USING LANDSAT SATRLLITE IMAGERY TO EXAMINE SPATIAL URBAN EXPANSION OF FIVE MUNICIPALITIES IN TAIWAN

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ABSTRACT: This objective of this research was on using the Landsat satellite imagery for GIS-based urbanisation spatial pattern analysis in five municipalities in Taiwan since 1980 to 2010. The five municipalities include Taipei, New Taipei, Taichung, Tainan and Kaohsiung. The satellite images used in this research contented Landsat MSS, Landsat TM, and Landsat ETM+. Urbanisation often results in the increasing the density of transportation systems and population growth, and ultimately leading to change of land cover. Forest lands, agricultural lands, and other naturally vegetated lands were converted into high density of urban constructions, such as buildings, urban concrete playgrounds and transportation systems. Urban structures, natural vegetation and water all have unique spectral reflectance characteristics. Using this characteristic, the Maximum Likelihood supervised classification was performed, and the images was divided into two classes, urban area and non-urban area in each municipality. The percentages of urban zone over the area of each municipality were calculated in every ten years since 1980 to 2010. The results indicated that population growth pressure caused the urbanisation spatial pattern to be significant dynamic. The urban pattern was started at a city centre core and was extended to outside regions. In Taiwan, urban patterns in each municipality was influenced by transportation systems, but was limited by natural barriers, such as river and mountainous areas. Overall, the Taipei, the capital city was developed in early stage, and approached fully urbanised in 2000 due to extremely high population density and fully integrated transportation systems. Other municipalities were still in stage of growth, and need enhance transportation systems and increase population from other places in order to assist the metropolis development.

1. INTROUDUCTION

Urbanisation has become a major issue worldwide in recent years. The phenomenon of urbanization usually accompanies with industrial, society or economic development. These developments in a city usually create employment positions, as the result, more people from rural areas come to work and live in the city, and city has gradually expanded. Urbanization is also defined by the United Nations as movement of people from rural to urban areas with population growth equating to urban migration.

As a city develops, the increasing density of population and economic and society activities demand more land be developed for public infrastructures (such as roads, water facilities and utilities), housing, industrial and commercial uses. Urbanisation can be considered as the observable transformation of spatial pattern of land use and land cover, such as the transformation of agricultural and forest land used in to construction areas or the gradual transformation of rural landscape in to urban form (Thapa &Murayama 2009). With the rapid urbanisation, the transformation of rural landscape to urban landscape has caused various impacts on ecosystems structure, function and dynamics (Thapa &Murayama 2009). In Taiwan, the five municipalities which include Taipei, New Taipei, Taichung, Tainan and Kaohsiung have urbanised rapidly in the last decade. With the completion of major transportation systems (such as Taiwan High Speed Rail, MRT, highways and expressways) and major constructions, the terrain and landforms in these municipalities have changed. Using satellite images for long term is able to observe the variation and change of urbanisation patterns in order to make a suitable urban plan and achieve the sustainable urbanisation in Taiwan.

2. RESEARCH METHODOLOGY

2.1 Study Area

The study area of this research was the five municipalities in Taiwan. The five municipalities include Taipei, New Taipei, Taichung, Tainan and Kaohsiung. Taipei was made a municipality in 1967; Kaohsiung was elevated in 1979; New Taipei, Taichung, and Tainan also elevated to a special municipality in 2010. The location of the five municipalities was shown in Figure 1. These municipalities are major cities of business, industry, culture and politics in Taiwan; as a consequence, these municipalities developed earlier than other cities in Taiwan, Taipei especially, the capital city of Taiwan.

