

Research of Urban Heat Island (UHI) in Shenzhen Based on Climatic Design and Urban Planning Strategies

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ABSTRACT

Urbanization with growing population and economic development in China has resulted in fast expansion of urban areas with rapidly land use change. The newly constructed high density city pattern is to meet the development of cities and at the cost of urban environment. Shenzhen, which regarded as the most rapidly urbanizing city in China in the last three decades is taken as an example to study the urban heat island (UHI) effect. As the urban heat island effect is the most common environmental issue associated with the urbanization and influence the sustainable development of Shenzhen, understanding the urban heat island in Shenzhen is highly important. In this paper, the climate condition of Shenzhen will be presented. Moreover, the performance of urban heat island in relation to urban planning and land use change will be analysed and discussed. Besides, several urban planning strategies are put forward. The conclusion presented in this paper can made available to the designer and used as a reference guideline for achieving sustainable urban planning for Shenzhen.

Keywords: *urban regeneration, urban heat island, urban planning strategies*

1. INTRODUCTION

1.1 Geography and climate condition of Shenzhen

Shenzhen, which regarded as the fastest developed city in China, is a coastal city belongs to the Pearl River Delta and located at the southeast of Guangdong Province (Huasheng, 1991). It is a liner city surrounded by hills and seas with a total area of 1992 km² hilly terrain (Chen, et al., 2014). The topography condition of Shenzhen is undulating, the southeast part is hilly with mountains which may block the typhoon in summer while the northwest part of Shenzhen is relatively low along the west coast (Ng, 2003). In this case, the land use pattern in Shenzhen is various including cropland, woodland, built up area, water body and unused land and there are four major rivers run through the city (Tianhong, et al., 2010).

Shenzhen enjoy a humid subtropical marine monsoon climate and belongs to the hot summer and warm winter climate zone (Song & Somasundaram, 2009). Influence by the East Asian monsoon, the summer in Shenzhen is wet and hot while the winter is comparatively dry and mild. The climate data for Shenzhen shows that the annual mean temperature is 22.55°C with monthly averages temperature ranging from 11.7°C in January to 32.2°C in July, the city enjoy 1933 hours sunshine per year and the annual rainfall in Shenzhen city is about 1966mm (China Meteorological Administration). In this case, the temperature in summer is high and cause the heat generate in the city which may lead to urban heat island effect.

1.2 Urbanization development of Shenzhen

Within 30 years, Shenzhen has experienced a tremendous change from a small fishing village to a modern city (Che, et al., 2011). Study shows that the population for Shenzhen is only 0.31 million in 1979 (Ng, 2003). With the Open Door Policy in China and the setting up of Special Economic Zone (SEZ) in 1980, the total population of Shenzhen was 4.69 million until 2001. And the urban population was increased to 10.37 million in 2010 (Shi & Yu, 2014). In this case, in order to balance the population grow, the expansion of urban areas with built up zones is needed. As a liner city, the rapid urban sprawl in Shenzhen was developed along several cores to the surrounding areas and there are four main axes for urban develop along west, middle, east and south (Xie, et al., 2013).

The urbanization of Shenzhen shows that the built up areas has extended to the middle of Shenzhen city and the western part along the coast from 1990 to 1994. From 1994 to 2005, the built up areas growing ever faster which occupied west of Shenzhen and expand to north part of Longgang district. The built up space increased from

0.63% to 33.42% while forest decreased from 38.71% to 29.96%; water bodies decreased from 7.41% to 5.64% and wetland decreased 0.21% (Che, et al., 2011).

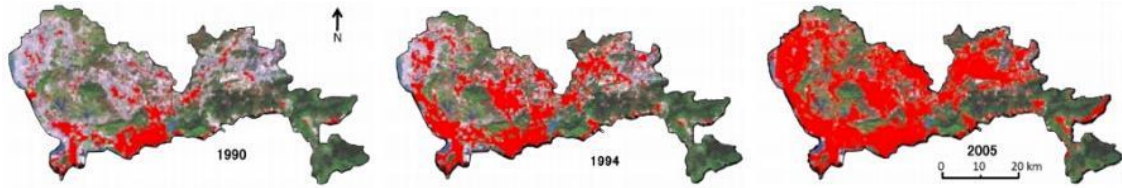


Figure 1: Urbanization pattern in Shenzhen (Che, et al., 2011).

