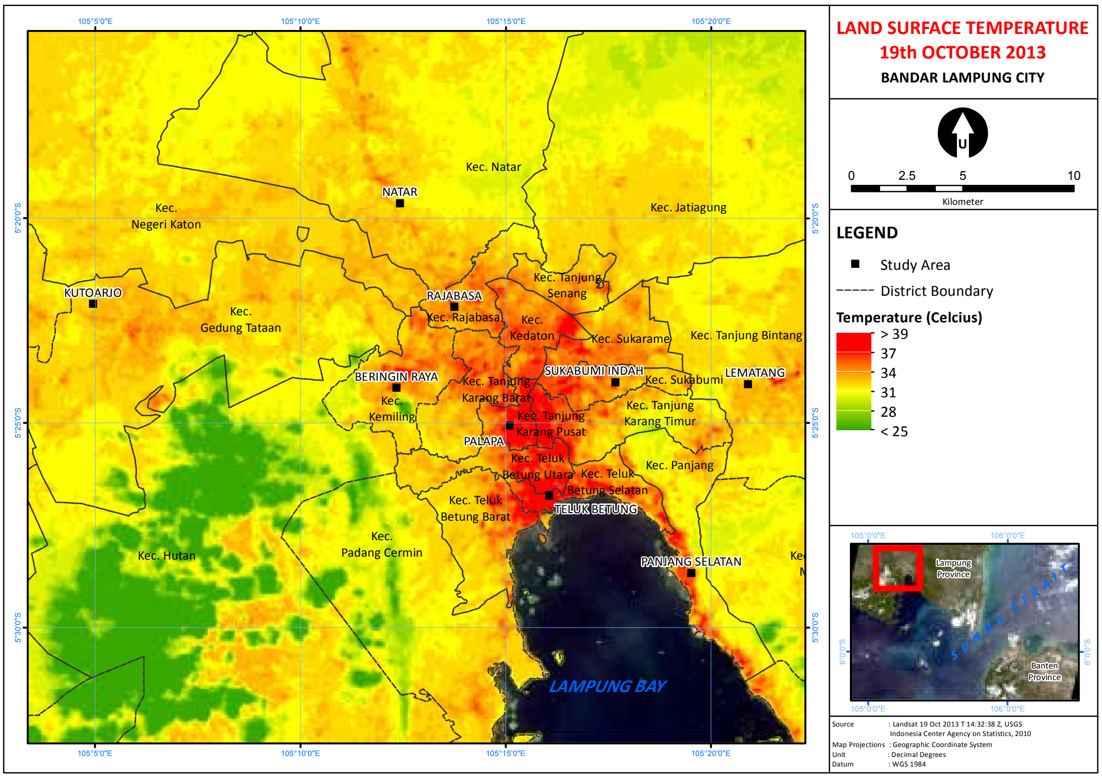


Figure 24. Surface temperature in Bandar Lampung, 28 October 2013

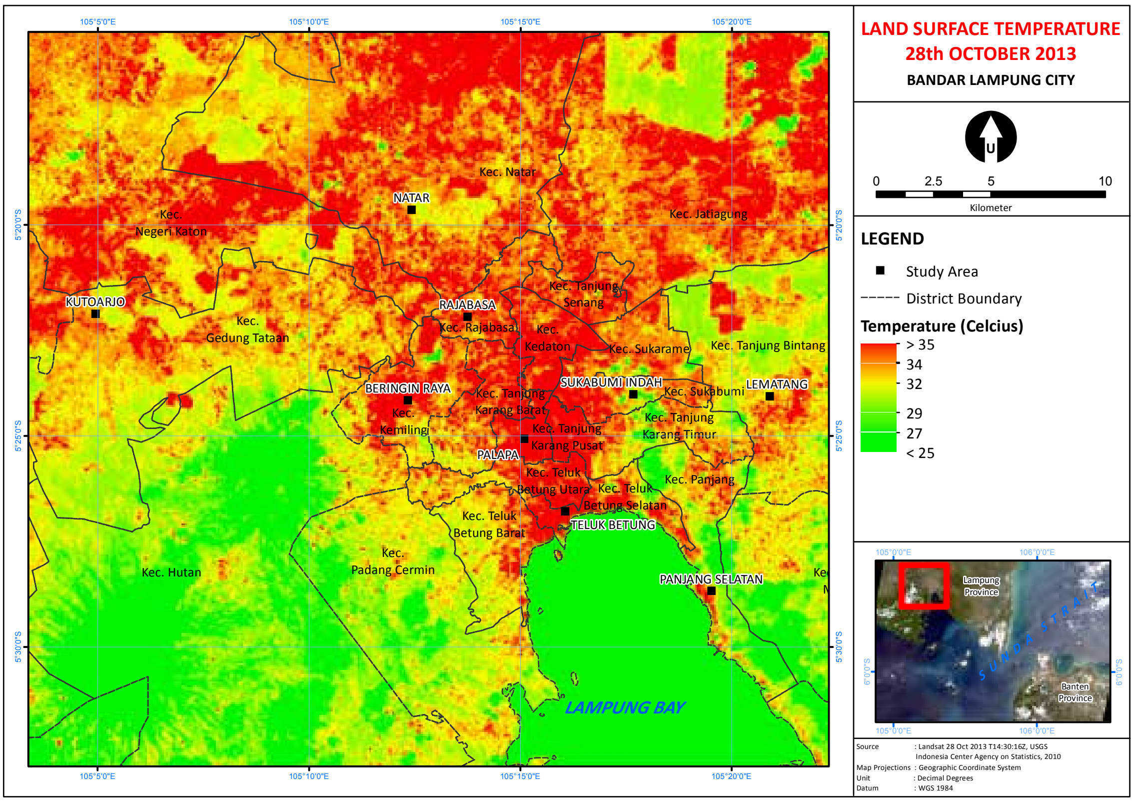


Figure 25. Surface temperature in Jakarta, 8 July 2013

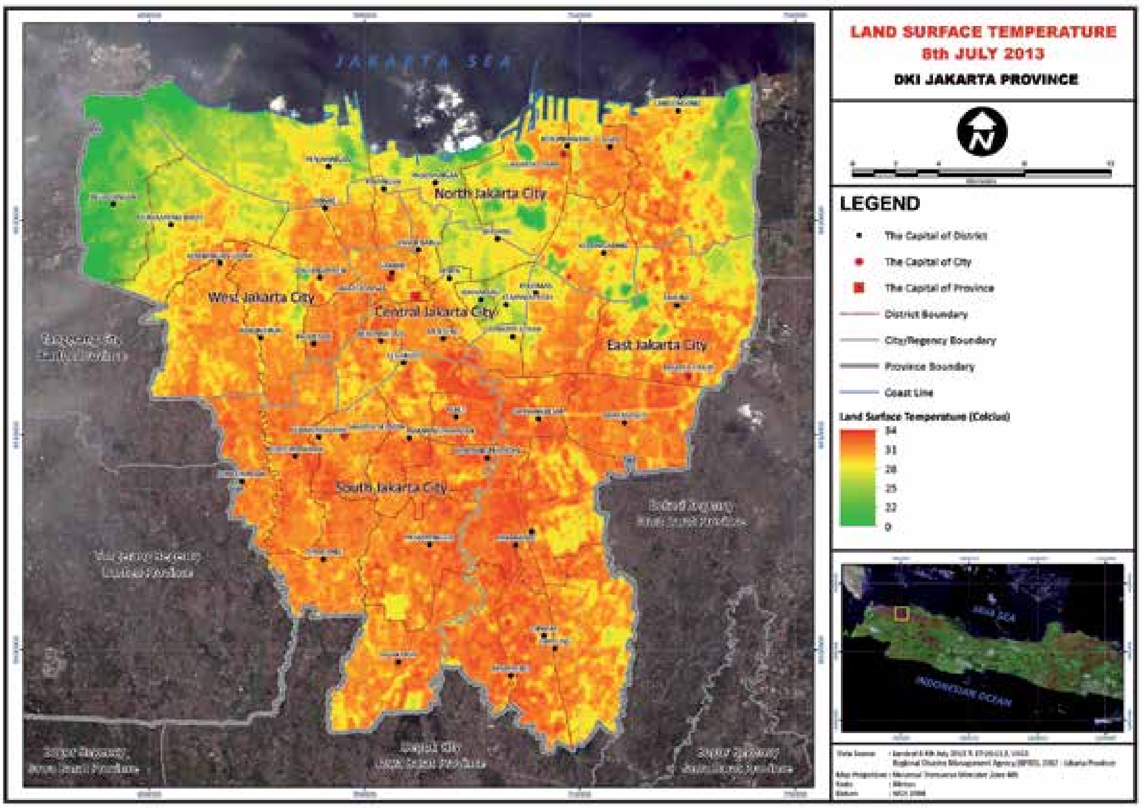
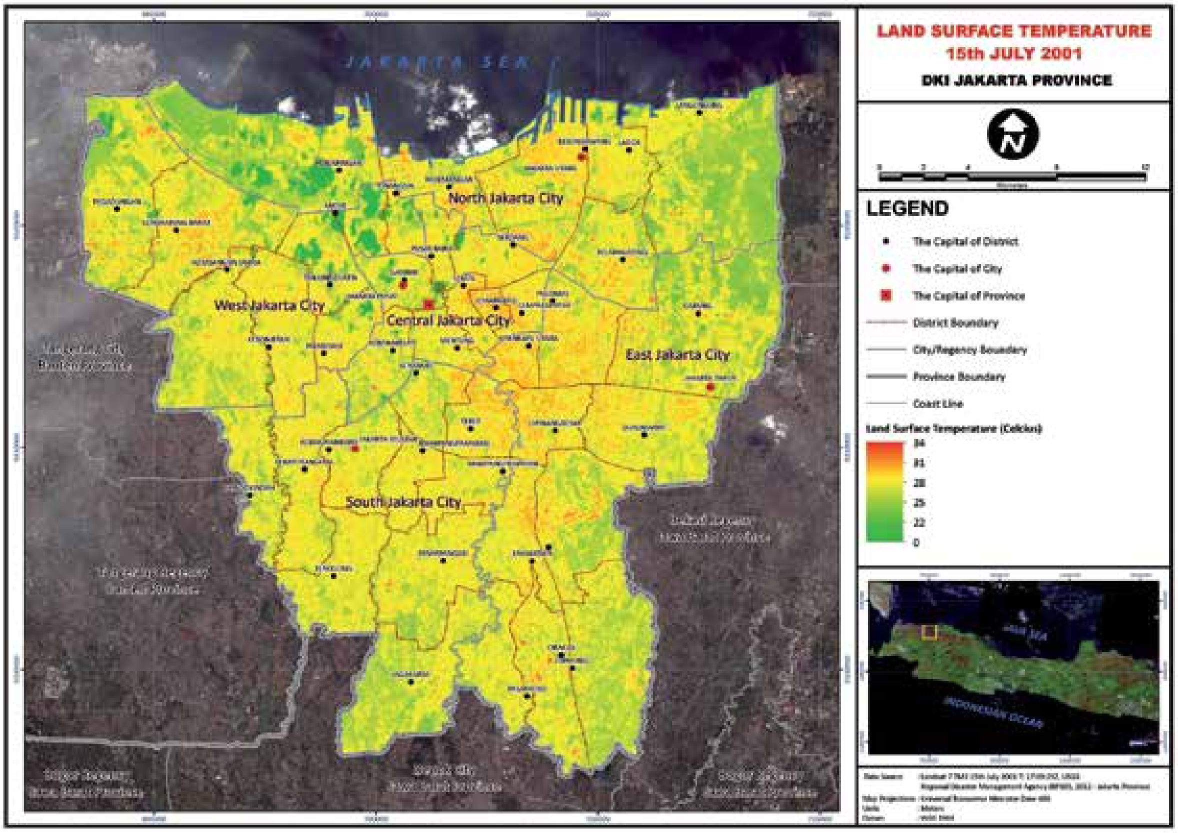


