Analysis of urban heat island intensity and its impact on regional precipitation over Tainan city in Taiwan

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ABSTRACT

Along with urban developing in Tainan, urban heat island (UHI) effect is more pronounced in the downtown areas. The generated convection from increasing UHI intensity may affect the precipitation around urban areas. In order to have better understanding the impact of UHI from urbanization on regional precipitation, the land cover types with supervised classification and the UHI intensity from Landsat data are used in this study. According to the results of land cover type in different time periods, the situation of urbanization and impervious surface area (ISA) in Tainan city can be obtained. Then the impact of UHI effect on the regional precipitation will be analyzed by association with the rainfall data during the summertime (June、July and August from 1993 to 2012 which exclude the data in typhoon periods from Center Weather Bureau in Taiwan). The preliminary results indicate that the expanded ISA will enlarge the intensity of UHI which might change (increase) the precipitation around the urban areas. More case studies and investigations are still ongoing to make the substantial results.

KEYWORD：Urban heat island effect, Precipitation, Impervious surface area

1. INTRODUCTION

The sudden precipitation made huge disaster in south Taiwan in the past years, in addition to the abnormal weather conditions, heat-island effect is the one of important reason. Along with urban size increases in Tainan, the precipitation were more pronounced not only in the downwind areas but also in the surrounding areas. In the other research, the precipitation will occur in the downwind areas to Mega-cities (Jaurequi and Romales, 1996, Kusaka et al., 2000). But there have the unique and complex topographic features in Taiwan, the precipitation will not occur in the downwind areas only (Lin et al., 2007)

Impervious surface area (ISA) will also increase. In the other researches, ISA was defined to road、parking area、sidewalk、roof…etc. Urban will keep the heat which from sun radiance by ISA, but the vegetation area is not, the heat will not keep in surface by latent heat. According to the study that the high temperature area will appear in the high value of ISA compare with the low value (Xiang 2005). Because of urbanization with ISA increase, strong convection will more frequent appear in urban area

and makes sudden precipitation. Because the floods was happened in Taiwan, it is important that try to find the relationship with precipitation and ISA to figure out the impact in Tainan area.

2. DATA

2.1. Center Weather Bureau data(CWB)

Data collect temperature and rainfall from CWB from 1993 to 2012, temperature data is for realize temperature change and the rainfall data is for find the relationship with ISA in Tainan area.

2.2. Landsat 5 TM and 7 ETM+ Data

There is high solution data form Landsat, and it is widely use in urban heat-island study, the data is selected from 1995 to 2012, which is without cloud. Thermal band is the sixth band in Landsat, it can analyze land surface radiance to compare the brightness temperature difference in an area. also can get the classification data and ISA from Landsat data of first band to seventh band (without sixth band).

2.3. Joint Typhoon Warning Center (JTWC).

When calculating the rainfall data, we not consider the effect from typhoon. So choose JTWC data to exclusion the rainfall data which cause by typhoon is a necessary step. We got the typhoon path from JTWC, if the position of typhoon was less than Shanhua station, rainfall data was excluded at the same time.

3. Method

First to know the land type changed in Tainan, we use Landsat 5/7 data to get the results by supervised classification from 1995 to 2012.

3.1. Supervised classification

There have three methods that is common used in supervised classification, it's minimum distance to means classifier, parallelepiped classifier and maximum likelihood classifier. Among the method we mention, maximum likelihood classifier is more accurate than other methods (Lim et al., 2003).

In the study, we use ENVI to calculate the land type classification. First is circle three different land use in Landsat image, like urban, water and vegetation. Because of different type their reflect characteristic is not the same to different band, so we can use it to get the land type classification.

3.2. Impervious surface area

ISA is a great indicator to realize the urbanization extent. Before we are going to calculate ISA, we need high solution Landsat images which is made for land type data. In our study, we use the data which from supervised classification to make a 5X5 sub-pixel image, then calculate how many urban type pixel in the 25 pixels, the percentage is the result we want for ISA. Fig. 1 is the schematic diagram, it ISA value is 10/25.