As a result of fast urbanization, Shenzhen is toward a shortage of land and resources, facing high density urban pattern and several environmental problems (Shi & Yu, 2014). For example, stress between industrial, residential and natural land, traffic jam, air pollution, reducing of green open space and urban heat island effect. Among them, urban heat island (UHI) issue is highly relevant to the urbanization process and has huge impact on the sustainable development of Shenzhen.

2. UHI ISSUE OF SHENZHEN

2.1 The special distribution of UHI in Shenzhen

Urban heat island effect is performed that the urban area temperature will be higher than the surrounding countryside (ZHANG, et al., 2011). Study shows that the temperature in Shenzhen is keeping increasing during the past 50 years reaching 28°C in 2005 and the extremely hot day in summer is also increase which gradually heat up the city, the temperature in the city center is approximately 3°C higher than the suburban area (Lin, 2011).

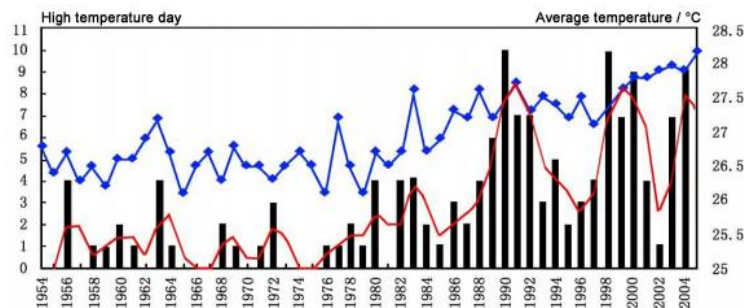


Figure 2: Temperature in Shenzhen (1954 – 2005) (Lin, 2011).

By using regional boundary layer model (RBLM), the studies illustrated that during the daytime, the UHI intensity can reach around 4°C at the western part of Shenzhen (ZHANG, et al., 2011). And the strong UHI effect is happened in Nanshan, Futian and western Bao'an district with temperature higher than 33°C while other part of Shenzhen are also facing obvious urban heat island effect with the temperature between 31°C to 33°C (ZHANG, et al., 2011). However, during the nighttime, the high value of UHI happened in the city center with high density in western Nanshan, western Luohu and western Bao'an district with temperature more than 27°C (ZHANG, et al., 2011). When it compared with the urbanization pattern of Shenzhen, it can be seen that the high value of UHI intensity happen in the construction areas which means that the urban planning with high density buildings areas will generate urban heat island effect.

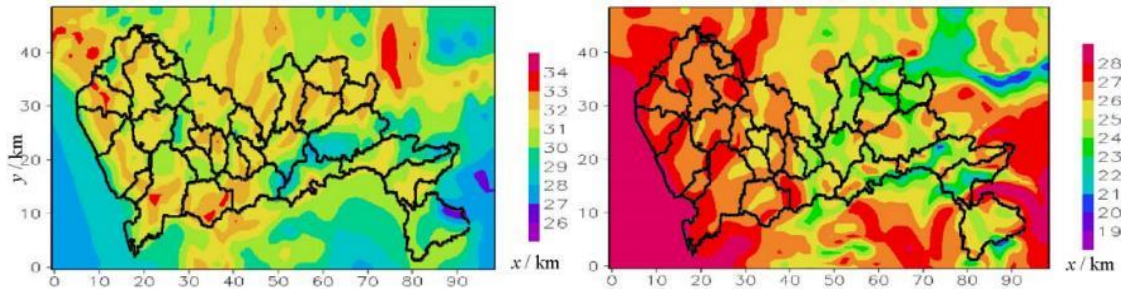


Figure 3: Air temperature during daytime and nighttime (ZHANG, et al., 2011).

2.2 The formation of UHI in Shenzhen

2.1.1. Land use change

Land use change is one of the key factors that generate UHI in Shenzhen. A study indicates that the land use pattern in Shenzhen has toward significant change during 1990 to 2008. The urban land is growing faster along the western coast and main road while the natural land with greenery is decreasing (Chen, et al., 2014). The UHI spatial distribution is highly match the urban land expansion pattern. For land use type of Shenzhen, the developed land dominate most part of the city land while the green land is limited to the mountain areas (Xie, et al., 2013). In this case, the constructed land will increase the surface roughness and have relatively high surface temperature thus generate the urban heat island effect in this areas.