Figure 26. Surface temperature in Jakarta, 15 July 2013



4.3 Reflections on results

The intensity of the urban heat island in this study is measured in terms of the difference in daily temperature between the urban centre and the surrounding sites with different land uses, in Bandar Lampung and Jakarta. The results showed that UHI was identified in both cities especially in the afternoon (when the maximum temperatures were recorded).

The UHI effect was identified in the morning in Bandar Lampung but not in Jakarta. When solar radiation reaches the Earth's surface it is divided into latent heat, which evaporates the moisture of land surface, and sensible heat which raises the air temperature. Lower temperatures in the suburban area in Bandar Lampung suggest that the area was more humid in the morning than in the city centre; this reflects the fact that land cover in areas surrounding Bandar Lampung is still dominated by vegetation. By comparison, in Jakarta all areas were dry even in the morning, meaning that the solar radiation directly increased the air temperature and did not create a temperature difference within the city centre.

In the afternoon, the UHI still existed in Bandar Lampung but was weaker than in the morning, with higher temperatures towards the coast. When the overnight moisture was gone, the whole city experienced a similar dryness and therefore air temperature was similar, particularly as not many buildings cover Bandar Lampung's land surfaces. In Jakarta, however, the UHI was more strongly apparent. This suggests that city centre areas, with densely built buildings, emit more heat radiation into the atmosphere.

In the evening the UHI effect was not identified in either city. When solar radiation decreases as the sun sets, radiation arises from long-wave radiation emitted by the land surface. At this time the only source of heat radiation is from land-surface emissions. At this time, the land-surface type does not influence the emissions much, though heat could be trapped by air pollutants.

Satellite observations, even over a few days, showed that temperature differences between the city centre and its surrounding areas existed in Bandar Lampung, whereas in Jakarta the whole city looked like a heat island. These satellite observations reflected land cover on a large scale. However, to study UHI at the community scale, direct measurement of air temperature at surface level is more applicable.

It should be understood that this study was done during only a short time, and the satellite observation was done on bright, clear days, so that the heat events of the area could be reflected and recognised as possible signs of UHI. This was sufficient to demonstrate the probable existence of UHI effects in urban areas. However, it is recommended that longer observations are carried out, at least over one year, especially during the dry season (June to September in Indonesia). In the case of Bandar Lampung, where there are very few official meteorological stations recording air temperature, it would be necessary to train and equip local communities to observe and record air temperatures – this could lead to a network of air temperature observers.

5 Identifying community vulnerability to urban heat islands

The methodology for carrying out the vulnerability assessment was to distribute questionnaires and interview households in the study communities, based on nine locations in Bandar Lampung and eight locations in Jakarta. Forty residents in each location were chosen randomly with no specific criteria regarding gender, education levels or employment. The questionnaire was compiled based on experience from previous vulnerability studies carried out by Mercy Corps Indonesia and discussions among the team. The questions were tailored to fit the components of vulnerability: exposure, sensitivity and adaptive capacity. A legal permit was obtained from the local government to meet and sample the residents in different areas representing different land-use types. Locations for community surveys followed the categorisations used in assessing UHI: suburban, residential, business and city centre areas, and attempts were made to select communities representing the majority groups in each area.

5.1 Main and sub-indicators

This study was composed of main indicators and sub-indicators for calculating the vulnerability indices as presented in Table 10. Detailed questions from the questionnaire are presented in Appendix 1, whilst Appendix 2 sets out the details of the calculations used to establish the vulnerability index.

Table 10. Vulnerability index main and sub-indicators for exposure, sensitivity and adaptive capacity

	Main indicators	**Sub-indicators**
Exposure	Community knowledge of climate change	Percentage of households that: Are aware of rising temperatures Think that temperatures have risen in the last 3 years Understand the causes of rising temperatures Realise the impacts of rising temperatures
	Climate variability	Average observed temperature deviation from long-term temperatures
Sensitivity	Water availability	Percentage of households with water Percentage of households using water from natural sources for business/ domestic purposes Time spent obtaining water from natural sources Water needs for each household Monthly expenses for water Distance from house to water source
	Health related to air temperature	Percentage of diseases caused by high temperatures Average distance from home to health facilities Average household expenses for health Percentage of households: Suffering from illness related to high temperatures With sick family members who are unable to engage in normal activities With health insurance Receiving support for health expenses
	Energy consumption	Percentage of households with no electricity Average electricity usage capacity Percentage of households adding more capacity to cope with temperature rises Average electricity expenses

	Main indicators	Sub-indicators
Adaptive capacity (community)	Social relationships	Ratio of households receiving/giving support from/to others Average number of community organisations Average number of environmental organisations Percentage of households: Active in social organisation Involved in programmes related to temperature rises Providing support to the neighbourhood
	Education	Percentage of households having less than 6 years' education
	Income	Percentage of households with: A single source of income An additional source of income
	House adaptation	Average house size Distance of house from neighbours Percentage of households: That have modified their house type With AC or fan With a non-permanent house With a permanent house With metal/asbestos roof

5.2 Results and discussions

The results from questionnaires that were distributed in the survey areas are presented in Appendix 3 for Bandar Lampung and Appendix 5 for Jakarta. The standardising value from the questionnaire results following Formula 1 are presented in Appendix 4 for Bandar Lampung and Appendix 6 for Jakarta. LVI indices were calculated from averaging the weighted averages of the standardising values for each location.

The results in Appendices 3 and 5 were aggregated following the contribution factors of IPCC vulnerability index (exposure, sensitivity and adaptive capacity) and the results (LVI-IPCC index) for each location are presented in Table 11 for Bandar Lampung and Table 12 for Jakarta.

The results of the livelihood vulnerability index (LVI) is ranged between 0 (low vulnerability) to 1 (high vulnerability) while LVI-IPCC ranges between –1 (low vulnerability) to +1 (high vulnerability).

5.3 Vulnerability indices for study areas in Bandar Lampung[1]

5.3.1 Exposure to natural disasters and climate variability

The assessment of exposure is compiled from community knowledge about climate change and temperature rises, and the observed air temperature. Communities in Natar had the highest index (0.6) in terms of not being well informed about climate change, while communities in Gedong Tataan had the highest (though relatively low) index (0.275) of not being aware of temperature rises. Panjang had the highest index of not knowing the causes and impacts of rising temperatures (0.7 and 0.875). Natar and Gedong Tataan are areas occupied mostly by agricultural activities where the communities may not have experienced or realised that temperatures are rising, while Panjang is a coastal area with fishing communities who may have lower education levels.

Results from air temperature observations show that Teluk Betung Selatan had the highest temperature rising index and therefore a high exposure index (0.549) and the lowest was Gedong Tataan (0.361). Aggregated from those results Natar, Panjang and Gedong Tataan are the community areas with the highest exposure (0.490; 0.460; 0.426 in Table 11) compared to other areas in Bandar Lampung and surrounding areas. The high exposure index was mostly caused by a lack of knowledge of climate change or rising temperature issues.

5.3.2 Sensitivity: water availability

Sukabumi is a residential area in the hills and had the highest sensitivity index in terms of water availability (0.499) followed by Tanjung Bintang, an industrial and manufacturing area. Households in those areas depend on natural water resources for their needs, as no clean water installations were built in these areas, though more generally access to piped, clean water is a frequent problem in Bandar Lampung. Since Panjang is a coastal area where drinking water is limited, the households in this area have to buy clean water; the index for water costs was high for Panjang (0.477). Averaging from those factors, Teluk Betung has the least sensitivity in terms of water availability (0.275). Teluk Betung is a commercial area and it may be that people who are doing business in the area do not live there and are also more able to afford the cost of buying water.

5.3.3 Sensitivity: health

The highest sensitivity index in terms of health was 0.49 in Tanjung Bintang, an industrial area. The high index was not necessarily due to illness caused by high temperatures, but mostly because households have no health insurance or financial support available when they are sick (the index was high for most areas except Kemiling, a residential area of mostly government offices). This therefore highlights how sensitivity is related to broader social and economic conditions which will underlie the ways in which individuals and households experience climate change. The health sensitivity index did not show any correlation to area/locations.

