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Research Paper

Methodological proposal to assess plastic greenhouses land cover change from the combination of archival aerial orthoimages and Landsat data

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This work outlines a methodological proposal to assess plastic covered greenhouses (PCG) land cover change from the combination of archival aerial orthoimages and Landsat data. In this way, landscape spatial metrics were semi-automatically derived to be used in the analysis of the spatial arrangement of PCG areas. The experimental process consisted of two main phases: (i) mapping PCG through a semi-automatic object-based image analysis (OBIA) approach relying on segmentation plus non-parametric supervised classification; (ii) processing the PCG classified objects to yield different landscape spatial metrics. The case study has focused on two high density PCG sites located in south-eastern Spain. To analyse PCG land cover evolution, each study site was composed of three multi-temporal remote sensed datasets formed by the fusion of orthoimages (O) derived from archival aerial photography and temporally corresponding Landsat images (L). In terms of PCG mapping performance, the best results were obtained when using O + L datasets as complementary data to be used in a data fusion process. In addition, a new feature called "Greenhouse Detection Index" has been successfully developed and tested, yielding excellent results at the mapping phase. Finally, the semi-automatically extracted PCG land cover metrics, though depicting some variability, have reproduced the behaviour and temporal trend of the manually obtained ones (manual digitalisation) reasonably well. These results can be translated to an exponential reduction of time and cost for analysing long-term PCG land cover change.

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Nomenclature/abbreviations

A_i	area of object i, m^2
A_t	total area considering all classes, m^2
AREA_MN	mean patch area, m^2
B	blue band
BRI	browning reflectance index
BSI	bare soil index
ED2	Euclidean distance 2
ENN_MN	mean Euclidian nearest neighbour distance, m
ETM+	Enhanced Thematic Mapper Plus
F_β	accuracy measure, %
FRAC_AM	area weighted mean patch fractal dimension
G	green band
GDI	greenhouse detection index
GSD	ground sample distance
GT	ground truth
H_{ij}	distance from object i to the nearest object j (from contour to contour) of the same class, m
KIA	kappa index of agreement
L	Landsat images
LP	subscript referred to the left pivot (located at the shortest wavelength, B band)
MDI	moment distance index (shape of reflectance spectrum)
MRS	multi-resolution segmentation
n	total number of objects in the class
NDVI	normalised difference vegetation index
Nir	near infrared
NP	number of patches, greenhouses
O	orthoimages aerial
OA	overall accuracy, %
OBIA	object-based image analysis
O + L	data fusion (orthoimage and Landsat data)
P_i	perimeter of the object i, m
PA	producer's accuracy, %
PAN	panchromatic band
PCG	plastic covered greenhouses
PD	patch density, number [100 ha]$^{-1}$
PGI	plastic greenhouse index
PMLI	plastic-mulched landcover index
R	red band
RF	random forest
RP	subscript referred to the right pivot (located at the longest wavelength, Swir2 band)
SA	study area
SP	scale parameter
Swir1	shortwave infrared-1
Swir2	shortwave infrared-2
TM	Thematic Mapper
UA	user's accuracy, %
VHR	very high resolution
Vi	index greenhouse vegetable land extraction
λ	wavelength, μm
ρ_i	reflectance corresponding to wavelength i (ranging from 0 to 1)

1. Introduction

1.1. Context

Greenhouse area around the world reached a value of 405,000 ha (FAO, 2013) during the first decade of the 21st century, and is mainly located in Europe (Mediterranean areas), North Africa, the Middle East and China. In the case of Spain, the surface dedicated to greenhouses has increased exponentially in the last decades from 546 ha in 1968 to 65,674 ha in 2016 (MAAMA, 2016). The largest concentration of greenhouses, mainly plastic covered greenhouses (PCG), is located in the south-eastern of Spain (south-eastern Andalusia and Murcia). In 2016, Andalusia region represented up to 74% of the total greenhouse land cover in Spain (MAAMA, 2016). Focussing on the province of Almeria, where this study has been undertaken, the PCG area represents approximately 44% of the total area of greenhouses in Spain (CAPDR, 2016).

The predominant greenhouse in Almeria is the “Parral” type (the traditional Mediterranean greenhouse), typical of warm regions and characterised by its low height, plastic cover and wooden or aluminium structure (Valera Martínez, Belmonte Ureña, Molina Aiz, & López Martínez, 2014). From the landscape point of view, PCG areas are characterised by a set of closely spaced patches constituting a continuous and shiny mosaic that has been called a “sea of plastic”, since there is no practical space between adjacent greenhouse patches (Fig. 1).

Overall, the arrival of this very intensive agricultural model to Almería led to a significant change in the patterns of land arrangement and landscape perception (Aznar-Sánchez & Sánchez-Picón, 2010). In fact, the aforementioned semi-industrialised agricultural model is linked to an important anthropic impact (Parra, Aguilar, & Calatrava, 2008) due to the construction of greenhouses and auxiliary infrastructure (e.g., road network, storage buildings, electrical network, irrigation network, irrigation ponds …). These activities contribute significantly to the modification of the environment (Arcidiacono & Porto, 2010). In this way, special care is required to carry out land planning and development tasks in these PCG areas, trying to minimise the environmental and visual impact (Rogge, Nevens, & Gulinck, 2008). To provide information on this issue, a panel of experts from the agri-food sector of the Community of Andalusia was consulted in a recent study. More than 50% of the panel members reported that, to date, there has been practically no design component in the planning of agri-food facilities such as PCG areas (González-Yebra, Aguilar, & Aguilar, 2018). Therefore, it seems clear that the study of the design and planning of PCG areas is an aspect to be considered, mainly to avoid uncontrolled development leading to negative social and environmental consequences (Aguilar, Bianconi, Aguilar, & Fernández, 2014; Picuno, Tortora, & Capobianco, 2011; Tarantino & Figorito, 2012). Among other problems, the agricultural use of plastic sheets produces high volumes of plastic waste in rural areas (Lanorte et al., 2017; Scarascia-Mugnozza, Sica, & Picuno, 2008). An interesting research line started in Spain in 1980s and 1990s, trying to link engineering and landscape