As UHI is characterized by land surface temperature (LST) and land cover and landscape patterns are the two main factors that influence the LST, the vegetation fraction and impervious surface areas of Shenzhen are illustrated below to show the relation between land use and UHI issue (Xie, et al., 2013). It can be concluded that the higher vegetation fraction areas the lower surface temperature and the higher value of impervious surface areas the higher the surface temperature due to the cooling effect of the vegetation. In this case, the reduction of greenery space was one of the reasons that cause UHI effect in Shenzhen.

2.1.2. High density built up areas

From the above analysis, it can be seen that Shenzhen has experienced a rapid urbanization and urban expansion period. The develop pattern of Shenzhen is toward a high rise and high density city like Hong Kong. A study of the greening space in Shenzhen shows that the forest land is quite large (Che, et al., 2011). However, within the urban built up areas are lack of greenery and open space. The zoning for street network of the most densely populated area of Shenzhen indicated that the street network is closely linked to each other without space for urban greenery (Wang, et al., 2013). And the planting of greenery cannot catch up with the construction of buildings and highways in the city. The existing trees planted along the streets may be too small to effectively reflect the solar radiation and cooling down the local temperature.

Besides, another study shows that among the high density areas of the city, wind cannot easily ventilated the region because the wind speed will reduce when passing the high density building areas. The wind speed will decrease from 2.7m/s to 1.2m/s when entering the urban districts (Lin, 2011). In most areas, the wind speed is only 1m/s or even create the stagnate zones. In this case, the heat will generate and stay in the urban areas due to the poor urban scale ventilation which will greatly increase the potential for UHI effect in Shenzhen.

2.1.3. Reduction of water bodies

The reduction of water bodies in Shenzhen is regarded as another factor that forming the UHI. Study shows that the river network of Shenzhen has toward a decrease from 1980 to 2005 (Zhou, et al., 2010). It can be seen that the river network complexity is decreased from 36.1 to 31.6 and the number and length of the river are also decrease during the urbanization with the total length of the rivers in Shenzhen shortened 355.4km (Zhou, et al., 2010). It can be concluded that with the fast development of urban areas, the water bodies have been influenced and the cooling effect of the rivers are also reduced. In this case, the surface temperature of Shenzhen is keep increasing with the decrease of water bodies therefore generate the UHI effect.

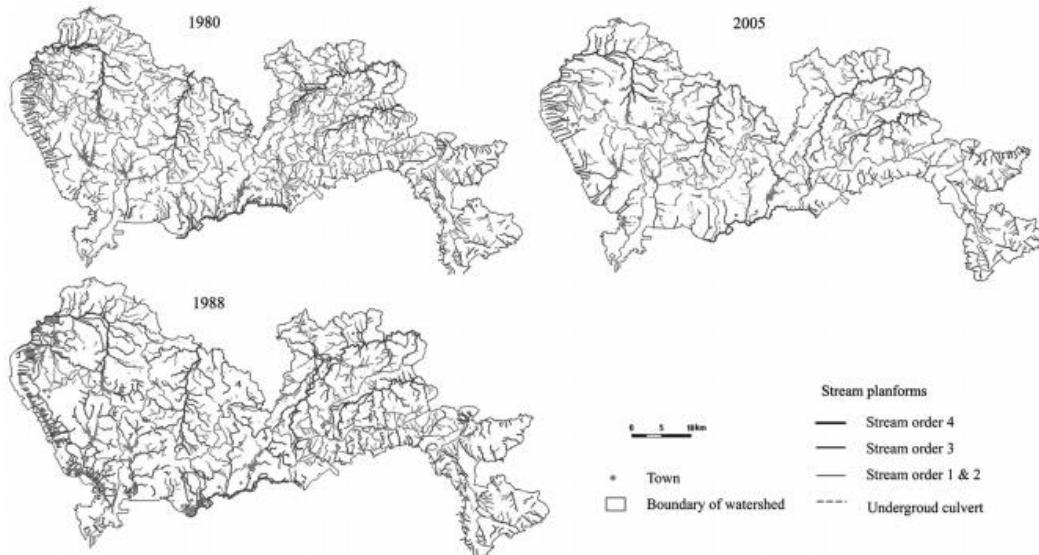


Figure 6: River network change in Shenzhen (Zhou, et al., 2010).

