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Spearman Correlation between the NDVI and *Quercus* Airborne Pollen in the SW of the Iberian Peninsula †

Rocío González-Naharro [1], Elia Quirós [1], Santiago Fernández-Rodríguez [2,*], Inmaculada Silva-Palacios [3], Rafael Tormo-Molina [4], José María Maya-Manzano [5], Alejandro Monroy-Colin [4], Raúl Pecero-Casimiro [4] and Ángela Gonzalo-Garijo [6]

1 Department of Graphic Expression, School of Technology, University of Extremadura, Avda. de la Universidad s/n, 10003 Cáceres, Spain; rgonzalebn@alumnos.unex.es (R.G.-N.); equiros@unex.es (E.Q.)
2 Department of Construction, School of Technology, University of Extremadura, Avda. de la Universidad s/n, 10003 Cáceres, Spain
3 Department of Applied Physics, Engineering Agricultural School, University of Extremadura, Avda. Adolfo Suárez s/n, 06006 Badajoz, Spain; insilva@unex.es
4 Department of Plant Biology, Ecology and Earth Sciences, Faculty of Science, University of Extremadura, Avda. Elvas s/n, 06006 Badajoz, Spain; ratormo@unex.es (R.T.-M.); bioamc@outlook.com (A.M.-C.); raulpc@unex.es (R.P.-C.)
5 School of Chemical and Pharmaceutical Sciences, Dublin Institute of Technology, Kevin Street, Dublin D08X622, Ireland; jmmaya@unex.es
6 Department of Allergology, Infanta Cristina University Hospital, Avda. Elvas s/n, 06006 Badajoz, Spain; magonzalog@gmail.com
* Correspondence: santiferro@unex.es; Tel.: +34-927-257000
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Abstract: New space technologies as Advanced Very High Resolution Radiometer (AVHRR) and the MODerate resolution Imaging Spectroradiometer (MODIS) have been used to display several phenological cycles of ecosystems around the world. The aim of this study was to establish the relationship between Normalized Difference Vegetation Index, NDVI, associated to oak trees within three training data polygons (15, 25 and 50 km-distance to the volumetric sampler Hirst), and the daily average *Quercus* airborne pollen concentrations in 20 years. The study was developed in Badajoz (SW Iberian Peninsula) with a continuous pollen recording in the period from 1994 to 2013. The main novelty of this study has been the analysis of the correlation between the two-time series, using Spearman test. Within the 20 studied years, 12 years obtained significant values in the Spearman test in the whole studied area.

Keywords: Normalized Difference Vegetation Index (NDVI); *Quercus* airborne pollen; Polygon oak trees; Spearman correlation; Pollination phenology

1. Introduction

Land cover changes and plant phenological response have been attributed to the impact of human activity on plant distribution [1]. NDVI and its relation with pollen grains seems to be considered as a topic increasingly popular due to their multiple applications in issues such as dispersal processes with the ecological scaling [2], phenological phenomena with the start days of birch pollen seasons [3], real-time monitoring with short-term forecasting of land surface phenology [4] or for long term data in a 20-year study of NDVI variability [5]. Many other applications of NDVI regarding

pollen have been maps: satellite-based map of onset of birch (Betula) flowering [6], and for identifying urban sources as cause of elevated grass pollen concentrations using GIS and remote sensing [7].

Mediterranean forest derived ecosystems in the SW of the Iberian Peninsula are named "savannah-like ecosystems" and formed, mainly, by tree species of the genus *Quercus* (oak) with five species as the most common: *Quercus ilex subsp. ballota* (=*Q. rotundifolia*), *Q. suber*, *Q. pyrenaica*, *Q. coccifera and Q. faginea* [8]. Those trees in the study area dominate natural and seminatural landscapes, only in Extremadura dehesas represent 34% of surface [9]. Potential Natural Vegetation (PNV) is analyzed by the size-frequency distribution polygons of soil and vegetation maps [10]. The use of polygons to delimit space units is widely used for riparian vegetation [11], for assessing different feature set's effects of land cover classification [6] and the relationship between this land cover surface and pollen grain concentrations for different wind direction patterns [12]. The aim of this study was to establish the relationship between NDVI associated to oak trees within three training data polygons (15, 25 and 50 km-distance to the volumetric sampler Hirst) and the daily average *Quercus* airborne pollen concentrations for 20 years of continuous recording (1994–2013) from an urban area in the SW of the Mediterranean region. Spearman correlation has been used to accomplish the goal.

2. Material and Methods

2.1. Sampling Site

The study area was located in Badajoz (SW Spain) in the border with Portugal. The training extent was encompassed in a diameter of 15, 25 and 50 km around a 7-day volumetric sampler pollen [13]. Sampling point was located (38°53′45″ N, 6°58′07″ W) on a terrace at 6 m above ground in a building of the Agricultural Engineering School of the University of Extremadura with *Quercus* pollen data from 20 years (1994–2013).

