Urban Forestry & Urban Greening 19 (2016) 88–94

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

# Normalized difference vegetation index (NDVI) as a marker of surrounding greenness in epidemiological studies: The case of Barcelona city

Mireia Gascon[a,b,c,d,*], Marta Cirach[b,c,d], David Martínez[b,c,d], Payam Dadvand[b,c,d], Antònia Valentín[b,c,d], Antoni Plasència[a], Mark J. Nieuwenhuijsen[b,c,d]

[a] ISGlobal, Barcelona Ctr. Int. Health Res. (CRESIB), Hospital Clínic – Universitat de Barcelona, Barcelona, Spain
[b] ISGlobal, Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain
[c] Universitat Pompeu Fabra (UPF), Barcelona, Spain
[d] CIBER Epidemiología y Salud Pública (CIBERESP), Barcelona, Spain

ARTICLE INFO

*Article history:*
Received 2 October 2015
Received in revised form 27 May 2016
Accepted 1 July 2016
Available online 12 July 2016

*Keywords:*
Built environment
Environmental epidemiology
Green spaces
NDVI
Urban

ABSTRACT

The normalized difference vegetation index (NDVI) is often used as a marker of surrounding greenness in epidemiological studies aiming to evaluate the health effects of green space in urban settings. However, it is not clear the relationship between built environment characteristics, including green space, and NDVI. We aimed to evaluate the relationship between built environment characteristics, based on land-use and land-cover maps, and NDVI as a marker of surrounding greenness in the city of Barcelona. We used data from an already existing cohort of pregnant women in Barcelona (N = 8402). NDVI was derived and averaged within buffers of 100 m and 300 m for each participant, and categories of the built environment ($m^2$) were derived from land-use and land-cover maps of Barcelona. We conducted ANOVA models to calculate the contribution ($R^2$) of each land-use (or land-cover) category. The variability in NDVI in Barcelona was mainly explained by urban green ($R^2$ between 0.32 and 0.53) and natural green areas ($R^2$ between 0.19 and 0.52), although for the latter less than 4% of the participants were exposed to this. Both land-use and land-cover maps explained NDVI at 300 m better (full models explaining 76% and 78%, respectively) than at 100 m buffers (full models explaining 55% and 54%, respectively). Results of the present study indicate that NDVI can be a useful greenness metric depending on the hypothesis and area of study. However, for certain sizes of study areas (buffers smaller than 100 m), NDVI might have a lower predictive value. Results of the present study should be replicated in studies from other cities with different urban characteristics and climate conditions.

© 2016 Elsevier GmbH. All rights reserved.

## 1. Introduction

Improved mental health (Gascon et al., 2015), better pregnancy outcomes (Dadvand et al., 2012a; Grazuleviciene et al., 2015), as well as a reduction of the risk of mortality (Lachowycz and Jones, 2014), cardiovascular diseases (Pereira et al., 2012), asthma related symptoms (Dadvand et al., 2014a) or obesity (Dadvand et al., 2014a; Lachowycz and Jones, 2011) have been reported in relation to residential green spaces (James et al., 2015). So far, in such studies two main approaches have been used to define exposure to residential green spaces: (1) distance to minor and/or major green spaces as a surrogate of access to green spaces and (2) amount of surrounding greenness within a certain buffer as a surrogate of general greenness of home, workplace, or school. Surrounding greenness has been mainly characterized as the percentage of green spaces measured based on land-cover or land-use maps, or as the amount of photosynthetically-active greenness measured by the satellite-derived normalized difference vegetation index (NDVI) (James et al., 2015).

NDVI is the most common and easy obtainable vegetation index to detect live green plant canopies using multispectral remote sensing data based on spectral reflectance measurements acquired in the visible (red band) and near-infrared regions, respectively

* Corresponding author at: Parc de Recerca Biomèdica de Barcelona (PRBB) – ISGlobal, Centre for Research in Environmental Epidemiology (CREAL), Doctor Aiguader, 88, 08003 Barcelona, Catalonia, Spain.

*E-mail addresses:* mgascon@creal.cat (M. Gascon), mcirach@creal.cat (M. Cirach), dmartinez@creal.cat (D. Martínez), pdadvand@creal.cat (P. Dadvand), avalentin@creal.cat (A. Valentín), antoni.plasencia@isglobal.org (A. Plasència), mnieuwenhuijsen@creal.cat (M.J. Nieuwenhuijsen).

http://dx.doi.org/10.1016/j.ufug.2016.07.001
1618-8667/© 2016 Elsevier GmbH. All rights reserved.

(James et al., 2015). NDVI values range from −1 to 1; in general terms, very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, water or snow. Moderate values (0.2–0.3) represent shrubs and grassland, while high values (0.6–0.8) indicate temperate and tropical rainforests (Weier and Herring, 2015). However, at urban scale it is not very clear which urban characteristics are actually explaining the NDVI values obtained within a certain area. Moreover, NDVI is limited in capturing the high spatial heterogeneity that exists in an urban setting, and therefore, depending on the resolution, NDVI can underestimate urban green space variability and availability. However, existing land-use and land-cover maps in the city of Barcelona are based on orthophotos of a high resolution (pixel size of 0.5 m) (Burriel Moreno et al., 2006; CREAF, 2013) and, therefore, we can consider them as the gold-standard to determine the distribution of different types of urban uses or urban areas.