2.1.4. Anthropogenic heat

Anthropogenic heat is another reason that forming UHI in Shenzhen. From the UHI distribution pattern, it can be concluded that the strongest UHI areas appear with high population density (Zhang, et al., 2011). Human's activities will significant increasing the energy consumption thus generate unwanted heat of those regions. Besides, study shows that the total number of motor vehicles and private car in Shenzhen are increasing. Reaching 2.72 million in 2014 with the annual growth rate of 16.2% and the vehicle density in Shenzhen is 440 per km which is much higher than the international standard (Zhang, et al., 2011).

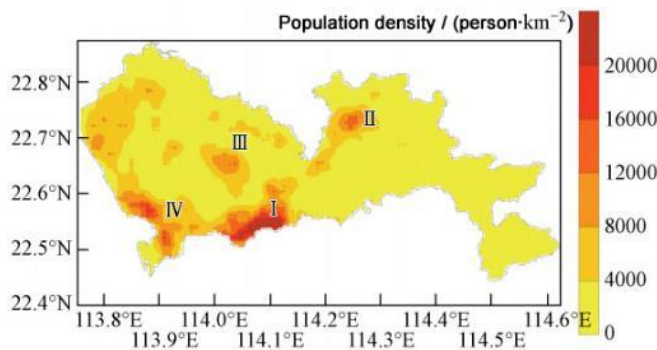


Figure 7: Population density of Shenzhen (Zhang, et al., 2011)

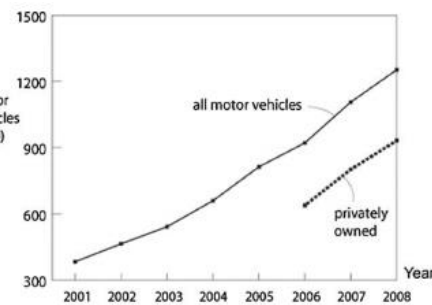


Figure 8: Motor vehicle and private car tendency in Shenzhen (Zacharias & Tang, 2010).

Besides, according to the studies of industrial and commercial zone location and the road network of Shenzhen indicates that the UHI effect is highly related to the anthropogenic heat generated by industrial and commercial activities and transportation. The western part with distribution of industrial and commercial districts and the central part with main road network are found to have higher UHI value in Shenzhen. Therefore the built up of buildings and the emission of the private cars are one of the key reason that forming the urban heat island.

3. URBAN PLANNING STRATEGIES TO CONTROL UHI

3.1 Ventilation corridors

In order to reduce the urban heat island effect in Shenzhen, ventilation corridors should be created both on city scale and district scale. On the city scale, as the dominate wind direction of Shenzhen is northeast, east and southeast, the wind path should be arranged northeast to southwest and northwest to southeast. And the wind corridors may follow the major roads and green lands and link to each other. Besides, the air path should prevailing

to the dominate wind direction and should be long and width enough to effectively ventilate the whole community. On the district scale, a new district known as the Low Carbon City locates in Pingdi district which can represent the future urban planning model of Shenzhen is designing the wind corridors according to the dominate wind direction to reduce the urban heat island effect. In this case, the wind can penetrate into the urban built up areas and bring away the urban heat.

3.2 Linkage of open space and increase greenery

Increase open space with greenery is another useful strategies to reduce urban heat island effect in the city due to the cooling effect of vegetation. A greenway has been built up which went through the whole Shenzhen city to increase greenery in the city and bring wind into the urban construction areas. In this case, the surrounding urban areas can be benefit from the greenway and the land surface temperature will to some extent decrease. The greenway can not only provide a space for people to enjoy nature and do exercise but also is a process toward sustainable urban planning for the future of Shenzhen.