5.3.4 Sensitivity: electricity needs

The sensitivity index in terms of electricity needs in Bandar Lampung was almost similar in all areas (between 0.3–0.4). All households in Bandar Lampung use electricity but with limited supply, therefore most households have not increased their electricity usage due to rising temperatures.

1 *See also Appendix 3.*

5.3.5 Adaptive capacity: social relationships

The survey showed that in all areas most households were unaware of or were not involved in any programme related to the environment. This is probably because no such programme exists in the survey areas.

The index shows low household participation in social and environmental activities (0.244–0.456); Sukabumi, a residential area, had the highest index (0.456) because this area is mostly occupied by a housing complex that is probably more organised.

5.3.6 Adaptive capacity: education

Three areas that had low capacity in terms of education are Gedong Tataan (0.5), Tanjung Bintang (0.475) and Natar (0.4). Gedong Tataan and Natar are agricultural areas where most of the young people go to other places for education or work, while Tanjung Bintang is an industrial area where most residents are contract workers who may have a lower level of education.

5.3.7 Adaptive capacity: income

In terms of income, most areas had a similar index of between 0.374–0.398. Two places had a higher index: 0.421 in Tanjung Karang Pusat in the city centre and 0.460 for Kemiling, a residential area home to mostly government officers. Income can be one determinant of adaptive capacity.

5.3.8 Adaptive capacity: home environment and adaptation

Most households in Bandar Lampung have demonstrated spontaneous adaptation related to rising air temperatures such as increasing ventilation (windows) or using fans or air conditioning. Most houses have trees in their yards. Therefore the indices were low, in the range of 0.097–0.270, indicating that these households had high self-adaptive capacity.

The LVI value calculated from the weighted average of all indices shows that Bandar Lampung had moderate vulnerability. Panjang had the highest vulnerability index (0.353) followed by Tanjung Bintang (0.336) and Natar (0.330). Panjang, near the coast, is an informal settlement, largely populated by residents earning low incomes in the fishing industry. Tanjung Bintang is an industrial area, where most people work in manufacturing as contract labourers and Natar is a palm oil plantation. It seems that vulnerability in the survey areas is therefore related more to economic considerations of income than to environmental conditions, again highlighting the role that socio-economic drivers play in levels of vulnerability.

5.3.9 Contributions to livelihood vulnerability index in Bandar Lampung

The LVI-IPCC index aggregated and categorised the indices calculated above as exposure (e), sensitivity (s) and adaptive capacity (a) and the vulnerability index is calculated by (e-a)*s. The LVI-IPCC index for Bandar Lampung is presented in Table 11.

Table 11. Calculation of LVI-IPCC contribution factors for each survey area in Bandar Lampung

Contributing factor	Contribution factor value								
	Natar	**Rajabasa**	**Tanjung Karang Pusat**	**Teluk Betung**	**Panjang**	**Gedung Tataan**	**Kemiling**	**Sukabumi**	**Tanjung Bintang**
Exposure	0.490	0.233	0.192	0.191	0.460	0.426	0.290	0.324	0.250
Sensitivity	0.359	0.337	0.370	0.291	0.355	0.312	0.350	0.379	0.442
Adaptive capacity	0.254	0.233	0.222	0.200	0.317	0.304	0.247	0.215	0.269
LVI-IPCC	**0.085**	**0.000**	**–0.011**	**–0.002**	**0.051**	**0.038**	**0.015**	**0.041**	**–0.008**

Exposure, which is composed of community knowledge of climate change and climate variability, shows that Natar, Panjang and Gedong Tataan had the highest indices and were therefore most exposed. Sensitivity, with regard to water, health and electricity needs show that Tanjung Bintang, Sukabumi and Natar had the highest indices and thus were the areas most sensitive to the impacts of climate change. The adaptive capacity index composed of social relationships, education, income and housing environment shows that Panjang and Gedong Tataan had the least adaptive capacity.

Finally, the LVI-IPCC index shows that Bandar Lampung has an index in the range of –0.008 to 0.085 which can be categorised as a moderate level of vulnerability to rising temperatures and UHI, since the index ranges from –1 (low vulnerability) to 1 (high vulnerability).

5.4 Vulnerability indices for study areas in Jakarta

5.4.1 Exposure to natural disasters and climate variability

The assessment of exposure is compiled from community knowledge about climate change and temperature rises, and the observed air temperature. Households in Johar Baru had the least knowledge about climate change – including not receiving information about climate change, not being aware of temperature rises, and not knowing the causes and impacts of temperature rise, with indices of 0.238, 0.143, 0.381 and 1.0 (very high vulnerability) respectively. Moreover, the climate data shows that Johar Baru has higher temperatures and that the index for climate variability was also the highest (0.345) compared to other areas. Therefore, Johar Baru had the highest index (0.441) in terms of exposure to climate change.

5.4.2 Sensitivity: water availability

Households in the Semanan area had the highest sensitivity to clean water availability (0.9) and as a consequence, Semanan had the highest index for the total cost for water needs (0.677) and also the highest sensitivity index in terms of water needs (0.460) while Johar Baru had the lowest index (0.220).

5.4.3 Sensitivity: health

Semanan also had the highest index for households that suffered from illness related to rising air temperatures (0.534) and the highest index of cost for healthcare (0.114) and no health insurance. Therefore, Semanan has the highest sensitivity index in terms of health followed by Cakung, while Johar Baru is the lowest (0.233).

5.4.4 Sensitivity: electricity needs

All households in the survey area use electricity and have no problems with the availability of electricity supply. The sensitivity index was different across the areas, mostly because of varying needs and eventually varying electricity costs. Semanan is an area with the highest index of sensitivity related to electricity needs (0.336) followed by Gambir (0.315), but in general the index was in a range of 0.212–0.336.

5.4.5 Adaptive capacity: social relationships

Household involvement in community organisations in the survey areas was quite low. The index was 0.636–1, mostly because respondents were not aware of any community organisations, especially in Kedoya Utara – the index of not knowing about community organisations was high at 0.733, explaining why the communities in Kedoya were not very active). In large cities, communities may be less tightly bonded due to the transient nature of certain populations, which might lower the rate of participation in social activities.

Regarding whether households were aware of environmental organisations or programmes, there was a range of responses, from all respondents being aware in Semanan, Kedoya Utara and Cempaka Putih, to not knowing any at all (Cakung). Similar patterns were seen regarding involvement in environmental programmes, ranging from all or mostly active (Cempaka Putih and Kayu Putih) to not at all active (Kedoya Utara, but also probably because no such programmes exist there). Therefore, Kedoya Utara is the area with lowest adaptive capacity (0.625) followed by Cakung (0.563), when considered from the angle of social relationships.

5.4.6 Adaptive capacity: education

Semanan, Johar Baru and Cakung were the survey areas with lowest education levels, as the indices were 0.4, 0.524 and 0.450 respectively. These areas are industrial areas with dense populations of migrant workers.

5.4.7 Adaptive capacity: income

All households in the survey areas have at least one income and some have an additional income source. The indices were similar in a range of 0.354–0.383 except for Kayu Putih which has the highest income index (0.417) because households in this area have the highest average income (0.251).

5.4.8 Adaptive capacity: home environment and adaptation

None of the households in the survey area have carried out structural adjustments to their homes to address rising air temperatures. However, all households have a fan or air conditioning due to the climate of Jakarta as a hot city. Most of the houses in the area do not have any green open space with trees, due to the high density of settlements. In general, the index for this is in the range of 0.337–0.394, except for Cempaka Putih at 0.228, because some houses in this area have green open space with trees planted in their yards, while Cakung and Duri Kosambi are the areas with the lowest adaptive capacity index (0.394 and 0.390).

The LVI value for the weighted average of all indices shows that Jakarta has a moderate level of vulnerability (0.260–0.384). Semanan has the highest vulnerability index (0.384) followed by Cakung Timur (0.359). Even though Semanan was identified as an agricultural area by respondents to the household survey, which suggests it should have a good water supply and more spacious housing, this area is surrounded by industrial and high-density settlements which may mean that the usual agricultural benefits are negated (i.e. more vegetation, better water, less building density).

5.4.9 Contributions to livelihood vulnerability index in Jakarta

The LVI-IPCC index aggregated and categorised those indices as exposure (e), sensitivity (s) and adaptive capacity (a) and the vulnerability index is calculated by (e-a)*s. The LVI-IPCC index for Jakarta is presented in Table 12.

Table 12. Calculation of LVI-IPCC contribution factors for each survey area in Jakarta

Contributing factor	Contribution factor value							
	Semanan	Kedoya Utara	Johar Baru	Gambir	Kayu Putih	Cakung Timur	Cempaka Putih Timur	Duri Kosambi
Exposure	0.152	0.135	0.441	0.218	0.209	0.198	0.160	0.166
Sensitivity	0.457	0.298	0.239	0.331	0.322	0.348	0.321	0.270
Adaptive capacity	0.393	0.416	0.370	0.355	0.337	0.420	0.236	0.398
LVI-IPCC	**–0.110**	**–0.084**	**0.017**	**–0.046**	**–0.041**	**–0.077**	**–0.025**	**–0.062**

Exposure, which is composed of community knowledge of climate change and climate variability shows that Johar Baru, the highest density urban area, had the highest index (0.441) and the highest temperature rises, according to the temperature data gathered. Other areas have indices in the range of0.135–0.218. The sensitivity in terms of water, health and electricity needs shows that Semanan has the highest sensitivity (0.457) followed by Cakung (0.348). This could mean that in most surveyed areas the water, electricity supply and health facilities are better compared to Semanan.

The adaptive capacity index composed of social relationships, education, income and housing environment shows that Cakung, Kedoya Utara and Semanan have the lowest adaptive capacity with indices of0.420, 0.416 and 0.393 respectively. These areas are occupied by people who work to support the surrounding industrial areas; they are more likely to have lower levels of education and income, which therefore reduces their ability to take measures to adapt to hot days. In conclusion, the LVI-IPCC index shows that Jakarta has index in range of –0.084 to 0.017 which is categorised as moderate vulnerability since the index range is from –1 (low vulnerability) to 1 (high vulnerability).