Figure 1: Study Area

2.2 Data Sources

The satellite images used in this research contented Landsat MSS, Landsat TM, and Landsat ETM+. Landsat satellites have been collecting images since 1972. One target of this research was calculating the percentages of urban zone over the area of each municipality were calculated in every ten years since 1980 to 2010; therefore, Landsat satellite imagery was suitable for this research. The satellites data used each municipality from 1980 to 2010 were summarised in Table 1. Landsat 2 and Landsat 3 images were used in 1980, and the resolution was 80m. Landsat 4 and Landsat 5 images were used in 1990, and the resolution was 30m. Landsat 7 images were used in 2000 and 2010, and the resolution used in this research was also 30m. On May 31, 2003, the Scan Line Corrector (SLC) which compensates for the forward motion of the satellite in t the ETM+ instrument for Landsat 7 failed (Huang et al. 2011). There were several gaps in using Landsat 7 ETM+ image data for 2010 data. Satellite dates used in 2010 were fixed by using Landsat 7 SLC-Off Gapes Filling program which were developed by the Centre for Space and Remote Sensing Research at the National Central University.

Table 1: List of Satellites Images

	1980	1990	2000	2010
Taipei	• Landsat 2 MSS 12/08/1977 • Landsat 2 MSS 01/26/1979	• Landsat 5 TM 07/22/1990	• Landsat 7 ETM+ 03/06/2001	• Landsat 7 ETM+ 03/31/2010
New Taipei	• Landsat 2 MSS 12/08/1977 • Landsat 2 MSS 01/26/1979	• Landsat 5 TM 07/22/1990	• Landsat 7 ETM+ 03/06/2001	• Landsat 7 ETM+ 03/31/2010
Taichung	• Landsat 2 MSS 01/26/1979	• Landsat 4 TM 07/21/1990 • Landsat 5 TM 07/22/1990	• Landsat 7 ETM+ 03/06/2001 • Landsat 7 ETM+ 03/13/2001	• Landsat 7 ETM+ 03/31/2010 • Landsat 7 ETM+ 03/06/2010
Tainan	• Landsat 2 MSS 01/08/1979 • Landsat 2 MSS 05/14/1979 • Landsat 3 MSS 02/22/1979	• Landsat 4 TM 07/21/1990 • Landsat 5 TM 07/06/1990	• Landsat 7 ETM+ 02/18/2001 • Landsat 7 ETM+ 03/13/2001	• Landsat 7 ETM+ 02/11/2010 • Landsat 7 ETM+ 03/06/2010
Kaohsiung	• Landsat 2 MSS 01/08/1979 • Landsat 2 MSS 05/14/1979 • Landsat 3 MSS 02/22/1979	• Landsat 4 TM 07/21/1990 • Landsat 5 TM 07/06/1990	• Landsat 7 ETM+ 02/18/2001 • Landsat 7 ETM+ 03/13/2001	• Landsat 7 ETM+ 02/11/2010 • Landsat 7 ETM+ 03/06/2010

2.3 Methodology

The satellite images used in the research were mostly clear. All satellite images and other vector data were projected into the TWD-67 projection, datum of Hu-Tzu-Shan. Before any analysis, the areas of croplands, lakes, river coursed and beds were eliminated in order to reduce the error of calculating urbanised area.

Urbanisation often results in the increasing the density of transportation infrastructures and population growth, and ultimately leading to significant change of land cover. Forest lands, agricultural lands, and other naturally vegetated lands were converted into high density of urban constructions, such as buildings, urban concrete playgrounds and transportation systems (Viet et al. 2006). Urban structures, natural vegetation and water all have unique spectral reflectance characteristics. Using this characteristic, the Maximum Likelihood supervised classification could be used in this research and the images was divided into two classes, urbanised area and non-urbanised area in each municipality.

Urbanised Area: roads, building sites, buildings, and public infrastructures

Non-Urbanised area: forests, grasslands, agricultural lands, rivers, mountain areas, and bare lands

The raster data of classification were converted into vector data for further analysis, comparison and correction. The area and percentage of urban zone for each municipality were calculated from the vector data. This research also used the population data from Department of Household Registration, the Ministry of the Interior and the vector data of transportation network from Institute of Transportation, Ministry Of Transportation And Communications to analyse the urban expansion in each municipality. The flow process of using the Landsat satellite imagery for GIS-based urbanisation spatial pattern analysis in five municipalities in Taiwan from 1980 to 2010 was shown in Figure 2.

