

Research Paper

Estimating potential outdoor water consumption in private urban landscapes by coupling high-resolution image analysis, irrigation water needs and evaporation estimation in Spain

Angela Hof^{a,*}, Nils Wolf^b^a Ruhr University Bochum, Geography Department, Landscape Ecology and Biogeography Group, Germany^b Ruhr University Bochum, Geography Department, Geomatics/Remote Sensing Group, Germany

HIGHLIGHTS

- We assess net irrigation requirements for gardens along a climatic gradient.
- Swimming pools and garden plantings were mapped accurately from WorldView-2 imagery.
- In the examined low-density urban landscapes, 44% of the plots are outdoor area.
- Outdoor landscape design seems not restricted by water availability or cost.
- Swimming pools contribute between 8% and 15% to potential outdoor water consumption.

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ABSTRACT

In the past two decades, the Spanish Mediterranean coast has experienced urban and demographic growth through the expansion of low-density residential areas characterized by ornamental gardens, swimming pools, and lawns. To determine the potential outdoor water demand, land cover data were mapped from high-resolution WorldView-2 imagery along a climatic gradient from Mallorca, in the Balearic Islands, to Andalusia in Spain. WorldView-2 imagery was analyzed by adopting object-based feature extraction to generate spatial information layers as additional input features (predictor variables) for supervised per-pixel classification. Swimming pools and gardens planted with turf grass, trees and shrubs were mapped automatically with high levels of overall accuracy, ranging from 88.98% to 96.13%. The resulting GIS (geographic information systems)-ready vector layer was used to calculate net irrigation requirements with the landscape coefficient method and to assess evaporative loss from swimming pools. The method and results can be used by urban planners, water managers, property owners and others to assess the implications of landscaping styles for water demand. Net irrigation requirements (April–September) range from 2335 m³/ha to 6330 m³/ha compared to 5400 m³/ha per year in irrigated agriculture in Spain. Per unit area, the same outdoor landscaping produces a 45.5% higher net irrigation requirement and 21.6% more evaporation from swimming pools along the climatic gradient. The combination of high-resolution image analysis and the landscape coefficient method captures the relevant information for the identification and quantification of outdoor water consumption in private urban landscapes.

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1. Introduction

From 1996 to 2006 the coastal zone of Mediterranean Spain has undergone unprecedented residential expansion through which

new low-density urban landscapes have evolved. This development is resulting in an urban model that is designed to achieve the highest real estate production, with almost no limitations of landscaping, ecological, urban or social order (Gaja, 2008). Residential tourism and the construction of second homes have played an important role in the process. The concept of ‘residential tourism’ has been used since the late 1970s to describe a development model based on the production of urban land for the construction of real estate property in tourist areas, with urban and demographic growth being the most significant expressions of the process (Mantecón, 2010). Second homes are buildings enumerated as secondary

* Corresponding author at: Ruhr University Bochum, Geography Department, Universitätsstrasse 150, 44780 Bochum, Germany. Tel.: +49 234 32 23375; fax: +49 234 32 14180.

E-mail addresses: angela.hof@ruhr-uni-bochum.de (A. Hof), nils.wolf@ruhr-uni-bochum.de (N. Wolf).