5.5 Comparing the livelihood vulnerability indices for Bandar Lampung and Jakarta

The main indicators used to compare the LVI of Bandar Lampung and Jakarta are presented in Table 13. For the main indicator of natural disasters and climate variability, Bandar Lampung was more vulnerable than Jakarta (with an index of 0.317 compared to 0.210). The households in Bandar Lampung have a lower knowledge of temperature rises and the potential impacts compared to Jakarta (0.250 compare to 0.05 and 0.458 to 0.243). Bandar Lampung has not yet experienced any significant temperature rises; thus the community respondents had not paid particular attention to the issue.

For water availability, Bandar Lampung was more vulnerable compared to Jakarta (0.405 to 0.266). The main water problem in Bandar Lampung is that households largely depend on water from natural sources; the government water installation of piped water has not reached most areas in this city and water is not efficiently used. Jakarta's water problems in general probably arise from limited availability.

For health issues related to temperature rises, both Bandar Lampung and Jakarta have similar index results (0.304 to 0.319). Health issues pose concerns largely because most households did not have health insurance and no alternative financial aids for healthcare. The Indonesian government recently launched a national health programme in January 2014. This scheme could offer the opportunity to resolve healthcare problems for most Indonesian people and thus increase adaptive capacity in this area.

For electricity, Bandar Lampung has a higher sensitivity index compared to Jakarta (0.344 to 0.270). Households in Bandar Lampung have not implemented any adaptation measures yet to combat rising air temperatures such as installing air conditioners. In addition, there were shortages in energy supply, with regular blackouts in the city.

Regarding social relationships, Bandar Lampung communities have better social ties within their residential areas, compared to Jakarta (0.339 to 0.440), perhaps due to the smaller size of the city. However, with regard to community programmes related to the environment, these were rarer in Bandar Lampung, perhaps because Jakarta attracts more such initiatives due to its size.

Table 13. Averages for LVI and standardised and main indicators indices, Bandar Lampung and Jakarta

Sub-component	Bandar Lampung		Jakarta	
	Average of standardised indices	Average from sub-component value	Average of standardised indices	Average from sub-component value
Natural disasters and climate variability				
Percentage of households aware of rising temperatures	0.250	0.317	0.050	0.210
Percentage of households who feel temperatures have not increased in the last 3 years	0.103		0.032	
Percentage of households unaware of the causes of rising temperatures	0.297		0.074	
Percentage of households unaware of the impacts of rising temperatures	0.458		0.243	
Average monthly air temperature	0.473		0.319	
Average monthly rainfall	0.323		0.540	

Sub-component	Bandar Lampung		Jakarta	
	Average of standardised indices	Average from sub-component value	Average of standardised indices	Average from sub-component value
Water availability				
Percentage of households with water problems	0.308	0.405	0.528	0.266
Percentage of households using water from natural sources (business)	0.867		0.133	
Percentage of households using water from natural resources (domestic)	0.659		0.452	
Time spent obtaining water from natural sources	0.085		0.143	
Water needs of each household	0.656		0.326	
Total cost of water/month	0.236		0.252	
Distance from house to water source	0.027		0.032	
Health issues related to rising temperatures				
Percentage of households affected by heat-related illness	0.156	0.304	0.156	0.319
Percentage of households with members unable to engage in normal daily activities	0.026		0.167	
Average distance between home and health facility	0.289		0.261	
Average cost for health per household	0.099		0.064	
Percentage of households with no health insurance	0.794		0.734	
Percentage of households who do not receive health benefits	0.458		0.530	
Electrcity needs				
Percentage of households without electricity	0.000	0.344	0.000	0.270
Average electrical power usage (watts)	0.251		0.171	
Percentage of households who have not used more electricity due to heat	0.931		0.895	
Average monthly cost for electricity	0.194		0.014	
Social relationships				
Percentage of households not active in social organisations	0.114	0.339	0.822	0.440
Percentage of households not active in community groups	0.052		0.204	
Percentage of households unaware of environmental programmes	0.199		0.304	
Percentage of households not part of an environmental programme	0.989		0.428	
Education				
Percentage of households < 6 years' education	0.247	0.247	0.265	0.265

Sub-component	Bandar Lampung		Jakarta	
	Average of standardised indices	**Average from sub-component value**	**Average of standardised indices**	**Average from sub-component value**
Income				
Percentage of households with single income source	0.883		0.786	
Percentage of households with additional income source	0.117	0.400	0.189	0.370
Average income	0.200		0.134	
Housing environment				
Percentage of households who have not modified their home	0.467		1.000	
Percentage of households without AC/fan	0.239		0.064	
Percentage of households living in slums	0.000		0.013	
Average building area	0.159		0.173	
Distance between house and right-hand neighbour	0.018		0.104	
Percentage of houses with zinc roof/asbestos	0.158	0.179	0.616	0.347
Distance between house and left-hand neighbour	0.019		0.020	
Distance between house and neighbour to the rear	0.020		0.018	
Percentage of households with semi-permanent house	0.216		0.030	
Percentage of households with no green open space	0.610		0.879	
Percentage of households with no trees	0.065		0.896	
	LVI Bandar Lampung	0.303	LVI Jakarta	0.311

For education and income there was not much difference between Bandar Lampung and Jakarta (0.247 to 0.265 and 0.400 to 0.370). In both cities, low education levels still dominate, which indicates a low adaptive capacity.

For housing environments, Bandar Lampung saw much better conditions compared to Jakarta (0.179 compared to 0.311). As a smaller city with an agricultural background, houses in Bandar Lampung have more open space with trees compared to Jakarta. However, given the size of Jakarta's population, the sampled groups are not necessarily representative of the housing conditions within the city as a whole.

In conclusion, the LVI index calculated from the weighted averages of all indicators shows that Bandar Lampung has a slightly lower vulnerability index (0.303) compared to Jakarta (0.311), thus Jakarta's population is slightly more vulnerable to the impacts of UHI.

5.6 Comparing the LVI-IPCC analysis for Bandar Lampung and Jakarta

The calculation of LVI-IPCC from the components of exposure, sensitivity and adaptive capacity for Bandar Lampung and Jakarta is presented in Table 14. Aggregating natural disasters and climate variability as an exposure indicator, Bandar Lampung is more exposed to climate variability than Jakarta (with an index of 0.317 compared to 0.210). Temperatures might be higher in Jakarta, but because the society in Bandar Lampung has a lower awareness of rising air temperatures and less knowledge of the impacts of climate change in general, including temperature rises, Bandar Lampung can be said to have a higher exposure compared to Jakarta.

Bandar Lampung is also more sensitive to the possibility of problems caused by rising temperatures (the index was 0.355 compared to 0.285) in terms of water, healthcare and electricity needs. Bandar Lampung needs to improve its provision of public services by increasing the provision of clean, piped water, energy supply and access to health facilities.

Table 14. Calculation of LVI-IPCC contributions for Bandar Lampung and Jakarta

Contributing factors Bandar Lampung	Main components	Component values	Number of components	Contributing factors values	LVI-IPCC results for Bandar Lampung
Adaptive capacity	Housing environment	0.347	11	0.348	–0.009
	Education	0.247	1		
	Social relationships	0.339	4		
	Income	0.400	3		
Sensitivity	Health	0.304	6	0.355	
	Electricity	0.344	4		
	Water	0.405	7		
Exposure	Natural disasters and climate variability	0.322	6	0.322	
Contributing factors Jakarta	**Main components**	**Component values**	**Number of components**	**Contributing factors values**	**LVI-IPCC results for Jakarta**
Adaptive capacity	Housing environment	0.179	11	0.269	–0.017
	Education	0.265	1		
	Social relationships	0.440	4		
	Income	0.370	3		
Sensitivity	Health	0.319	6	0.285	
	Electricity	0.270	4		
	Water	0.265	7		
Exposure	Natural disasters and climate variability	0.210	6	0.210	

Because of better social relationships and a better housing environment, Bandar Lampung has a better adaptive capacity compared to Jakarta (0.348 compared to 0.269); however, this is more a natural spontaneous adaptive capacity; it was not the result of any community ability to deal with climate change or temperature rises. Most areas did not have any programmes or activities to increase community capacity in terms of understanding and responding to the impacts of climate change.

In conclusion, the LVI-IPCC index shows that Bandar Lampung is less vulnerable compared to Jakarta (–0.009 and –0.017 respectively); however, both are at a moderate level. At the same time, it must be recognised that the results draw from a small sample of each city’s population, and there will be variability across different areas of the city and sectors of society in terms of their sensitivity, exposure, and adaptive capacity.

6 Conclusions and recommendations

The study results indicate that UHI is present both in Jakarta and Bandar Lampung, and this effect may be related to the patterns of land cover in general. Even though land-cover impacts were not investigated in this study, this could be implied from the fact that vegetated areas generally have lower air temperatures because of moisture in the air. Jakarta sees higher temperatures because of human activity in high-density urban areas, combined with densely built-up areas which trap and radiate heat emissions.

The results of the vulnerability assessment suggest that residents in the surveyed areas in both Bandar Lampung and Jakarta have average levels of vulnerability to temperature rises, with Bandar Lampung slightly less vulnerable compared to Jakarta. Bandar Lampung ranked lower in term of communities' knowledge about climate change and also in provision of public facilities such as water supply and healthcare; however, it had a high score in adaptation, particularly in the form of natural and spontaneous adaptation, which was not necessarily because participants were aware of the impacts of rising temperatures. Jakarta saw higher sensitivity because the communities in the surveyed areas suffered from more hot days. While some areas had adequate public services, better income and education levels, other areas lacked these. Jakarta had a low index in adaptation mostly because of low participation in community programmes, especially those related to the environment.