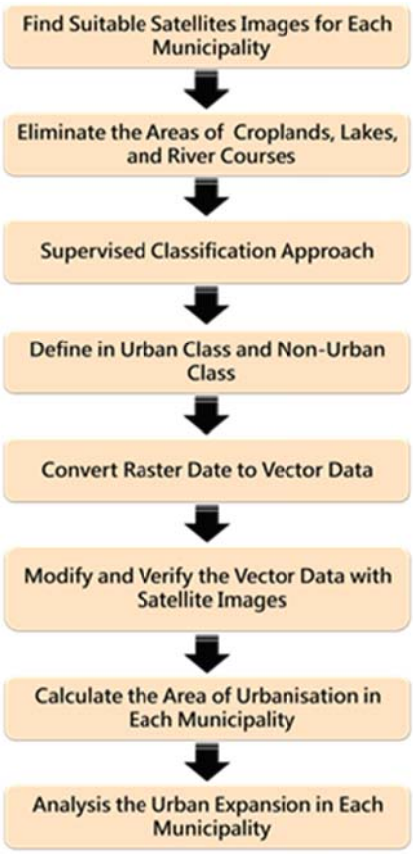

Figure 2: Flow Process of this Research

3. RESULTS

3.1 General

The area and percentage of urban zone for each municipality from 1980 to 2010 were summarised in Table 2. The urbanisation spatial patterns were shown in Figure 3 and 4, and the results indicated that population growth pressure caused the urbanisation spatial pattern to be significant dynamic. The urban pattern was started at a city centre core and was extended to outside regions. In Taiwan, urban patterns in each municipality was influenced by transportation systems, but was limited by natural barriers, such as river and mountainous areas.

Table 2: Area and Percentage of Urban Zone in Five Municipalities from 1980 to 2010

Municipality Name	*Total Area*	*Area of Urban Zone*							
		1980		*1990*		*2000*		*2010*	
	km^2	*km^2*	*%*	*km^2*	*%*	*km^2*	*%*	*km^2*	*%*
Taipei	271.8	58.9	21.7%	91.6	33.7%	108.3	39.8%	112.2	41.3%
New Taipei	1,957.3	135.1	6.9%	172.2	8.8%	250.3	12.8%	330.9	16.9%
Taichung	2,239.7	42.6	1.9%	226.7	10.1%	342.7	15.3%	402.7	18.0%
Tainan	2258.8	67.5	3.0%	117.2	5.2%	152.8	6.8%	232.8	10.3%
Kaohsiung	2963.3	92.9	3.1%	170.9	5.8%	210.6	7.1%	291.2	9.8%

3.2 Taipei

Taipei is the capital city of Taiwan; therefore, it has the highest population density in five municipalities and transportation systems are fully integrated comparing with other municipalities. With great transportation systems and high population density, the two important factors of affecting the degree of urbanisation, the urbanisation

pattern was expanded significantly in early stage from 1980 to 2000. From 2000 to 2010, the expansion of the city has stagnated. The reason might be there was no more space for development in Taipei, and the development trended to be vertical, more skyscrapers, rather than horizontal expansion.