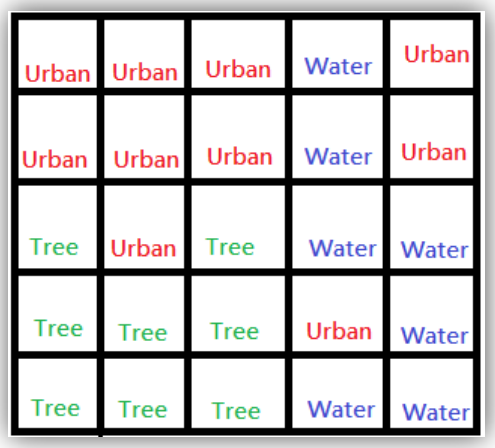

Fig. 1. ISA schematic diagram

3.3. Data from CWB

Data from the 30 sites in Tainan where available from 1993 to 2013. For temperature, we use Optimum Interpolation Methods (OI) to plot it distribution in 1993 and 2013, then find the UHI changed. The UHI formula is

$$\mathrm{UHI} = P_t - Rural_t$$

Where

$P_t =$ The point which we want to caculate

$\mathrm{Rural_t} =$ Temperature in rural

For precipitation, we use OI to plot it distributions from 1993 to 2013, which exclude the data in typhoon days from Center Weather Bureau (CWB).

3.4. Brightness temperature

Brightness temperature can makes us to observe the heat radiance and temperature in the whole area. Landsat image is a digital number (DN) image, DN's value is from 0 to 255, the value is high means the heat radiance also in high value, the temperature is higher too. So first step is change the DN to radiance which get from satellite.

$$L_\lambda = \frac{L_{max} - L_{min}}{QCAL_{max} - QCAL_{min}}(DN - QCAL_{min}) + L_{min}$$

where

$QCAL_{max}$ Maximum quantized calibrated pixel value (DN = 255) corresponding to L_{max}

$QCAL_{min}$ Minimum quantized calibrated pixel value (DN =0) corresponding to L_{min}

L_{max} Spectral radiance that is scaled to $QCAL_{max}$

L_{min} Spectral radiance that is scaled to $QCAL_{min}$

L_λ The radiance was observed from satellite

Thermal band data (band 6) from Landsat 5/7 can convert from radiance to brightness temperature by plunk function, the conversion formula is

$$T = \frac{K2}{\ln(\frac{K1}{L_\lambda} + 1)}$$

where

T brightness temperature

K1 calibration constant 2 in kelvin

L2 calibration constant 1 in W/(m^2 ・sr・/ m)

L_λ The value was observed from satellite

4. Results and fururе works

To analyze the urbanization we need high spatial resolution data that can be used to observe the urban change easier. We select 1995, 2006 and 2012 Landsat data to find the urbanization in Tainan (Fig. 2).