The findings of average (moderate) vulnerability indices in both cities with different underlying reasons should be seen as a warning: without any effort to address this vulnerability, both cities could shift into highly vulnerable conditions. In both cities, it is important to recognise that different areas and sectors of the population will have different levels of exposure, sensitivity and adaptive capacity, and the methodology presented here offers an initial assessment of this variation but does not comprehensively cover all parts of the city.

Conducting studies of UHI identification together with a vulnerability index gives a more complete picture of the possible environmental changes due to climate change, in this case rising local air temperatures, and how local populations will be affected in terms of exposure, sensitivity and adaptive capacity. Each item in those categories provides information about the particular areas to which the community is sensitive and their capacity to adapt. Collecting this type of information can be a good base for short- and long-term planning for adaptation to climate change and disaster risk reduction programmes.

Based on the results, a key priority for the Bandar Lampung local government (and also other districts around Bandar Lampung) should be to improve the communities' knowledge and awareness of climate change and its impacts. Community programmes should be linked to environmental issues and focused on climate change impacts, both in terms of possible disasters related to hydrometeorology such as flooding and drought, and problems in daily life caused by hotter days.

Even though Bandar Lampung's current land cover plays a role in protecting the city from hot days, city development plans have to be carefully monitored and enforced to ensure this effect remains. Bandar Lampung has the possibility to grow into a big city and development patterns in most large cities in Indonesia have tended to ignore the environmental side of city planning in favour of economic benefit.

Improving public facilities related to healthcare, water and electrical capacity is necessary in both cities, in order to address all three components underlying vulnerability; however, this will require dedicated government budget plans. Communities need to learn how to adapt with limited sources/facilities such as preventing illness by having a healthy neighbourhood environment and preventing communicable disease, and using water and electricity efficiently to reduce waste.

Jakarta faces serious problems related to urbanisation especially in providing affordable housing and livelihood options. The need for more housing and business areas decreases the green area in this city. Impermeable land surfaces are dominating Jakarta land cover, with the implication that rising air temperatures is unavoidable. Policies such as the promotion of green roofs could have an impact on limiting the UHI effect.

This study is limited in scope, being of limited duration and focusing only on particular areas of both cities. However, since the study has used standard methods both in measuring the air temperature and in using the IPCC index to assess the vulnerability, it is useful for identifying key underlying drivers of vulnerability in each case, which may then be used to tailor local government plans and development.

The key for a good representative study of vulnerability assessments depends firstly on the choice of locations/ communities as the survey/study target. The targeted communities should be strongly related to the possible disaster caused by the temperature rising or any other climate change impact that is being assessed. For instance, prioritise poor communities in dense urban areas when considering the impact of UHI, communities along coastal areas for the impact sea-level rise, and communities living in riparian areas for flash floods and landslides.

Secondly, questionnaires need to be well-designed and implemented by good enumerators. What subjects and questions should be included in the questionnaires and how the answers are explored by various people will determine the indices that will lead to the conclusion as to whether the area is more or less vulnerable. A rigorous methodology will lead to rigorous conclusions, which are important as this will be the basis of local government policy and programmes.

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Appendix 1. Research Questionnaire

Vulnerability Assessment of UHI Impact

(Case study: Bandar Lampung & Jakarta Metropolitan Area)

Respondent Number ....

Respondent Name ....

Ethnic group ....

Village Name ....

District ....

Name of ....

Date of ....

FACULTY OF AGRICULTURE
LAMPUNG UNIVERSITY
BANDAR LAMPUNG
2013

Appendix 1. Questionnaire

I. Respondent identity

1. Name

2. Additional income source

3. Education level (years of formal education)

4. Length of time with additional income

5. Household size

No	Name	M/F	Age	Family relation	Formal education	Non-formal education (any kind of training)						Occupation
						Type of training	Date	Duration	Intensity (times)	Training agent		
										Government	Private	
1												
2												
3												
4												
5												
6												

6. Family income sources

No	Name of family member	Type of job	Income/day/month/year (IDR)	Expenditure/day/month/year (IDR)	Net income/day/month/year (IDR)

7. Asset ownership

No	Item	Ownership		No	Item	Ownership	
		Yes	No			Yes	No
1	**Electronics**			**3**	**Valuables**		
	Radio				Gold		
	TV				Other jewellery		
	Refrigerator			**4**	**Money/savings**		
	AC (air conditioner)				Family savings		
	DVD/video player/CD				Children's savings		
	Laptop/PC						
2	**Vehicles**						
	Car						
	Motorcycle						
	Bicycle						
	Truck/pick-up						

8. Family expenditure

No	Spending item	Amount (IDR)			No	Spending Item	Amount (IDR)		
		Week	Month	Year			Week	Month	Year
1	**Food**				**2**	**Non-food Spending**			
	Staple foods					Clothing			
	Side dishes					Transport			
	Beverages					Communications			
	Snacks					Electricity			
	Vegetables					Health			
	Cigarettes					Beauty care			
	Other					Social participation			
						House maintenance			
						Education			
						Other			

II. Neighbourhood environment

A. House and front/backyard

1. Are you the owner of the house? Yes/no

   If yes, what is the status of your house?:

   a. Owner.

   b. Rent

2. What size is your front/backyard? (m x m)
3. What size is your home? (m x m)
4. What type of house is it?

   a. Permanent

   b. Semi-permanent

   c. Non-permanent

5. How many doors and windows are in your house?
6. Do you have an open outdoor area near your home such as a green area or park? Yes/no
7. If yes, what size is it? (m x m)
8. Have you planted any trees in your yard? Yes/no
9. If yes, what kind of tree?
10. What other plants do you have?

B. Neighbourhood condition

1. What kind of neighbourhood do you live in?
    a. Industrial
    b. Business
    c. Offices
    d. Housing complex
    e. Agricultural
2. What distance is your house (in metres) from:
    a. The nearest house
    b. Right-hand side neighbour
    c. Left-hand side neighbour
    d. Rear neighbour
3. Do you feel comfortable in your area on hot days? Yes/no
4. If not, what do you do to cope with the heat?
    a. Move to a cooler area
    b. Install AC/fan
    c. Add more windows and ventilators
5. Do you think that conditions in your neighbourhood affect the air temperature of your house? Yes/no

III. Vulnerability to temperature rising exposure

1. Did you know that temperatures have been rising recently? Yes/no
2. If yes, how did find out?
    a. TV
    b. Radio
    c. Newspaper
    d. Weather report
    e. Internet
    f. Government
    g. Friends
3. Do you think that air temperatures have risen in the last 3 years? Yes/no
4. If yes, how does this make you feel?
    a. Hot
    b. Sweating
    c. Disturbed sleep
    d. Often thirsty
    e. Dizzy
    f. Tired
    g. Overheated

5. Do you know why temperatures are rising? Yes/No
6. If yes, in your opinion what causes it?
    a. Vehicle emissions
    b. Industrial emissions
    c. AC/refrigerators
    d. Forest fires
    e. Forest degradation
    f. City size
    g. People density
    h. Road asphalt/cement
7. Do you know what the impacts are of rising temperatures? Yes/no
8. If yes, what are they?
    a. Higher demand for electricity
    b. More incidences of disease (Dengue, respiratory diseases)
    c. Lack of available drinking water

Sensitivity

Water

9. Have you ever had water supply problems? Yes/no
10. What kinds of problems?
11. Do you think that increasing water demand is related to temperatures rising? Yes/no
12. How much water do you need for:
    a. Drinking (ltr/day)
    b. Showering and private needs (ltr/day)
    c. Cooking (ltr/day)
13. Where do you source your water?
    a. Government water installation
    b. Natural source
    c. River
    d. Bought
14. How much do outspend on water? (IDR/day/week/month)
15. How far is your house from a water source? (m/km)
16. How long does it take you to reach your water source? (min/hour)

Health

17. Do you and your family ever experience health problems because of rising temperatures? Yes/no

18. If yes, what kinds of illness? How many people in your family have been affected?

19. How often do health problems occur in your family? When?

20. Do you and your family ever have chronic health problems that affect your ability to work or engage in activities? Yes/no

21. How many people in your family suffer from chronic health problems? How often? When?

22. How much have you spent on treatment for heat-related illnesses? (IDR/day/week/month/year)

23. Have you or your family ever received any financial support for treating heat-related illnesses? Yes/no

24. If yes, how much? (IDR/month) How many times in the last 3 years?

25. Besides family members, do other people live in your house? Yes/no. If yes, how many?

26. Are there any health facilities available in your area? Yes/no

27. What kind of facility?

    a. Hospital

    b. Community health centre

    c. Local health centre

    d. Local clinic

    e. Integrated health service

28. How far is your house from the following health facilities?

    a. Hospital (m/km)

    b. Community health centre (m/km)

    c. Local health centre (m/km)

    d. Local clinic (m/km)

    e. Integrated health service (m/km)

29. Is your income enough to cover health expenses? Yes/no

30. How long does it take you to reach the health facilities?

    a. Hospital (minutes)

    b. Community health centre (minutes)

    c. Local health centre (minutes)

    d. Local clinic (minutes)

    e. Integrated health service (minutes)

Electricity

31. Do you have electricity in your house? Yes/no

32. Has your electricity bill increased because of rising temperatures? Yes/no

33. What is the maximum electricity capacity in your house?

    Before rising temperatures began:

    a. 450kWh
    b. 900 kWh
    c. 1300kWh
    d. 2200 kWh

    After rising temperatures began:

    a. 450kWh
    b. 900 kWh
    c. 1300kWh
    d. 2200 kWh

34. Why did you need to increase the capacity?
    a. Installing AC
    b. Having a refrigerator
    c. Having a fan
35. Is your income enough to cover your water, health and electricity needs? Yes/no
36. If not, how do you cover the costs?
    a. Bank overdraft
    b. Borrowing from neighbour
    c. Borrowing from an illegal agency
    d. Borrowing from relatives
37. How much do you spend on electricity? (IDR/month)

Adaptive capacity

Social relationships

38. Do your friends, relatives or neighbours ever help when you are sick (e.g. taking you to hospital, help with medicines, childcare etc.)? Yes/no
39. Do you ever offer help to your friends, relatives or neighbour? Yes/no
40. What kind of help did you offer?