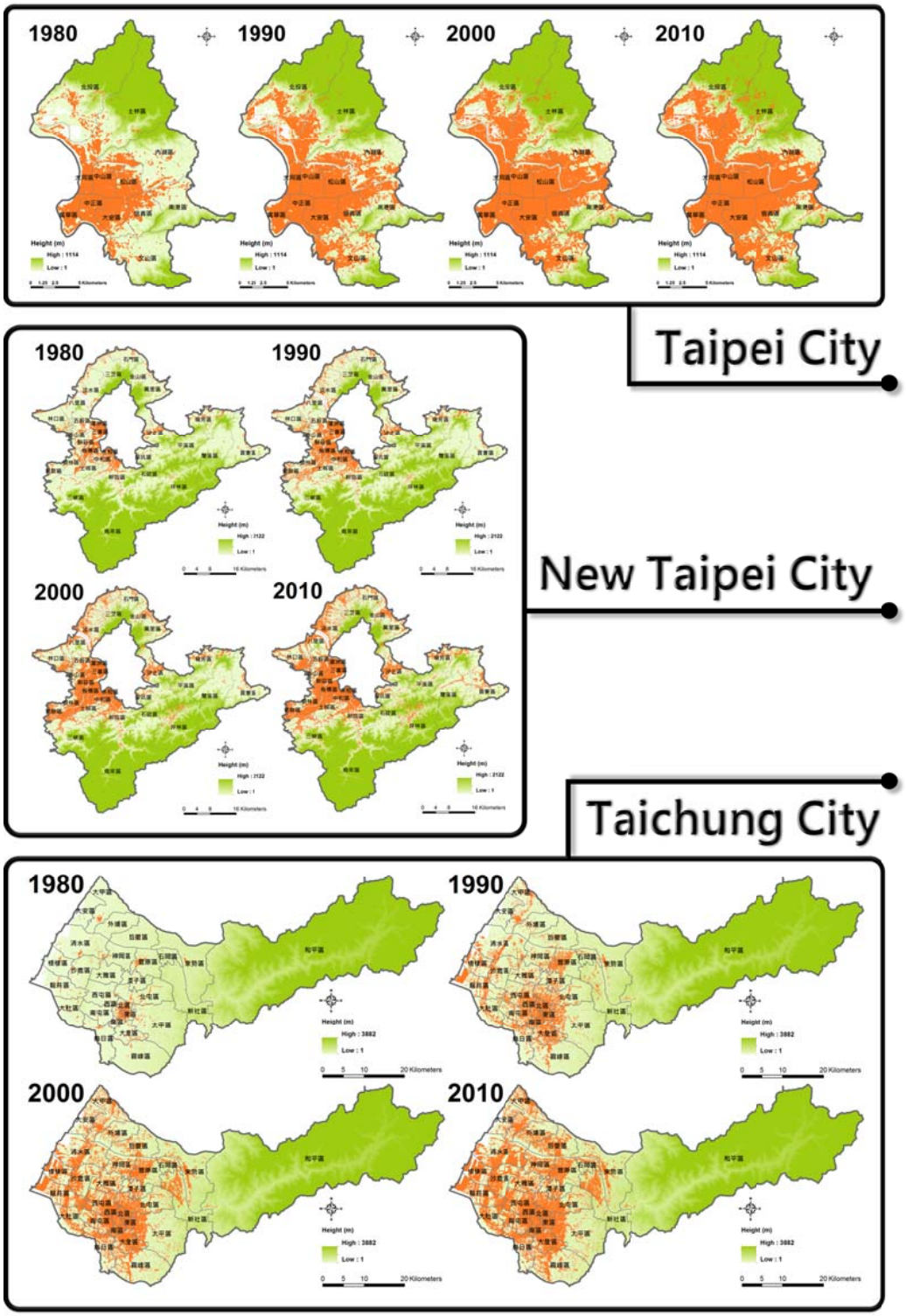

Figure 3: Urbanisation Spatial Patterns in Taipei, New Taipei and Taichung from 1980 to 2010

3.2 New Taipei

The domain of New Taipei completely surrounds Taipei and there are numbers of MRT, expressways and highways connecting these two cities; consequently, Taipei became the centre core of development for New Taipei. Urbanisation patterns of these two cities were combined and extended to outside regions from 1980 to 2010. During

2000 to 2010, New Taipei had a significant expansion of the urban zone, and the city growth rate of New Taipei was fastest in five municipalities.