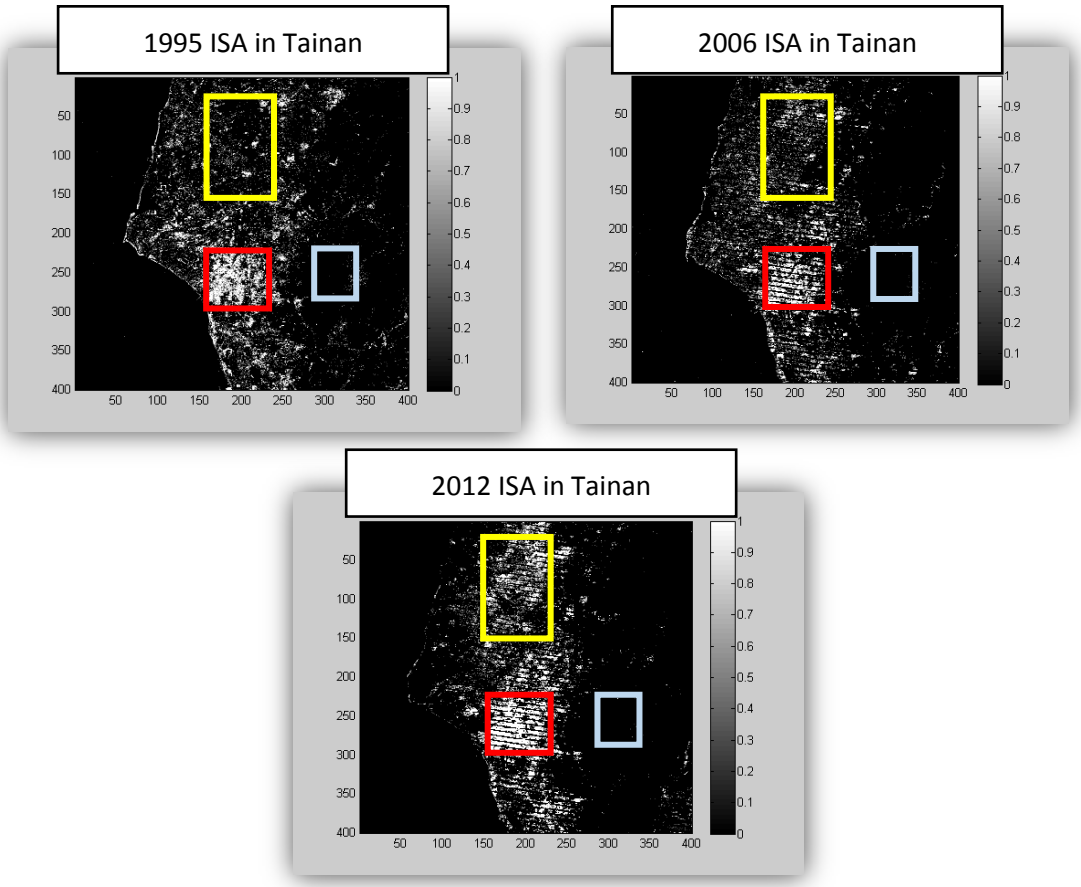

Fig. 2 1995、2006、2012 ISA distribution

Brightness temperature and UHI image which is made by thermal band from Landsat, we follow that to circle three areas which represent for urban (red), developing(yellow) and rural(light blue) area (Fig. 2). Xiang and Crane (2005) use three threshold value 10-40% for low development density, 41-60% for medium development density and 61-100% for high development density to investigate urban growth in the Tampa Bay. We also use the method to make three threshold to investigate urbanization in Tainan (Fig. 3).