Facilities (government)

41. Are these kinds of facilities or programmes provided by your local government?

No	Current programmes/facilities	Area(m^2)	Number	Start date	Condition
1	Green areas				
2	Public parks				
3	Public health: Hospital Community health centre Local health centre Integrated health service				
4	Tree planting				
No	**Future programmes**	**Available/not available**	**Area (m^2)**	**Number**	**Start date**
1	Green areas				
	Public parks				
	Public health: Hospital Community health centre Local health centre Integrated health service				
	Tree planting				

Household adaptation strategies

42. With the rising temperature, what strategies have you and your family planned?
    a. Remodel the house (explain)
    b. Planting trees (explain)
    c. Using rainwater for bathing and washing
    d. Preventing illness (explain)
43. Do you ever participate in any activities/training/programmes related to rising temperature?
    a. Trees planting
    b. Developing public park
    c. Making green areas
44. If yes, then when was that?
45. How much of your income do you save? (IDR/month)
46. Do you have any insurance? Yes/no
47. If yes, what kind of insurance?

Appendix 2. Methodology for constructing the vulnerability index

Calculating LVI-IPCC Index

Standardising indices

Since the unit of each sub-indicator will be different, it is necessary to standardise the unit with the formula

$$\text{Index}_{\text{sub-indicators}} = \frac{S - S_{min}}{S_{max} - S_{min}} \quad (1)$$

S = real score of each sub-indicator
S_{min} = minimum score of each sub-indicator
S_{max} = maximum score of each sub-indicator

Averaging sub-indicator indices

$$\text{M}_{\text{sub-indicator}} = \frac{\Sigma_{i=1}^{n} \, Index_{sub\text{-}indicators}}{n} \quad (2)$$

Calculating main indicator indices

$$\text{Index}_{\text{main indicators}} = \frac{\Sigma_{i=1}^{n} \, W_{Mi} M_{sub\text{-}indicators}}{\Sigma_{i=1}^{7} W_{Mi}} \quad (3)$$

W= weighing factor

Calculating IPCC vulnerability index

$$\text{CF}_{(e,a,s)} = \frac{\Sigma_{i=1}^{n} \, W_{Mi} M_{main\ indicators}}{\Sigma_{i=1}^{7} W_{Mi}} \quad (4)$$

CF = contribution factor of e (exposure), a (adaptive capacity) and s (sensitivity)

$$\text{VI}_{\text{IPCC}} = (e - a)*s \quad (5)$$

VI = Vulnerability index
LVI is ranged between 0 (low vulnerability) to 1 (high vulnerability), while
LVI-IPCCis ranged between –1 (low vulnerability) to +1 (high vulnerability).

Appendix 3. Questionnaire survey results, Bandar Lampung

Main indicators	Sub-indicators	Units	Natar	Raja-basa	Tanjung Karang Pusat	Teluk Betung Selatan	Panjang	Gedong Tataan	Kemiling	Sukabumi	Tanjung Bintang	Bandar Lampung	Max	Min
1. Natural disasters and climate variability	Percentage of households unaware of rising temperatures	Percent	60	7.5	10	10	37.5	47.5	12.5	12.5	27.5	25.00	100	0
	Percentage of households who don't think temperatures have risen in a 3-year period	Percent	22.5	10	7.5	0	0	27.5	20	5	0	10.28	100	0
	Percentage of households who don't know the causes of rising air temperatures	Percent	50	17.5	7.5	7.5	70	42.5	20	30	22.5	29.72	100	0
	Percentage of households who don't know the impact of rising air temperatures	Percent	80	25	12.5	10	87.5	70	42.5	67.5	17.5	45.83	100	0
	Average monthly air temperature(from climate data observation)	Celsius	29.86	29.51	29.18	30.89	29.8	27.49	29.39	29.47	29.24	29.43	39	21
	Average monthly rainfall(from climate data)	mm	171	171	171	171	171	171	171	171	171	171	343	89

Main indicators	Sub-indicators	Units	Natar	Raja-basa	Tanjung Karang Pusat	Teluk Betung Selatan	Panjang	Gedong Tataan	Kemiling	Sukabumi	Tanjung Bintang	Bandar Lampung	Max	Min
2. Water	Percentage of households with water problems	Percent	55	5	10	30	22.5	37.5	20	22.5	75	30.83	100	0
	Percentage of households using water from natural water sources for business use	Percent	40	90	100	100	100	90	100	100	60	86.67	100	0
	Percentage of households using water from natural water resources for domestic use	Percent	100	100	97.5	37.5	35	75	47.5	95	97.5	76.11	100	30
	Time used to reach natural water sources	Minutes	0.775	0.075	0	0	4.57	0.387	6.4	2.8	0.275	1.70	20	0
	Water needs of each household	ltr/day	547.64	936.60	763.6	255.09	718.52	234.64	898.72	1005.8	824.86	687.27	1019	53.33
	Total cost for water/month	IDR	45,950	33,375	28,225	65,925	98,600	49,450	63,500	46,875	34,775	51,852.78	200,000	6000
	Distance from house to water	m	0.925	0.275	0.5	0	80.05	1.36	617.93	8.33	6.8	79.57	3000	0
3. Health	Percentage of households who suffer from diseases caused by heat	Per cent	30	0.175	20	2.5	12.5	0	30	15	30	15.58	100	0
	Percentage of households with sick family members unable to engage in normal daily activities	Percent	0.1	0	5	5	12.5	0	0.425	0.125	0.275	2.60	100	0
	Average distance between house and health facility	m	992.5	218.8	877.5	1,775.0	1,742.5	562.5	856	2,033	4,000	1450.79	5,000	5

Main indicators	Sub-indicators	Units	Natar	Raja-basa	Tanjung Karang Pusat	Teluk Betung Selatan	Panjang	Gedong Tataan	Kemiling	Sukabumi	Tanjung Bintang	Bandar Lampung	Max	Min
	Average household cost for health	IDR	75,000	120,000	300,000	510,000	900,000	145,000	105,000	90,000	240,000	276,111.11	3E+06	0
	Percentage of households who don't have health insurance	Percent	80	77.5	70	92.5	92.5	92.5	47.5	75	87.5	79.44	100	0
	Percentage of households who don't receive health benefits	Percent	72.5	25	75	5	7.5	70	37.5	32.5	87.5	45.83	100	0
4. Electricity	Percentage of households who don't use electricity	Percent	0	0	0	0	0	0	0	0	0	0.00	100	0
	Average electrical power usage(watt)	Watt	836.25	1076.25	978.75	917.5	895	628.75	1038.75	785	842.5	888.75	2200	450
	Percentage of households who have not increased use of electrical power due to rising temperatures	Percent	97.5	97.5	87.5	90	97.5	97.5	82.5	92.5	95	93.06	100	0
	Average cost for electricity/ month	IDR	105,900	174,875	145,875	172,375	114,400	70,375	177,125	115,500	92,750	129,908.33	600,000	17,000

Main indicators	Sub-indicators	Units	Natar	Raja-basa	Tanjung Karang Pusat	Teluk Betung Selatan	Panjang	Gedong Tataan	Kemiling	Sukabumi	Tanjung Bintang	Bandar Lampung	Max	Min
5. Social relationships	Percentage of households who are not active in an organisation	Percent	0	0	0	5	2.5	55	12.5	27.5	0	11.39	100	0
	Percentage of households who are not involved in a community group/ organisation	Per cent	0	0	0	5	0	2.5	12	27.5	0	5.22	100	0
	Percentage of households unaware of environmental programmes	Per cent	25	25	0	12.5	55	22.5	12	27.5	0	19.94	100	0
	Percentage of households who have not joined a programme for reducing air temperature e. g. local tree-planting activities	Per cent	100	100	97.5	92.5	100	100	100	100	100	98.89	100	0
6. Education	Percentage of households with less than 6 years' education	Per cent	40	0	32.5	15	35	50	2.5	0	47.5	24.72	100	0
7. Income	Percentage of households with one source of income	Per cent	100	100	100	100	100	82.5	75	90	47.5	88.33	100	
	Percentage of households with an additional income(besides their main job)	Per cent	0	0	0	0	0	17.5	25	10	52.5	11.67	100	0
	Average income	IDR	1.94 million	1.94 million	2.78 million	2.06 million	1.38 million	1.60 million	3.93 million	2.1 million	1.74 million	2.16 million	10 million	200,000

Main indicators	Sub-indicators	Units	Natar	Raja-basa	Tanjung Karang Pusat	Teluk Betung Selatan	Panjang	Gedong Tataan	Kemiling	Sukabumi	Tanjung Bintang	Bandar Lampung	Max	Min
8. Housing Environment	Percentage of households who have not modified their home	Per cent	100	100	55	10	40	2.5	87.5	2.5	22.5	46.67	100	0
	Percentage of households who don't have AC/fan	Per cent	42.5	2.5	5	2.5	12.5	87.5	12.5	10	40	23.89	100	0
	Percentage of households living in informal housing	Per cent	0	0	0	0	0	0	0	0	0	0.00	100	0
	Average building size	m^2	79.35	109.05	77	78.65	57.45	67.05	90.05	38	66	200.40	400	12
	Distance between house and right-hand neighbour	m	3.9	0.9	0.825	0.76	0.15	4.7	0.825	1.2	3	1.84	100	0
	Percentage of houses with zinc/asbestos roof	Per cent	5	7.5	2.5	12.5	62.5	12.5	2.5	0	37.5	15.83	100	0
	Distance between house and left-hand neighbour	m	6	0.3	0.475	0.725	0.1	4.66	0.425	0.95	3.3	1.87	100	0
	Distance between house and rear neighbour	m	4.7	1	0.25	0.4	0.1	4.01	3	0.425	4.54	2.01	100	0
	Percentage of households with a semi-permanent house	Per cent	5	7.5	2.5	12.5	64	62.5	2.5	0	37.5	21.56	100	0
	Percentage of households with no green open space	Per cent	12.5	50	77.5	65	96.25	35	57.5	77.5	77.5	60.97	100	0
	Percentage of households with no trees in green open space	Per cent	35	57.5	50	87.12	96.25	50	62.5	75	75	65.37	100	0