In epidemiological studies, in order to provide appropriate evidence of the health effects of a particular exposure, it is important to properly characterize this exposure and to minimize exposure misclassification (Burns et al., 2014). Many studies evaluating the health effects of living near green spaces have used NDVI as a proxy to define exposure to urban green spaces, but none of them has actually assessed the relationship between built environment characteristics, including green space, and NDVI. Therefore, in the current study we aimed to evaluate the relationship between built environment characteristics, based on land-use and land-cover maps, and NDVI as a marker of surrounding greenness in the city of Barcelona (Catalonia, Spain).

## 2. Materials and methods

### *2.1. The city of study*

Various epidemiological studies have been conducted in the city of Barcelona in relation to green spaces and health outcomes (Dadvand et al., 2014a,b; Triguero-Mas et al., 2015; Dadvand et al., 2015); for this reason we conducted the current study in this city located in Catalonia, Spain. It has an area of approximately 100 km$^2$ and is limited by the coastline in the south-east and by the Collserola hills (the highest point, Tibidabo, is 516 m) in the north-west. Currently 1.6 million inhabitants live in Barcelona, which has a high population density of 16.056 inhabitants/km$^2$. Barcelona has a Mediterranean climate, with relatively humid and mild winters and warm and dry summers. The rainiest seasons are autumn and spring.

### *2.2. The study participants*

We based the current study on data obtained from a cohort of pregnant women recruited during 2001–2005 from the obstetrics department of the Hospital Clinic of Barcelona, a major university hospital covering Barcelona city (Figueras et al., 2008). We limited the analyses to those participants residing in the city of Barcelona with known residential address at the time of delivery (N = 8402).

### *2.3. NDVI*

To determine the surrounding greenness we used NDVI derived from the Landsat 8 OLI/TIRS data at 30 m × 30 m resolution. The Landsat 8 imagery data was acquired for April 16th 2007 covering Barcelona city area. Surrounding greenness was abstracted as the average of NDVI in buffers of 100 m and 300 m around each maternal place of residence which was geocoded according to the address at delivery time.

### *2.4. Land use and land cover maps*

In order to define factors of the built environment that explain NDVI we used two types of land maps (land-use map and land-cover map). Although both of them are based on orthophotos of a resolution of a pixel size of 0.5 m (Burriel Moreno et al., 2006; CREAF, 2013), the categories created for each map provide different types of information regarding the characteristics of the area of study. Therefore, we considered that, in order to answer our research question, it was important to use both maps.

The first map that we used was the "Ecologic map of Barcelona", a land-use map prepared by the Centre for Ecological Research and Forestry Application (CREAF) (Burriel Moreno et al., 2006). This map displays the ecological areas that compose the urban green infrastructure (natural areas, semi-natural areas and built-up areas). For the current study we used the edition of 2004.The map is organized in a hierarchical legend of three levels. Level 3 (the most detailed classification) contains a total of 58 categories, level 2 groups the original categories into 31 and level 1 groups them into 10, which were the categories used to conduct the current study. These 10 categories are: natural waters, urban waters, crops, abandoned crops, dense urban area, non-dense urban area, natural green, urban green, non-green natural areas, non-built area (Burriel Moreno et al., 2006). Table 1 describes the land-uses indentified in the 8402 buffers analyzed.

The second map was the "Map of Land Covers of Catalonia (2005–2007)" (CREAF, 2013), which contains a total of 233 simple covers, hierarchically grouped into different levels. To conduct this study we used the level grouping these 233 categories into 24, which are: landfills, continental waters, deciduous forests, conifer forests, sclerophyllous forests, arboreal crops, herbaceous crops, sea, shrubs, cliffs, riverbank plantations, beaches, meadows, rocks and screes, wetland vegetation, riverbank vegetation, roads and parking areas, vineyards, areas under construction, burned areas, industrial areas, barren areas, urban areas, urban green. Table 1 describes the land-covers indentified in the 8402 buffers analyzed.

### *2.5. The analyses*

We conducted the current study using the buffers of 100 m and 300 m, which are buffer sizes commonly used in epidemiological studies. The buffer of 500 m has also been used in such studies, but because of the size of the city of Barcelona we considered that conducting the analyses using this buffer would not be appropriate, as the variability between subjects would be minor. For each category of land-use or land-cover we obtained the total amount of m$^2$, respectively, within the buffer of interest.

We first calculated spearman correlations between each land-use and each land-cover category, respectively. In order to understand the degree of correlation between land-use and land-cover categories, we also calculated the correlation between the categories of both types of land maps. Secondly, we estimated the association between NDVI and the several land-use categories, on one hand, and the land-cover categories, on the other hand, by including the respective categories in linear regression models. In order to observe changes, the estimates are presented for each one hectare of increase of each land-use (or land-cover) category by multiplying by 10000 (1 ha) the original estimates, which were for each 1 m$^2$. Thirdly, also separately for land-use and land-cover maps, we conducted ANOVA models to calculate the contribution ($R^2$, %) of each land-use (or land-cover) category. We first included each variable alone (one single variable model) and, secondly, we included all of them in one single model (full model). The existence of collinearity between variables included in the full model could lead to an overrepresentation of some of these variables and to an underrepresentation of others on the variability (%) explained. In

Download English Version:

https://daneshyari.com/en/article/93918

Download Persian Version:

https://daneshyari.com/article/93918

Daneshyari.com