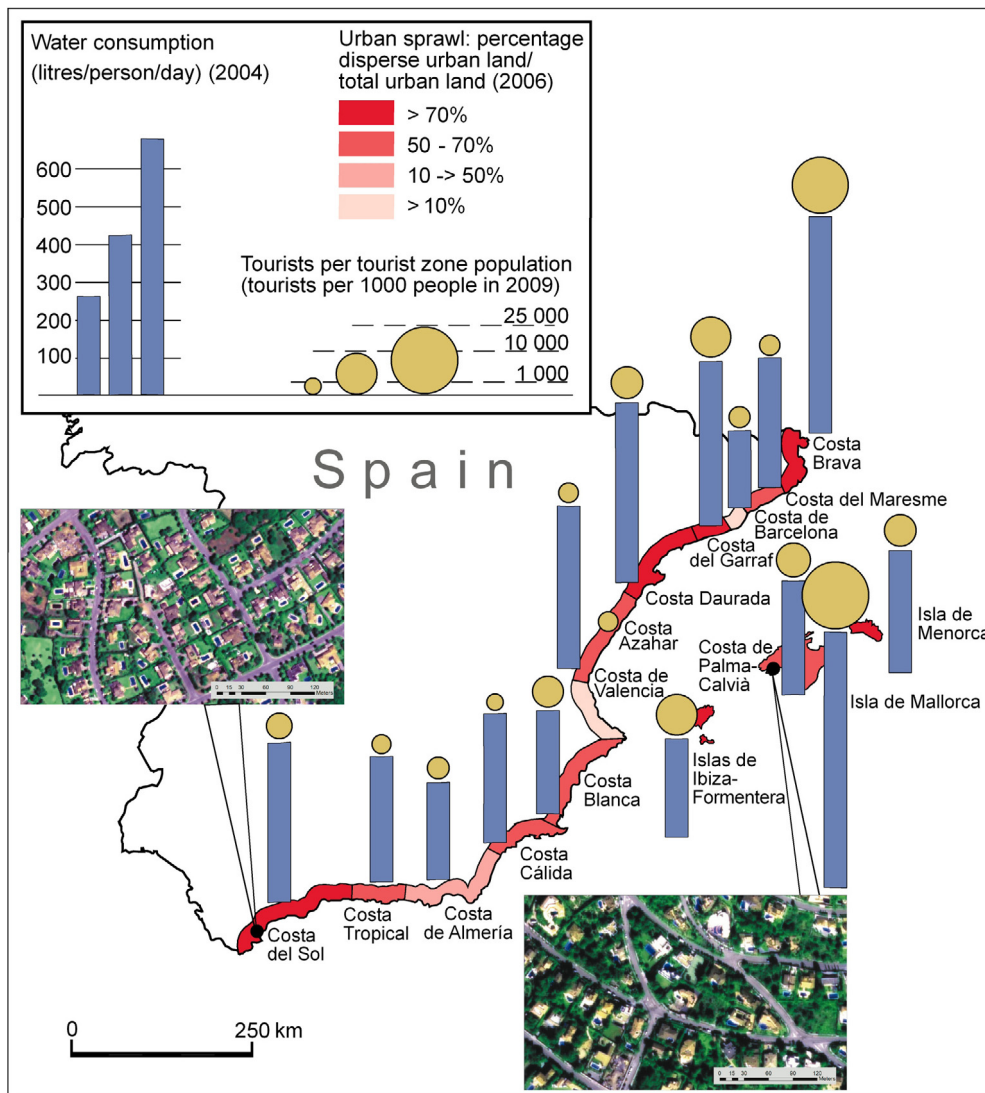


Fig. 1. Water consumption, tourist infrastructure concentration and urban sprawl in the tourist areas of the Spanish Mediterranean coast. The location of the study areas on the Costa del Sol and the Costa de Palma-Calvià is shown. Design and cartography by the authors, based on data in Saurí et al. (2011) and true colour composites of the used WorldView-2 satellite images. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

family dwellings in the census of population and housing in Spain, meaning that they are not considered being the principal residence and they are used for only part of the year (Barke, 2007). The context of research presented in this paper is the increasing residential water demand in the Spanish coastal areas, which is considered to be explicitly linked to urban and residential growth, including urban sprawl driven by residential tourism (Saurí et al., 2011). The concentration of urban landscape change in space and time is reflected in high per capita water consumption levels, a high tourist concentration, and urban sprawl; exacerbating the intense pressure on water resources in Spain (Fig. 1).

1.1. The linkages between residential land use patterns and water demand

In terms of the urban landscape, both residential and second homes are likely to have more private green space than other forms of urban development. Some authors have called this a 'garden effect', meaning an increase in garden area since the majority of the 'growing' residential area is low-density housing accompanied by gardens (Meeus & Gulinck, 2008). However, the character of that housing development landscape may reflect social contrasts.

Thus lifestyle behaviour and neighbourhood cohesiveness becomes a determinant of vegetation cover and plot design (irrigated landscaping, swimming pools) on private lands (Domene & Saurí, 2006; Wentz & Gober, 2007). This urban landscape transformation is placing additional pressures on water supply and water quality and creates a permanent demand for the maintenance of gardens and swimming pools. Such outdoor water use can account for up to 70% of residential water use (Domene, Saurí, & Pares, 2005; Loh & Coghlan, 2003; Wentz & Gober, 2007), with observations at household level showing that landscape irrigation use alone amounted to 46% of the total water use (Salvador, Bautista-Capetillo, & Playán, 2011).

The work reported here assesses the quantities of potential outdoor water consumption created from the same residential land use pattern along a climatic gradient. The approach is illustrated by an analysis of two locations in Spain, the Costa del Sol and Mallorca, Balearic Islands, which are at the same time major tourist zones and that exhibit urban sprawl due to the expansion of residential tourism and low-density urban expansion (Fig. 1).

Several studies in urban and tourism science have discussed the causal linkages between residential water demand and urban land use pattern. The absence of a pool and a garden results in a two

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