EVALUATION OF SURFACE HEAT FLUXES FOR DIFFERENT LAND COVER IN HEAT ISLAND EFFECT

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ABSTRACT ... Our goal is to obtain a better scientific understanding how to define the nature and role of remotely sensed land surface parameters and energy fluxes in the heat island phenomena, and local and regional weather and climate. By using the MODIS visible and thermal imagery data and analyzing the surface energy flux images associated with the change of the landcover and landuse in study area, we will estimate and present how significant is the magnitude of the heat island heat effect and its relation with the surface parameters and the energy fluxes in Taiwan. To achieve our objective, we used the energy budget components such as net radiation, soil heat flux, sensible heat flux, and latent heat flux in the study area of interest derived form remotely sensed data to understand the island heat effect. The result shows that the water is the most important component to decrease the temperature, and the more the consumed net radiation to latent heat, the lower urban surface temperature.

KEY WORDS: Heat Island Effect, MODIS, Surface Heat Flux

1. INTRODUCTION

Thousands of human lives were claimed by the heat wave in Europe in Summer 2003. The strength of the heat wave is manifested as the environment of the residential areas favors the heat island effect. Knowledge on the pattern and strength of the heat island effect is crucial to reduce, if not to prevent human beings from, the threat of the heat wave.

The heat island is usually produced and pronounced as the man-made structures and constructions are increased such as buildings and roads, primarily made of asphalt and concrete. The man-made structures and constructions change not only the landscape, but also the state of the land surface characteristics and energy balance by influencing the surface albedo, thermal capacity, heat conduction...etc. In another word, the urban heat island effect may be examined through accessing the land surface characteristics and energy balance components.

In this paper, we present a direct method to analyze the magnitude of the heat island effect by examining the distributions of temperature and evapotranspiration in the study area. Three major steps are proceeded to achieve our goal: 1) retrieve the ground temperature, 2) estimate the vegetation index and the surface heat fluxes such as the sensible heat and latent heat fluxes, and 3) analyze the relationship between the ground temperature and those energy fluxes and parameters.

2. SATELLITE DATA

Several 2006 MODIS Level 1B data acquired from Center of Space and Remote Sensing Research (CSRSR), National Central University, Taiwan are used to estimate the surface heat fluxes over rice paddy fields in Taiwan's Chiayi Plain. Four MODIS bands are used in this study. Band 1 and band 2 are used to estimate the surface albedo and NDVI, and band 31 and band 32 are used to retrieve surface temperature.

Table 1. The Bands MODIS are used in this study

MODIS Spatial Resolution: 1km		
Band	Bandwidth (μm)	Spectral Region
1	0.620-0.670	Red
2	0.841-0.876	Near Infrared (NIR)
31	10.78-11.28	Thermal Infrared (TIR)
32	11.77-12.27	Thermal Infrared (TIR)

3. METHODOLOGY

The methodology is based on the Simplified Surface Energy Balance Index model to retrieve the surface heat fluxes by using MODIS data [1]. The energy balance equation at the land-air interface may be written as

$$R_n = G_0 + H + \lambda E \quad (1)$$

where:
R_n = net radiation [W/m^2]
G_0 = soil heat flux [W/m^2]
H = sensible heat flux [W/m^2]
λE = latent heat flux [W/m^2].

According to the surface energy balance equation, the net radiation is first derived

$$R_n = K^{\downarrow} - K^{\uparrow} + L^{\downarrow} - L^{\uparrow} \quad (2)$$

$$R_n = (1 - r_0) K^{\downarrow} + L^{\downarrow} - L^{\uparrow} \quad (3)$$

where the incoming shortwave radiation, K↓, is measured in the field. The reflected shortwave radiation, K↑ , is defined by the surface albedo, and the emitted longwave radiation L↑ is defined by the surface temperature (Stefan Boltzmann equation), and L↓ is the long wave radiation coming from the sky [2].