Appendix 4. Standardised index value of sub and main components and LVI, Bandar Lampung

Sub and main components	Index value of sub and main components								
	Natar	Rajabasa	Tanjung Karang Pusat	Teluk Betung Selatan	Panjang	Gedong Tataan	Kemiling	Sukabumi	Tanjung Bintang
Natural disasters and climate variability sub-component	0.490	0.233	0.192	0.191	0.460	0.426	0.290	0.324	0.250
Households unaware of rising temperatures	0.600	0.075	0.100	0.100	0.375	0.475	0.125	0.125	0.275
Households who don't think temperatures have risen in a 3-year period	0.225	0.100	0.075	0.000	0.000	0.275	0.200	0.050	0.000
Households who don't know the causes of rising air temperatures	0.500	0.175	0.075	0.075	0.700	0.425	0.200	0.300	0.225
Households who don't know what the impacts are of rising air temperatures	0.800	0.250	0.125	0.100	0.875	0.700	0.425	0.675	0.175
Average monthly air temperature	0.492	0.473	0.454	0.549	0.489	0.361	0.466	0.471	0.500
Average monthly rainfall	0.323	0.323	0.323	0.323	0.323	0.323	0.323	0.323	0.323
Water sub-component	0.387	0.430	0.416	0.275	0.388	0.336	0.450	0.499	0.468
Households with water problems	0.550	0.050	0.100	0.300	0.225	0.375	0.200	0.225	0.750
Households using water from natural water sources for business use	0.400	0.900	1.000	1.000	1.000	0.900	1.000	1.000	0.600
Households using water from natural water resources for domestic use	1.000	1.000	0.964	0.107	0.071	0.643	0.250	0.929	0.964

Sub and main components	Index value of sub and main components								
	Natar	Rajabasa	Tanjung Karang Pusat	Teluk Betung Selatan	Panjang	Gedong Tataan	Kemiling	Sukabumi	Tanjung Bintang
Time taken to reach natural water sources	0.039	0.004	0.000	0.000	0.229	0.019	0.320	0.140	0.014
Water needs of each household	0.512	0.915	0.736	0.209	0.689	0.188	0.875	0.986	0.799
Total cost for water/month	0.206	0.141	0.115	0.309	0.477	0.224	0.296	0.211	0.148
Distance from house to water	0.000	0.000	0.000	0.000	0.027	0.000	0.206	0.003	0.002
Health sub-component	0.342	0.185	0.330	0.264	0.320	0.298	0.227	0.277	0.490
Households who suffer from diseases caused by heat	0.300	0.002	0.200	0.025	0.125	0.000	0.300	0.150	0.300
Households with sick family members unable to engage in normal daily activities	0.001	0.000	0.050	0.050	0.125	0.000	0.004	0.001	0.003
Average distance between house and health facility	0.198	0.043	0.175	0.354	0.348	0.112	0.170	0.406	0.800
Average household health costs	0.027	0.043	0.107	0.182	0.321	0.052	0.038	0.032	0.086
Households who don’t have health insurance	0.800	0.775	0.700	0.925	0.925	0.925	0.475	0.750	0.875
Households who don’t receive health benefits	0.725	0.250	0.750	0.050	0.075	0.700	0.375	0.325	0.875
Electricity sub-component	0.337	0.401	0.350	0.358	0.349	0.292	0.359	0.321	0.326
Households who don’t use electricity	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average electrical power usage (watt)	0.221	0.358	0.302	0.267	0.254	0.102	0.336	0.191	0.224
Households who have not increased use of electrical power due to rising temperatures	0.975	0.975	0.875	0.900	0.975	0.975	0.825	0.925	0.950
Average cost for electricity/month	0.152	0.271	0.221	0.267	0.167	0.092	0.275	0.169	0.130
Social relationships sub-component	0.313	0.313	0.244	0.288	0.394	0.450	0.341	0.456	0.250
Households who are not active in an organisation	0.000	0.000	0.000	0.050	0.025	0.550	0.125	0.275	0.000
Households who are not involved in a community group/ organisation	0.000	0.000	0.000	0.050	0.000	0.025	0.120	0.275	0.000
Households unaware of environmental programmes	0.250	0.250	0.000	0.125	0.550	0.225	0.120	0.275	0.000

Sub and main components	Index value of sub and main components								
	Natar	Rajabasa	Tanjung Karang Pusat	Teluk Betung Selatan	Panjang	Gedong Tataan	Kemiling	Sukabumi	Tanjung Bintang
Households who have not joined a programme for reducing air temperature e. g. local tree-planting act	1.000	1.000	0.975	0.925	1.000	1.000	1.000	1.000	1.000
Education sub-component	0.400	0.000	0.325	0.150	0.350	0.500	0.025	0.000	0.475
Households with less than 6 years' education	0.400	0.000	0.325	0.150	0.350	0.500	0.025	0.000	0.475
Income sub-component	0.393	0.393	0.421	0.397	0.374	0.381	0.460	0.398	0.386
Households with one source of income	1.000	1.000	1.000	1.000	1.000	0.825	0.750	0.900	0.475
Households with an additional income (besides their main job)	0.000	0.000	0.000	0.000	0.000	0.175	0.250	0.100	0.525
Average income	0.178	0.178	0.262	0.190	0.121	0.143	0.380	0.195	0.157
Housing environment sub-component	0.182	0.182	0.151	0.118	0.270	0.211	0.175	0.097	0.225
Households who have not modified their home	1.000	1.000	0.550	0.100	0.400	0.025	0.875	0.025	0.225
Households who don't have AC/fan	0.425	0.025	0.050	0.025	0.125	0.875	0.125	0.100	0.400
Households living in informal housing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average building size	0.174	0.250	0.167	0.172	0.117	0.142	0.201	0.066	0.138
Distance between house and right-hand neighbour	0.039	0.009	0.008	0.008	0.002	0.047	0.008	0.012	0.033
Houses with zinc/asbestos roof	0.050	0.075	0.025	0.125	0.625	0.125	0.025	0.000	0.375
Distance between house and left-hand neighbour	0.059	0.003	0.005	0.007	0.001	0.047	0.004	0.010	0.033
Distance between house and rear neighbour	0.047	0.010	0.003	0.004	0.001	0.040	0.027	0.004	0.045
Households with a semi-permanent house	0.050	0.075	0.025	0.125	0.640	0.625	0.025	0.000	0.375
Households with no green open space	0.125	0.500	0.775	0.650	0.963	0.350	0.575	0.775	0.775
Households with no trees in green open space	0.035	0.058	0.050	0.087	0.096	0.050	0.063	0.075	0.075
LVI value	**0.330**	**0.275**	**0.278**	**0.235**	**0.353**	**0.325**	**0.295**	**0.297**	**0.336**

Appendix 5. Questionnaire survey results, Jakarta

Main indicators	Sub-indicators	Units	Semanan	Kedoya Utara	Johar Baru	Gambir	Kayu Putih	Cakung Timur	Cempaka Putih Timur	Duri Kosambi	Max	Min
1. Natural disasters and climate variability	Percentage of households unaware of rising temperatures	Per cent	0	0	23.81	0	7.15	0	0	9.1	100	0
	Percentage of households who don't think temperatures have risen in a 3-year period	Per cent	0	0	14.29	6.67	0	0	0	4.55	100	0
	Percentage of households who don't know the causes of rising air temperatures	Per cent	0	0	38.08	7.14	14.29	0	0	0	100	0
	Percentage of households who don't know the impact of rising air temperatures	Per cent	10	0	100	33.33	21.43	30	0	0	100	0
	Average monthly air temperature (from climate data observation)	Celsius	29.6	29.6	30.86	30.02	29.88	30.88	32.12	30.48	42	25
	Average monthly rainfall (from climate data)	Mm	215	215	215	215	215	215	215	215	315	97.7

Main indicators	Sub-indicators	Units	Semanan	Kedoya Utara	Johar Baru	Gambir	Kayu Putih	Cakung Timur	Cempaka Putih Timur	Duri Kosambi	Max	Min
2. Water	Percentage of households with water problems	Per cent	90	100	14.28	40	14.28	100	0	63.64	100	0
	Percentage of households using water from natural water sources for business use	Per cent	0	0	0	6.67	0	0	85.72	13.64	100	0
	Percentage of households using water from natural water resources for domestic use	Per cent	100	0	6.67	6.67	71.43	63.16	100	13.64	100	0
	Time used to reach natural water sources	Minute	1.5	0	1.52	0.4	0	0	0	0	3	0
	Water needs of each household	ltr/day	76.82	103.55	105	209.71	250.56	140.63	112.12	147.21	419	10
	Total cost for water/month	IDR	406,000	76,433	270,000	173,467	112,857	44,200	62,143	64,818	600,000	0
	Distance from house to water	m	20	0	21.19	9.33	0	0	0	0	200	0

Main indicators	Sub-indicators	Units	Semanan	Kedoya Utara	Johar Baru	Gambir	Kayu Putih	Cakung Timur	Cempaka Putih Timur	Duri Kosambi	Max	Min
3. Health	Percentage of households who suffer from diseases caused by heat	Per cent	50	3.33	28.57	6.67	0	0	0	36.36	100	0
	Percentage of households with sick family members unable to engage in normal daily activities	Per cent	50	0	14.28	46.67	0	0	0	22.73	100	0
	Average distance between house and health facility	m	1,300	1,500	200	500	664.285	1,050	1,142.86	1,090.91	3000	200
	Average household cost for health	IDR	455,000	250,000	250,000	250,000	250,000	12,500	250,000	346,364	4 million	0
	Percentage of households who don't have health insurance	Per cent	100	100	47.62	53.33	78.57	100	71.43	36.36	100	0
	Percentage of households who don't receive health benefits	Per cent	70	43.33	42.86	66.67	64.29	80	57.14	0	100	0
4. Electricity	Percentage of households who don't use electricity	Per cent	0	0	0	0	0	0	0	0	100	0
	Average electrical power usage (watt)	Watt	1,455	918.33	821.43	1,200	830	652.5	900	988.64	3500	450
	Percentage of households who have not increased use of electrical power due to rising temperatures	Per cent	100	100	100	100	71.43	100	85.72	59.09	100	0
	Average cost for electricity/month	IDR	228,500	826,167	126,429	248,000	185,000	82,000	125,714	114,318	15,000,000	25,000