Besides, several strategies are needed on the district scale to improve the local environment as microclimate play an important role in the whole urban climate condition. In order to build up the Low Carbon City, several strategies are put forward. Buildings are setback to widen the streets; open spaces are design within the high density built up areas for better ventilation and provide outdoor thermal comfort; trees are planting at the sidewalks at the initial stage of urban planning to improve the environment at the pedestrian level. What's more, the green belts are closely linked with the surrounding nature land to make sure the cooling effect. In some really high dense areas where building setback and open spaces are hard to design, vertical planting and roof gardens are needed to increase the greenery in this areas.

3.3 Building design toward sustainable urban planning

Buildings which take up the biggest parts of urban built up areas should be design properly to reduce the urban heat island effect in Shenzhen. As Shenzhen is locates at the hot summer and warm winter climate zone the same as Hong Kong, the urban planning guideline published by the Hong Kong Planning Department can also applied in Shenzhen. For building orientation and disposition, in order to catch wind, the building orientation and disposition is very important. Building should be oriented to face the prevailing wind with large openings, the main street should parallel or up to 30° with the dominate wind and the length of building façade along with the prevailing wind should be longer to reduce stagnant zone behind the building (HK Planning Department, 2014). For building height, a mix of low-rise and high-rise building will benefit the wind movement. Increase the building height of the behind building along with the prevailing wind direction can enhance the ventilation and allow the wind to reach the building behind (HK Planning Department, 2014). Besides, for building permeability, better ventilation pattern can be achieved by creating gaps and openings on the buildings.

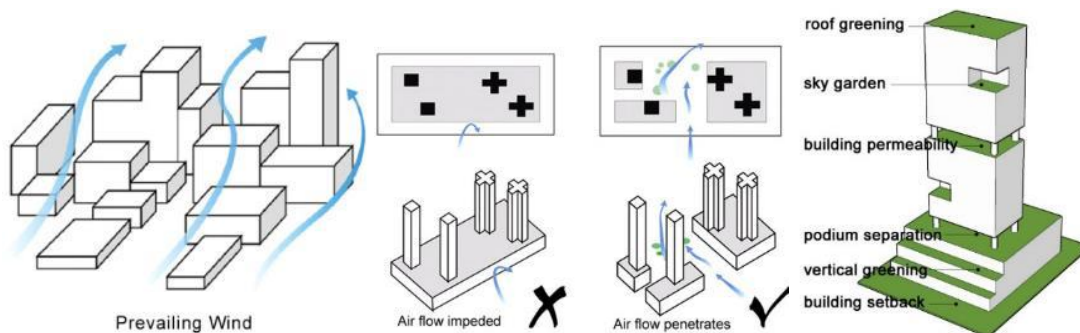


Figure 11: Building height and podium separation (HK Planning Department, 2014).

Figure 12: Building permeability (By author).

3.4 Green transportation system

Green transportation system is highly recommended in Shenzhen in the form of green subway system and electric vehicles. By encouraging people to use public transportation, the number of private cars can be greatly reduce therefore the anthropogenic heat generate by cars can also decrease. Besides, the electric vehicles are green because it uses electricity instead of burning gasoline. In this case, the heat release by the transportation can be reduced and thus make great contribution to the control of urban heat island effect in Shenzhen.

4. CONCLUSION

Urban heat island is considered as one of the most important environmental issue as it influences the sustainable urban development and living environment directly. The urban heat island effect in Shenzhen is becoming much more obvious since 1980 with the rapid urbanization process. From the analysis of spatial distribution of UHI and land surface temperature, the strong UHI appeared at the urban construction areas with high density building pattern. Land use change during the urbanization process, high density built up areas, reduction of water bodies and anthropogenic heat generated by human activities are the main factors that forming UHI in Shenzhen. Shenzhen which locates in the hot summer and warm winter climate zone in China, has huge potential to reduce UHI effect and achieve sustainable urban planning in the future. Several climatic based design and urban planning strategies such as ventilation corridors, linkage of open space and increase greenery, building design toward sustainable urban planning and green transportation system are put forwarded to control the UHI in Shenzhen. Therefore, the urban planning strategies presented in this paper can made available to the designer and used as a reference guideline for achieving sustainable urban planning for Shenzhen and any other cities with similar urban climate condition.

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