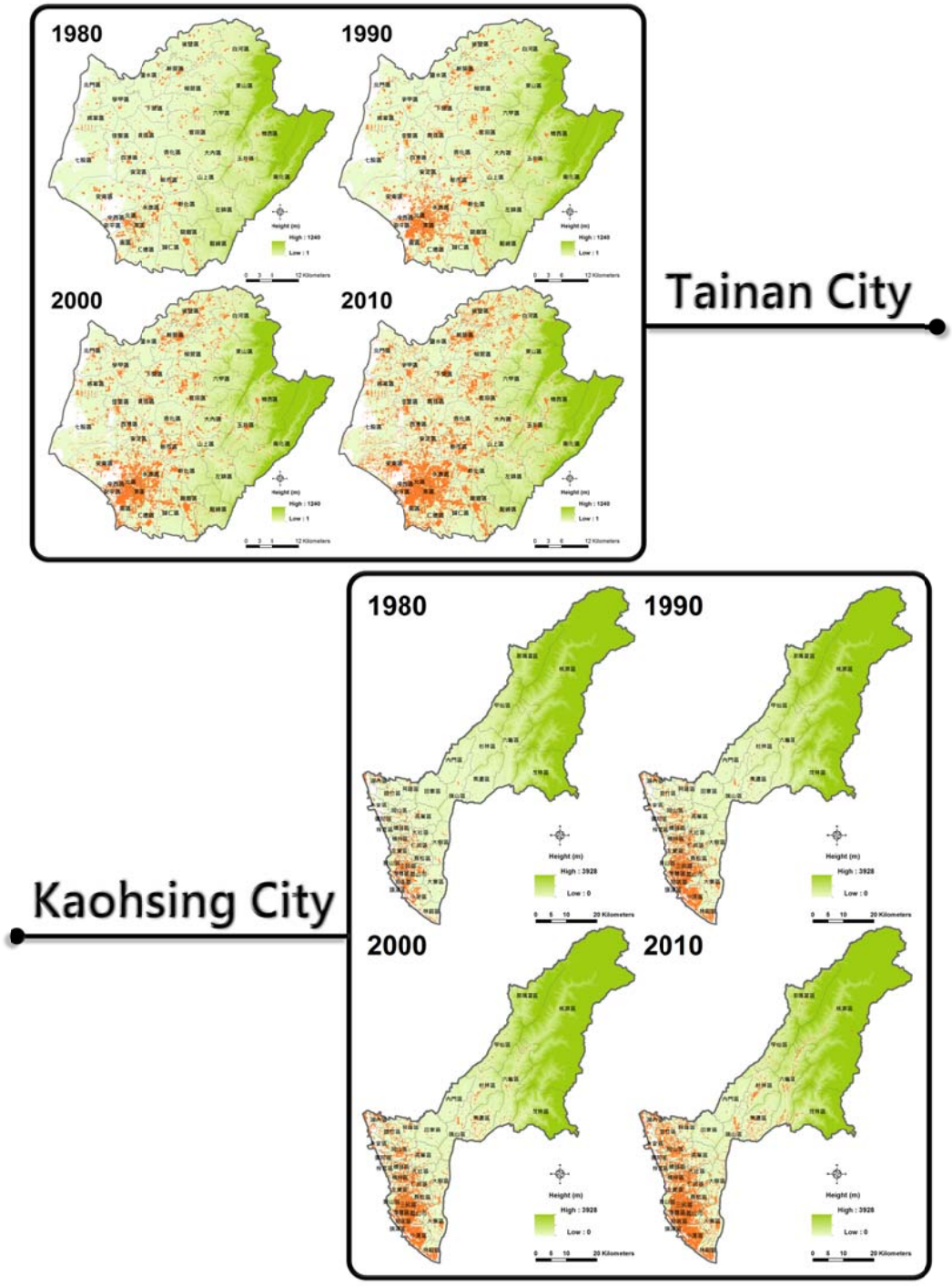

Figure 4: Urbanisation Spatial Patterns in Tainan and Kaohsiung from 1980 to 2010