Main indicators	Sub-indicators	Units	Semanan	Kedoya Utara	Johar Baru	Gambir	Kayu Putih	Cakung Timur	Cempaka Putih Timur	Duri Kosambi	Max	Min
5. Social relationships	Percentage of households who are not active in an organisation	Per cent	90	76.67	76.19	80	85.72	100	85.72	63.64	100	0
	Percentage of households who are not involved in a community group/ organisation	Per cent	20	73.33	0	26.67	7.14	0	0	36.36	100	0
	Percentage of households unaware of environmental programmes	Per cent	0	0	52.38	33.33	21.43	100	0	36.36	100	0
	Percentage of households who have not joined a programme for reducing air temperature e. g. local tree-planting activities	Per cent	80	100	23.33	33.33	8.33	25	0	72.73	100	0
6. Education	Percentage of households with less than 6 years' education	Per cent	40	33.33	52.38	20	21.43	45	0	0	100	0
7. Income	Percentage of households with one source of income	Per cent	80	76.67	85.72	86.67	71.43	65	100	63.64	100	0
	Percentage of households with an additional income (besides their main job)	Per cent	20	23.33	14.28	13.33	28.57	15	0	36.36	100	0
	Average income	IDR	3,450,000	2,295,000	1,602,381	2,920,000	5,539,286	3,350,000	3,000,000	2,827,273	21,000,000	350,000

Main indicators	Sub-indicators	Units	Semanan	Kedoya Utara	Johar Baru	Gambir	Kayu Putih	Cakung Timur	Cempaka Putih Timur	Duri Kosambi	Max	Min
8. Housing environment	Percentage of households who have not modified their home	Per cent	100	100	100	100	100	100	100	100	100	0
	Percentage of households who don't have AC/fan	Per cent	10	16.67	4.76	0	0	20	0	0	100	0
	Percentage of households living in informal housing	Per cent	0	0	0	0	0	10	0	0	100	0
	Average building size	m^2	10	0	4.76	6.67	14.29	25	0	77.33	100	0
	Distance between house and right-hand neighbour	m	32.4	35.9	18	32.6	75.71	70.5	22.43	27.4	300	9
	Percentage of houses with zinc/asbestos roof	Per cent	80	80	85.71	80	42.86	70	0	54.55	100	0
	Distance between house and left-hand neighbour	m	1	1	0	0	1.43	2.75	1.28	0.68	50	0
	Distance between house and rear neighbour	m	1	1	0	0	0.285	3	1.28	0.68	50	0
	Percentage of households with a semi-permanent house	Per cent	4.5	1	0	0.67	0.5	2.75	1.43	1.25	50	0
	Percentage of households with no green open space	Per cent	90	93.33	95.24	80	92.86	85	71.43	95.45	100	0
	Percentage of households with no trees in green open space	Per cent	90	93.33	100	93.33	92.86	85	66.67	95.45	100	0

Appendix 6. Standardised index value of sub and main components and LVI, Jakarta

Sub and main components	Index value of sub and main components							
	Semanan	Kedoya Utara	Johar Baru	Gambir	Kayu Putih	Cakung Timur	Cempaka Putih Timur	Duri Kosambi
Natural disasters and climate variability sub-component	0.152	0.135	0.441	0.218	0.209	0.198	0.160	0.166
Households unaware of rising temperatures	0.000	0.000	0.238	0.000	0.072	0.000	0.000	0.091
Households who don’t think temperatures have risen in a 3-year period	0.000	0.000	0.143	0.067	0.000	0.000	0.000	0.046
Households who don’t know the causes of rising air temperatures	0.000	0.000	0.381	0.071	0.143	0.000	0.000	0.000
Households who don’t know what the impacts are of rising air temperatures	0.100	0.000	1.000	0.333	0.214	0.300	0.000	0.000
Average monthly air temperature	0.271	0.271	0.345	0.295	0.287	0.346	0.419	0.322
Average monthly rainfall	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540
Water sub-component	0.461	0.266	0.220	0.353	0.425	0.392	0.395	0.352
Households with water problems	0.900	1.000	0.143	0.400	0.143	1.000	0.000	0.636
Households using water from natural water sources for business use	0.000	0.000	0.000	0.067	0.000	0.000	0.857	0.136
Households using water from natural water resources for domestic use	1.000	0.000	0.067	0.067	0.714	0.632	1.000	0.136
Time taken to reach natural water sources	0.500	0.000	0.507	0.133	0.000	0.000	0.000	0.000

Sub and main components	Index value of sub and main components							
	Semanan	Kedoya Utara	Johar Baru	Gambir	Kayu Putih	Cakung Timur	Cempaka Putih Timur	Duri Kosambi
Water needs of each household	0.163	0.229	0.232	0.488	0.588	0.319	0.250	0.335
Total cost for water/ month	0.677	0.127	0.450	0.289	0.188	0.074	0.104	0.108
Distance from house to water	0.100	0.000	0.106	0.047	0.000	0.000	0.000	0.000
Health sub-component	0.534	0.332	0.233	0.317	0.276	0.351	0.281	0.227
Households who suffer from diseases caused by heat	0.500	0.033	0.286	0.067	0.000	0.000	0.000	0.364
Households with sick family members unable to engage in normal daily activities	0.500	0.000	0.143	0.467	0.000	0.000	0.000	0.227
Average distance between house and health facility	0.393	0.464	0.000	0.107	0.166	0.304	0.337	0.318
Average household health costs	0.114	0.063	0.063	0.063	0.063	0.003	0.063	0.087
Households who don't have health insurance	1.000	1.000	0.476	0.533	0.786	1.000	0.714	0.364
Households who don't receive health benefits	0.700	0.433	0.429	0.667	0.643	0.800	0.571	0.000
Electricity sub-component	0.336	0.302	0.282	0.315	0.212	0.268	0.253	0.193
Households who don't use electricity	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average electrical power usage (watt)	0.330	0.154	0.122	0.246	0.125	0.066	0.148	0.177
Households who have not increased use of electrical power due to rising temperatures	1.000	1.000	1.000	1.000	0.714	1.000	0.857	0.591
Average cost for electricity/month	0.014	0.054	0.007	0.015	0.011	0.004	0.007	0.006
Social relationships sub-component	0.475	0.625	0.380	0.433	0.307	0.563	0.214	0.523
Households who are not active in an organisation	0.900	0.767	0.762	0.800	0.857	1.000	0.857	0.636

Sub and main components	Index value of sub and main components							
	Semanan	Kedoya Utara	Johar Baru	Gambir	Kayu Putih	Cakung Timur	Cempaka Putih Timur	Duri Kosambi
Households who are not involved in a community group/ organisation	0.200	0.733	0.000	0.267	0.071	0.000	0.000	0.364
Households unaware of environmental programmes	0.000	0.000	0.524	0.333	0.214	1.000	0.000	0.364
Households who have not joined a programme for reducing air temperature e. g. local tree-planting act	0.800	1.000	0.233	0.333	0.083	0.250	0.000	0.727
Education sub-component	0.400	0.333	0.524	0.200	0.214	0.450	0.000	0.000
Households with less than 6 years' education	0.400	0.333	0.524	0.200	0.214	0.450	0.000	0.000
Income sub-component	0.383	0.365	0.354	0.375	0.417	0.315	0.376	0.373
Households with one source of income	0.800	0.767	0.857	0.867	0.714	0.650	1.000	0.636
Households with an additional income (besides their main job)	0.200	0.233	0.143	0.133	0.286	0.150	0.000	0.364
Average income	0.150	0.094	0.061	0.124	0.251	0.145	0.128	0.120
Housing environment sub-component	0.365	0.362	0.358	0.336	0.337	0.394	0.228	0.395
Households who have not modified their home	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Households who don't have AC/fan	0.100	0.167	0.048	0.000	0.000	0.200	0.000	0.000
Households living in informal housing	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000
Average building size	0.100	0.000	0.048	0.067	0.143	0.250	0.000	0.773
Distance between house and right-hand neighbour	0.080	0.092	0.031	0.081	0.229	0.211	0.046	0.063
Houses with zinc/ asbestos roof	0.800	0.800	0.857	0.800	0.429	0.700	0.000	0.546
Distance between house and left-hand neighbour	0.020	0.020	0.000	0.000	0.029	0.055	0.026	0.014

Sub and main components	Index value of sub and main components							
	Semanan	**Kedoya Utara**	**Johar Baru**	**Gambir**	**Kayu Putih**	**Cakung Timur**	**Cempaka Putih Timur**	**Duri Kosambi**
Distance between house and rear neighbour	0.020	0.020	0.000	0.000	0.006	0.060	0.026	0.014
Households with a semi-permanent house	0.090	0.020	0.000	0.013	0.010	0.055	0.029	0.025
Households with no green open space	0.900	0.933	0.952	0.800	0.929	0.850	0.714	0.955
Households with no trees in green open space	0.900	0.933	1.000	0.933	0.929	0.850	0.667	0.955
LVI Value	0.384	0.328	0.327	0.326	0.313	0.359	0.260	0.313

The impact of urban heat islands: Assessing vulnerability in Indonesia

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80-86 Gray's Inn Road, London WC1X 8NH, UK
Tel: +44 (0)20 3463 7399
Fax: +44 (0)20 3514 9055
email: humans@iied.org
www.iied.org