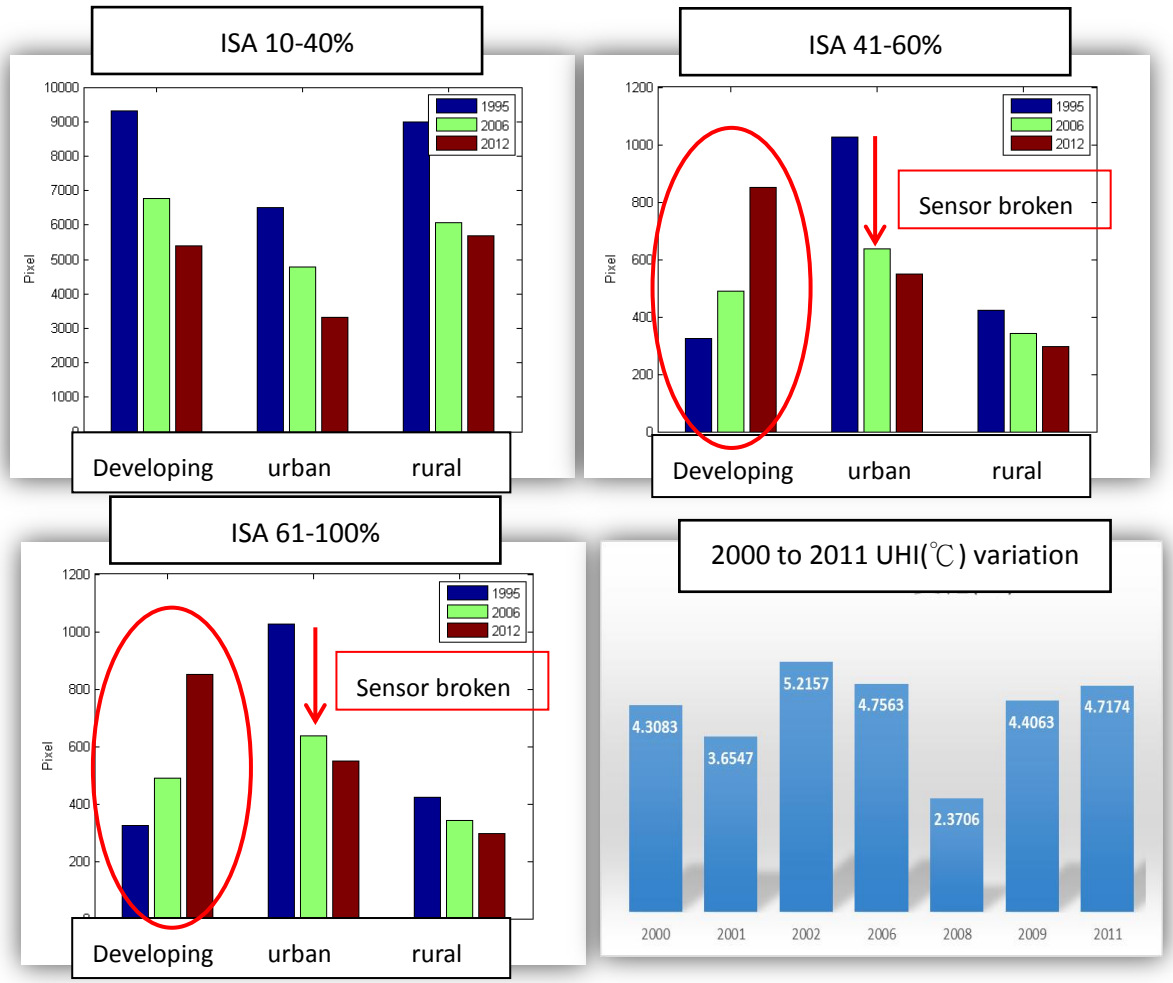

Fig. 3 ISA developing in 1995、2006、2012 and UHI variation 2000-2011(Tainan city)

First of all, Landsat data have a sensor broken since 2005, so there is a gap in the image, and the total number of pixels will be lower than 2005.

In Fig. 3, we can find there is no significant change in urban and rural area, but the developing area ISA from 41 to 100% is getting larger. Therefore, it means that a huge developing is occurring in the “yellow” area. The trend in ISA variation is different with developing area which compare with urban and rural area, because of developing area is getting increase but urban and rural is not even there is a sensor broken since 2005. The significant change area is found by the result, and then can focus on the UHI variation and precipitation changed over the area from 1993 to 2012.

Brightness temperature for UHI is calculated from Landsat data, and there will be many factors to affect the result. In order to realize the real regional temperature, CWB temperature data from each station in Tainan can be used, and then the real UHI can be calculated. When it comes to temperature and ISA data, we know that the area with high temperature is accompanied with high ISA. We already collected rainfall data from CWB from 1993 to 2013. In the future, precipitation distribution images can be plotted by OI method, and then combining the ISA data to find their relationship or the precipitation area changed. Hopefully, we will be able to find the urban heat island intensity and its impact on regional precipitation over Tainan city in Taiwan.

5. References

1. Chen, L., 2006. Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes.Remote Sensing of Environment, Vol. 104, Issue 2, 30 September 2006, pp 133-146
2. Dousset, B. and F. Gourmelon.,2003.Satellite multi-sensor data analysis of urban surface temperatures and landcover. Photogrammetry and Remote Sensing, Vol.58, pp43-54.
3. Jaurequi, E., Romales, E., 1996. Urban effects on convective precipitation in Mexico City. Atmospheric Environment 30, 3383–3389.
4. Kusaka, H., Kimura, F., Hirakuchi, H., Mizutori, M., 2000. The effects of land-use alteration on the sea breeze and daytime heat island in the Tokyo metropolitan area. Journal of the Meteorological Society of Japan 78, 405–420.
5. Lim, H.S., M. Z. MatJafri, and K. Abdullah., 2003. Evaluation of conventional digital camera scenes for thermatic information extraction. School of Physics University Saint Malaysia.
6. Lin, C. Y., Chen, W. C., Liu, S. C., Liou, Y. A., Liu, G. R., & Lin, T. H. (2008). Numerical study of the impact of urbanization on the precipitation over Taiwan.Atmospheric Environment, 42(13), 2934-2947.
7. Wu, C. and A. T. Murray., 2003. Estimating impervious surface distribution by spectral mixture analysis. Remote Sensing of Environment, Vol. 84, pp493-505.
8. Xian, G. and Crane., M. (2005). Assessments of urban growth in the Tampa Bay watershed using remote sensing data. Remote Sensing of Environment, 97: 203-215.
9. Xian, G., Yang, L., Klaver, J. M., Hossain, N. (2005). Measuring urban sprawl and extent through multi-temporal imperviousness mapping. Urban Dynamic Topic Report, USGS Circular (in press).