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Evaluation of the DisTrad thermal sharpening methodology for urban areas

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ABSTRACT

The goal of this paper is to evaluate the DisTrad sharpening technique for deriving land surface temperatures over urban areas. While the original DisTrad technique is based on the correlation between land surface temperature and NDVI, this study evaluates the performance of DisTrad over different land covers by analysing the correlation between land surface temperature and 15 different indices: BASVI, *R*, *B*, NDWI, NDBaI, SVI, SAVI, NDBI, NDSI, UI, FC, VC, *V*, IBI, NDVI. In addition, we have analysed the correlation between land surface temperature and impervious percentage. These indices and land surface temperature were derived from a Landsat 7 ETM+ image of 2001 covering the city of Dublin. It is concluded that for most indices selecting 25% of the pixels with the lowest coefficient of variance increases the correlation between the index and the land surface temperature. Results show that the DisTrad technique in combination with impervious percentage sharpens urban areas at 30 m resolution most successfully. Although vegetation cover was high during acquisition of the image, the use of impervious percentage showed improved results compared to NDVI. This allows an improved estimation of spatial patterns of urban heat islands.

1. Introduction

Rapid urbanization since the industrial revolution has resulted in large changes in the landscape from global to local scales. One of the consequences of this anthropogenic land-cover change is an increase of the urban land surface temperature leading to a modified thermal climate that is warmer than the surrounding non-urbanized areas, also described as the urban heat island (UHI) effect (Voogt and Oke, 2003). The UHI effect raises pollution levels, modifies precipitation patterns and increases demands for air conditioning (Chen et al., 2007). Hence, identifying, measuring and modelling the patterns of energy fluxes and land surface temperature in urban areas has become an important scientific and applied topic.

Urban areas are spatially complex and spectrally heterogeneous in broadband image data of medium spatial resolution, and this complicates image classification (Barnsley and Barr, 1996) and thermal differentiation. The goal of thermal sharpening is to unmix thermal images with a low spatial resolution using the information from the pixel composition of co-registered images with a higher spatial resolution (Zhukov et al., 1999). Thermal sharpening is a promising technique, and various methods for unmixing land surface temperature for vegetated areas have been developed during the last ten years. Examples of such techniques are the Multi-sensor Multi-resolution Technique (MMT) (Zhukov et al., 1999), DisTrad (Kustas et al., 2003) and TsHARP (Agam et al., 2007). Thermally sharpened images have been used for modelling evapotranspiration in agricultural areas, for example, the associated flux disaggregation technique DisALEXI (Norman et al., 2003; Anderson et al., 1997) has been designed to map evapotranspiration at finer spatial resolutions suitable for agricultural management (i.e. 100–250 m) using imagery from multiple satellite platforms or aircraft. So far, thermal sharpening techniques have not been tested for use in urban areas.

Each land-cover type gives a specific contribution to the land surface temperature. On the other hand spectral indices have shown to be able to characterize different land-cover types (Zhao and Chen, 2005). Hence, functional relationships between spectral indices and land surface temperature were found to be a useful basis for thermal sharpening (Kustas et al., 2003). The idea of thermal sharpening is then that a functional relationship between a spectral index and land surface temperature can be utilized to sharpen the generally coarse resolution of the thermal image to the higher resolution of the multi-spectral images.

Landsat 7 ETM+ acquires spectral reflectances in visible, near-infrared and short wave wavelengths at 30 m resolution, as well as thermal infrared emission at 60 m resolution. The thermal band

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has a relatively low spatial resolution, which may be improved by a sharpening technique. In this study Landsat 7 ETM+ thermal images will therefore be sharpened to create a new thermal image with the resolution of the reflective bands (30 m) and an accuracy that is comparable with the original thermal band (60 m). Hence, the objective is to evaluate the DisTrad technique (Kustas et al., 2003) for sharpening radiometric surface temperatures for urban areas by testing fifteen spectral indices characterizing different land covers. Next to these spectral indices, we have analysed the correlation between land surface temperature and percentage of impervious surface cover. Testing will be performed on the urban area of Dublin, Ireland.

2. Study area and data

2.1. Study area

The study area covers the Greater Dublin area (Fig. 1), which is bounded by the longitudes 6°00′ and 6°48′ West and latitudes 53°07′ and 53°35′ North and comprises 2700 km^2. The study area is limited to the urbanized Mid-East of Greater Dublin as it is estimated to be the fastest growing part of the city. The population of Dublin was until recently expected to grow with 51% by 2021 (Irish Health, 2010). The rapid urban expansion started in the 1980s and 1990s and was fuelled by the building of new roads that drove residential and commercial development rapidly outward into the urban fringe (Kitchen, 2002). Hence, Dublin shows heterogeneous urban landscape patterns with higher densities in the urban core, such as, e.g. industrial and commercial zones, and lower densities in the periphery, such as suburban residential neighbourhoods with extensive grass and tree covered zones (Fig. 2).