2.2. Space Images NDVI NOAA/ AVHRR

NDVI image records can be accessed through the United States Geological Survey (USGS). Daily data offered by the service includes the period from 1981 to 2013 in the website https://earthexplorer.usgs.gov/. In order to establish the NDVI images to be studied, the total days of *Quercus* Main Pollen Season (MPS) between 1994 and 2013 were calculated, based on the previous study by Fernández-Rodríguez et al. [14]. These *Quercus* MPS were estimated using the 5–95% range defined by [15].

2.3. Cartography

Due to the fact that our study area is located in the border between Spain and Portugal, it was necessary to use two different cartographic sources: in the Spanish part of the study, the Extremadura Forest Map (MFEx) has been used, while in the Portuguese part, data of the Fifth National Forest Inventory of Portugal (IFN5) concerning oak and cork oak locations were employed. This IFN5 information was provided by the Autoridade Florestal Nacional (AFN) (2010) and belongs to the National Forest Inventory 2005–06, Continental Portugal—IFN5 2005–2006, Lisbon.

2.4. Statistical Analysis

The relationship between *Quercus* pollen concentration and NDVI was correlated by Spearman test.

3. Results

The correlation was statistically studied using the Spearman test. The results forthcoming from the Spearman correlation test (Table 1) show those years 1996, 1999 and 2012 had non-significant correlations with pollen concentration within the three training areas. Additionally, years 1994, 2000

and 2006 had few significant correlations in only one training area, having substantial dispersions in the other training areas.

Table 1. Statistical Spearman test results in the three training areas (significant correlations in bold).

Year	LAGS	50 Km		25 Km		15 Km	
		Spearman Correlation	Spearman *p*-Value	Spearman Correlation	Spearman *p*-Value	Spearman Correlation	Spearman *p*-Value
1994	9	**0.3510**	**0.0080**	0.3220	0.0160	0.3120	0.0190
1995	8	**0.5320**	**<0.0001**	**0.3490**	**0.0100**	**0.2870**	**0.0360**
1996	1	0.2070	0.1380	0.1920	0.1690	0.1450	0.3000
1997	1	**0.5930**	**<0.0001**	**0.6340**	**<0.0001**	**0.5760**	**<0.0001**
1998	10	**0.3910**	**0.0010**	**0.3810**	**0.0020**	0.0970	0.4390
1999	1	0.0900	0.5200	0.1480	0.2890	0.0830	0.5550
2000	12	0.2170	0.1040	**0.2200**	**0.0460**	0.1480	0.2710
2001	4	**0.5210**	**<0.0001**	**0.5060**	**<0.0001**	**0.5000**	**<0.0001**
2002	1	**0.4280**	**0.0010**	**0.5330**	**<0.0001**	**0.3940**	**0.0020**
2003	11	**0.3060**	**0.0060**	**0.3000**	**0.0070**	**0.2550**	**0.0220**
2004	4	**0.2820**	**0.0410**	**0.4060**	**0.0030**	**0.3570**	**0.0090**
2005	12	**0.4820**	**0.0000**	**0.5210**	**<0.0001**	**0.3510**	**0.0060**
2006	15	**0.2290**	**0.0470**	0.1080	0.3510	0.1030	0.3770
2007	13	**0.3190**	**0.0060**	**0.3370**	**0.0040**	**0.3220**	**0.0060**
2008	7	**0.4370**	**0.0010**	**0.4400**	**0.0010**	**0.4160**	**0.0020**
2009	6	**0.2570**	**0.0460**	**0.2580**	**0.0450**	**0.2800**	**0.0290**
2010	9	0.2520	0.0620	**0.3260**	**0.0150**	**0.3500**	**0.0080**
2011	1	**0.6080**	**0.0000**	**0.6060**	**0.0000**	**0.5950**	**0.0000**
2012	13	0.0350	0.7580	-0.0480	0.6740	-0.2030	0.0720
2013	9	**0.4690**	**0.0000**	**0.4790**	**0.0000**	**0.4490**	**0.0010**

4. Conclusions

The main novelty of this study has been the analysis of the correlation between the value NDVI of holm oaks and cork oaks (*Quercus rotundifolia* and *Quercus suber*) inside to the regional scale with short distances: remote urban (50 km), peri-uban (25 km) and urban areas (15 km) with *Quercus* airborne pollen for a long term data (1994–2013) in the SW Iberian Peninsula, using Spearman correlation test. Within the 20 studied years, 12 years obtained significant values in the Spearman test in the whole studied area. Differences found between years could be explained due to meteorology without discarding the influence of long distance airborne pollen transport. Future studies are proposed with phenological and meteorological data and other types of pollen grains for trying to get better not only a short-term, but also real-time monitoring could be implemented for forecasting pollen concentrations.

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Conflicts of Interest: The authors declare no conflict of interest.

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