The soil heat flux, G0, is determined by the thermal conductivity of the soil and the temperature gradient of the topsoil. We used an empirical equation established by Bastiannssen(1995)[3] to estimate the G0:

G0 = Γ* Rn (4)

$$\Gamma = T_0 (0.0032 + 0.0062 r_0)(1 - 0.978 NDVI^4) \quad (5)$$

where To is the measured surface temperature, and the Normalized Difference Vegetation Index, NDVI, is defined as:

NDVI=(NIR-VIR)/(NIR+VIR)
(6)

That is, the net radiation term is a balance among all incoming and outgoing shortwave and longwave radiation, as well as energy conducted into the ground, some of which can be measured directly by the remote sensing techniques. The soil heat flux is derived with an empirical relationship between the vegetation and surface characteristics. The sensible and latent heat fluxes are not calculated as separate parameters, but linked to each other through the evaporative fraction, Λ, which is determined as:

$$\Lambda = \frac{\lambda E}{\lambda E + H} = \frac{\lambda E}{R_n - G_0} \quad (7)$$

Among the energy budget components, sensible and latent heat fluxes are generally partitioned from the net energy through the evaporation and radiation controlled analysis. When the surface is wet or heavily vegetated, the net energy is mainly used to consume water in soil and vegetation through evaporation and evapotranspiration (namely, evaporation controlled). That is, most net radiation is converted to latent heat flux. On the other hand, when the surface is rather dry, few of the latent heat flux will be consumed, most net radiation is converted to sensible heat flux for heating the surface and this case is called radiation controlled. A schematic representation of S-SEBI is given in Fig. 1. By using the reflectance-to-temperature relationships, we can determine the sensible and latent heat fluxes.

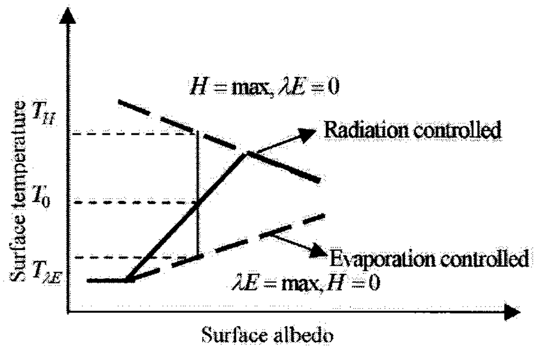


Fig.1. Schematic representation of the relationship between surface reflectance and temperature together with the basic principles of S-SEBI.

4. RESULTS

Figure 2 is our study area, and this region about 40*40 square kilometer. Figure 3 is the MODIS product which MODIS/Terra Land Cover Type Yearly L3 Global 1km SIN Grid is acquired in USGS websites, and the primary land cover scheme identifies 17 classes of land cover defined by the International Geosphere-Biosphere Programme (IGBP). In Figure3, forest is mainly in dark green, cropland is in yellow, and the buildings are in red. After classification, it is found the range of the Chiayi city and the source of anthropogenic heat.

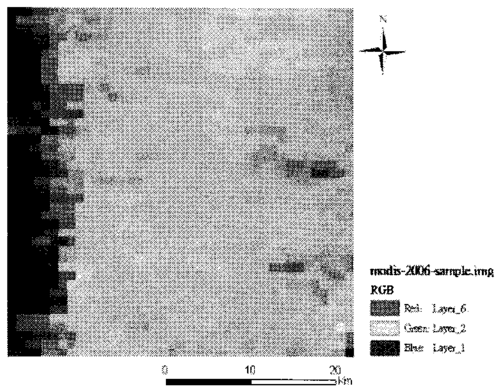


Fig.2 Our study area

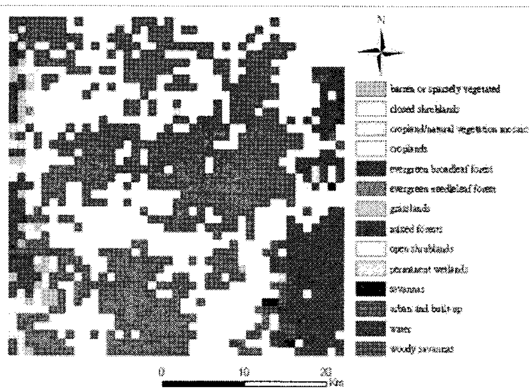
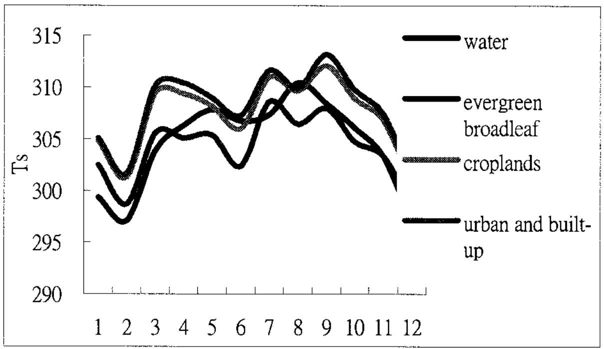
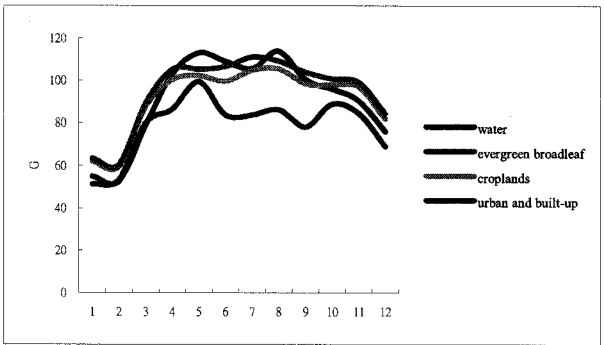
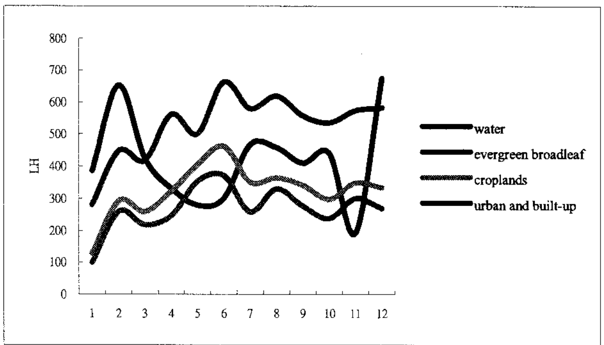


Fig.3. Land cover classification of Chiayi area

Thirty MODIS images were used to estimate the surface heat fluxes over the study area, and the monthly average surface temperature and surface heat fluxes are derived to compared with different kinds of land cover. Of course, the surface temperature of urban surface is highest in all kinds of land cover. However, the cropland which is usually near the urban area cause the classified error in lower resolution images such as MODIS data. The results show that the tread of croplands and urban surface in surface temperature and surface heat fluxes are similar.







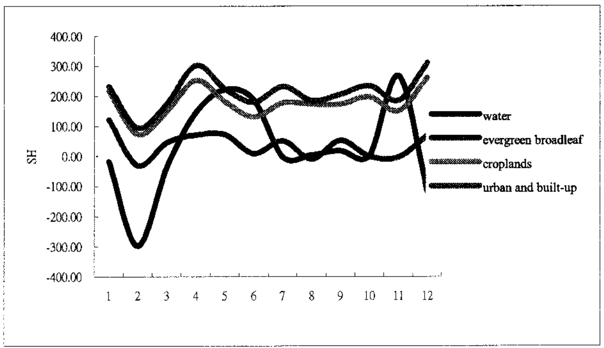


Fig. 4 Monthly average surface heat fluxes over different land cover in 2006

Compared with the sensible heat flux and latent heat flux in different kinds of land cover, the results show that the urban surface is rather dry as most net radiation is converted to sensible heat flux for heating the surface. However, in the areas of wet surface such as water or evergreen broadleaf, most net radiation is converted to latent heat flux. This means that water in soil and vegetation is consumed by the evaporation and evapotranspiration.

5. CONCLUSIONS

We used the MODIS satellite images derived surface energy fluxes to quantify the heat island effect. Satellite-observed surface skin temperature and land surface energy fluxes serve as core factors of the analysis. Land use is first classified. Then, surface temperature and surface energy fluxes are derived. This study shows that the urban surface is rather dry as most net radiation is converted to sensible heat flux for heating the surface and the vegetation canopy transfer about 63% of the net radiation energy into latent heat fluxes and 37% into the sensible heat fluxes. Finally, it is found that the latent heat is an indicator of the strength of urban heat island effect and can be used to quantify the magnitude of urban heat island effect.

6. ACKNOWLEDGMENT

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