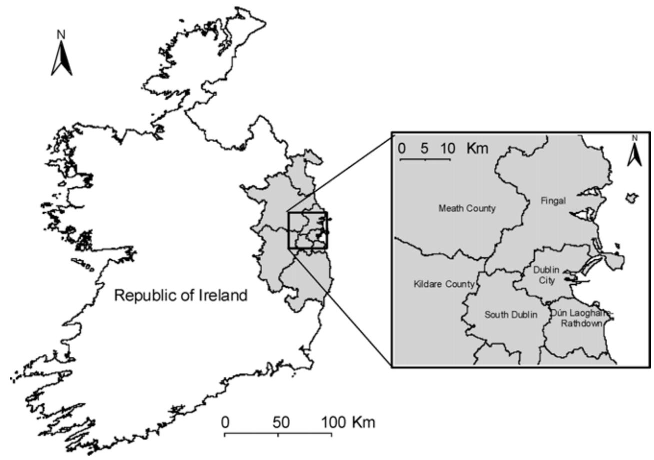

Fig. 1. Ireland with inset figure indicating the study area: the Greater Dublin region.

The intensity of the urbanization enhances the UHI effect. Hence, the city is a good example to validate thermal sharpening with a wide range of spectral indices and land surface temperatures.

2.2. Satellite data

We used a Landsat 7 ETM+ image that was acquired on May 24th, 2001 (11.12 am) in this study. The image dataset consists of a thermal band (low gain) and 6 multispectral bands, which respectively have a resolution of 60 m and 30 m The image bands were rectified to the Irish grid coordinate system (UTM/WGS-84 Zone 29N), and the digital numbers were converted to exo-atmospheric reflectance.

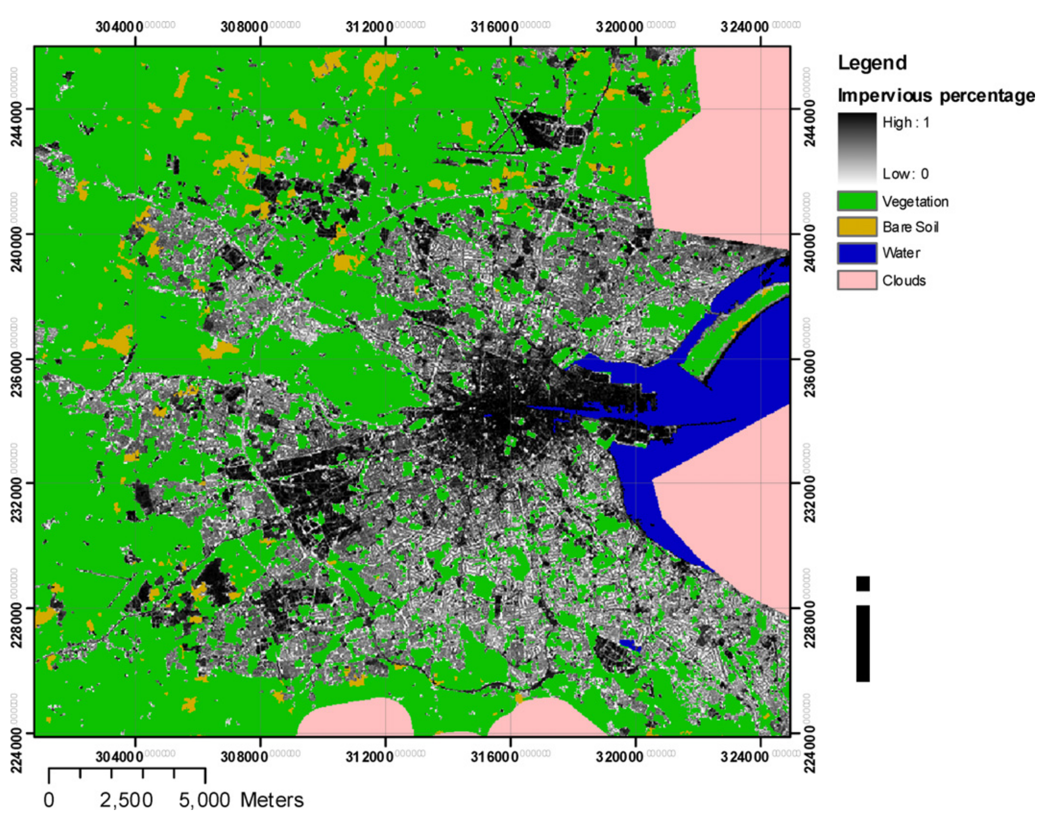

Fig. 2. Land-use/land-cover map indicating the percentage of impervious surface within the urban mask in grey shades.
Adapted from Van de Voorde et al. (2011).