3.3 Taichung

The urbanisation pattern for Taichung was influenced by transportation systems. In 1980, there were no convenient transportation systems in Taichung; therefore, the population and development were concentrated in the centre core. A significant expression of the urban area occurred during 1980 to 2000, and the growth occurred along main transportation axes, railways and expressways. Till 2010, transportation systems were fairly integrated linking the city centre core and suburban town centres and the development of Taichung metropolitan area were gradually

complete. The percentage of urban zone area in 2010 was 18.0% and only behind Taipei, the capital city. The west region of Taichung was mountainous areas, hence there is nearly no development in this region.

3.4 Tainan

The administrative area of Tainan is extensive; as a result, the Tainan city centre core was smaller than other municipalities, and city centre core and suburban town centres were developed independently in early stage. With the gradual development of transportation systems, city centre core and suburban town centres were connected together, and urbanisation had taken place along transportation systems. In 2010, the percentage of urban zone area was only 10.3%, but there were a significant expansion of the urban area during 2000 to 2010 with 3.5% city growth rate.

3.5 Kaohsiung

Kaohsiung is the largest city in southern Taiwan. The administrative area of Kaohsiung is also extensive and the administrative area is the largest in five municipalities. In 2010, the percentage of urban zone area was only 9.8%, and ranked in the last in five municipalities. The distribution of urban development in Kaohsiung is extremely uneven. City developments are concentrated in the south-west plains and the harbour area, and these regions were fully urbanised in 2010, similar to Taipei. These regions link Tainan City and Pingtung County together, and become major metropolitan area in south Taiwan. On the other hand, more than 60% area in Kaohsiung is located in mountainous and hilly areas, and there were a few developments in these regions.

3.6 Overall

Overall, the population density and the intensity of transportation systems have reached the peak in Taipei in 2010; as a result, the city development has the sign of saturation. In the other municipalities, the percentages of urbanisation area were all less than 20% in 2010, and these municipalities are still in the stage of developing. Building network-intensive transportation systems will attract more people from other places, and improve the degree of urbanisation.

4. CONCLUSION AND RECOMMENDATION

To conclude, this research has demonstrated that Taipei, the capital city was developed in early stage, and approached fully urbanised in 2000 due to extremely high population density and fully integrated transportation systems. Other municipalities were still in stage of growth, and need enhance transportation systems and increase population from other places in order to assist the metropolis development

To validate and confirm these results, more high resolution satellites images can be used, such as SPOT 1 to SPOT5, which have received images since 1986. Such an analysis would support the identification of urban growth patterns of major cities in Taiwan over time. Overall, the result met the research objective. Further researchers can use these results as an urbanisation spatial pattern database to do further analysis of urbanisation or urban planning in Taiwan and help cities toward urban sustainability.

6. REFERENCE

2010 A Land Use Change Detection Program Report. Construction and Planning Agency Ministry of the Interior, Taiwan), pp. 69–117.

Huang, Y., Fipps, G., Lacey, R.E. & Thomson, S.J., 2011. Landsat Satellite Multi-Spectral Image Classification of Land Cover and Land Use Changes for GIS-Based Urbanization Analysis in Irrigation Districts of Lower Rio Grande Valley of Texas. Applied Remote Sensing Journal, 2(1), pp. 27-36.

Thapa, R.B. & Murayama, Y., 2009. Examining Spatiotemporal Urbanization Patterns in Kathmandu Valley, Nepal: Remote Sensing and Spatial Metrics Approaches. Remote Sensing, 1 (3), pp. 534–556.

Viet, P.B., Duan, H.D., Raghavan, V. & Shibayama, M., 2006. Using Satellite Imagery to Study Spatial Expansion of Hanoi City. International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences.