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Current anthropogenic pressures on agro-ecological protected coastal wetlands

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HIGHLIGHTS

- Direct and Indirect pressures of urban origin are found in l'Albufera Natural Park.
- Soil sealing was 18.6% in the administrative area in 2011, and 5.2% in the Park.
- A large number of pharmaceuticals (13 out of 17) were detected in surface waters.
- Connectivity is produced between densely populated areas, SWTPs and irrigated land.

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ABSTRACT

Coastal wetlands are areas that suffer from great pressure. Much of it is due to the rapid development of the surrounding artificial landscapes, where socio-economic factors lead to alterations in the nearby environment, affecting the quality of natural and agricultural systems. This work analyses interconnections among landscapes under the hypothesis that urban-artificial impacts could be detected on soils and waters of an agro-ecological protected area, L'Albufera de Valencia Natural Park, located in the vicinity of the City of Valencia, Spain. The methodological framework developed addresses two types of anthropogenic pressure: (1) direct, due to artificialisation of soil covers that cause soil sealing, and (2) indirect, which are related to water flows coming from urban populations through sewage and irrigation systems and which, ultimately, will be identified by the presence of emerging pharmaceutical contaminants in waters of the protected area. For soil sealing, a methodology based on temporal comparison of two digital layers for the years 1991 and 2011, applying Geographical Information Systems and landscapes metrics, was applied. To determine presence of emerging contaminants, 21 water samples within the Natural Park were analysed applying liquid chromatography tandem mass spectrometry for the detection of 17 pharmaceutical compounds. Results showed that both processes are present in the Natural Park, with a clear geographical pattern. Soil sealing and presence of pharmaceuticals are more intensive in the northern part of the study area. This is related to population density (detection of pharmaceuticals) and land cover conversion from agricultural and natural surfaces to artificial ones (soil sealing).

1. Introduction

World population is becoming increasingly urban. It is expected that people living in cities will account for two-thirds of the world's total inhabitants by the year 2050 (United Nations, 2012), giving rise to environmental impacts on a global scale (Hassan et al., 2005). As urban population concentration is greater in coastal zones (McGranahan et al., 2007), impacts on estuaries and coastal lagoons (due to their accessibility) may be more acute, exacerbating the historical degradation that has been going on for centuries (Lotze et al., 2006). Despite their richness in biodiversity, Mediterranean coastal wetlands are examples of the fragility of these areas because they are exposed to human activities such as farming systems (Readman et al., 1993) and constant urban sprawl (Li et al., 2010).

Pressures exerted by urban systems on the surrounding natural areas should be understood as direct (e.g. conversion and artificialisation of existing land covers) and indirect (e.g. externalisation of urban pollutants to natural and semi-natural landscapes), of which the main processes are anthropogenic soil sealing (Prokop et al., 2011) and outsourcing of (emerging) contaminants (Richardson, 2012) not treated in Sewage Water Treatment Plants (SWTPs), respectively.

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Soil sealing is defined as the covering of soil due to urbanisation and infrastructure construction. Thus, soil is no longer able to perform the range of functions associated with it (European Environment Agency, 2002). It is considered one of the most threatening soil degradation processes worldwide, and especially affects the pre-littoral and littoral areas of the Mediterranean ecosystems, where intensive urban development took place between 1970 and 2010 (UNEP/MAP, 2012). According to Wilby and Perry (2006), there is a continuous trend towards intensification of city-dwelling populations; a process that is likely to continue in the near future, which in turn makes the need to obtain accurate data on soil sealing spatial structures at local level more relevant.

Indirect pressures of urbanisation may be described as the type of undesirable actions in other (nearby or distant) natural or semi natural landscape entities. Pharmaceutical compounds for human treatment have been detected in aquatic environments (Brausch et al., 2012). They are considered emerging contaminants (EC). Richardson (2008, 2010, 2012) shows recent lists of EC, and their identification on water analysis (Richardson, 2009; Richardson and Ternes, 2011).

Approaches to help understand the dynamics of urban/artificial areas in the surrounding open space systems should be analysed taking in consideration distinct types of threats. The aim of this work is the development of an integral methodology, based on environmental forensic criteria (Murphy and Morrison, 2007) and Geographical Information Systems (GIS) (Longley et al., 2005), to determine the way direct and indirect pressures are exerted on natural ecosystems. Therefore, two types of processes (or main drivers) were analysed: the increment of artificial surfaces (direct pressures) and the flow of pharmaceuticals in surfaces waters (indirect pressure). The methodology was applied in the Natural Park of L'Albufera de Valencia and surrounding municipalities to obtain background on (1) how artificial surfaces extend from existing built up areas and (2) how prescribed substances travel from urban and agricultural water systems to the protected area.

The working hypothesis considers that there are transfer mechanisms of urban processes to nearby protected natural landscapes, represented by the enlargement and externalisation of artificial soil covers and the continuity of water flows. Therefore, connectivity between different environmental compartments is established regardless their dominant land use and level of environmental protection.

Specific objectives were (1) to determine rates and trends of artificial surface expansion represented by soil sealing and fragmentation; (2) to identify water paths of pharmaceutical compounds of urban origin and the hydrological connectivity between different environments (urban and agriculture); and (3) to establish spatial differences according to incidence of artificial surface expansion for soil sealing degradation, and to presence and concentration of pharmaceutical compounds contaminants.

2. Material and methods

2.1. Study area

The study was applied to L'Albufera de Valencia Natural Park and surrounding municipalities, located in Spain (Fig. 1). The original wetland area was evolved in the large alluvial plain formed by the river Turia to the north and the Júcar to the south. The area presents a complex relationship between its intrinsic natural importance (endemic species, biodiversity and hydrological buffering) and human activities (traditional agriculture and hinterland industrial and settlement development).

The current Natural Park covers 274.4 km^2, including its marine area. Due to secular alterations within its limits, a large proportion of the land belongs to rice fields, which occupy the primitive marshland, with only a few hectares still in their natural state (Soria et al., 2002). In the continental margins of the Natural Park, intensive irrigated farming is also found. A shallow lagoon is located in the centre; it is almost circular in shape and covers an area of 23.7 km^2.

The hydrology combines human management system and natural contributions, with water coming from the historic irrigation system as the main source of water inflows to the Natural Park. There is a very dense structure of overland artificial channels for irrigation, 59.7 km in length with a density of 323 m/km^2, with waters mainly coming from the rivers Jucar and Turia, which finally drain into the lake or directly to the sea. These water contributions, particularly those from rice fields, make up almost 70% of the total waters circulating the Natural Park and draining into the lake (Soria and Vicente, 2002). They are crucial in the function of ecosystems and in the recharge and chemistry of underground waters. Three channels connect the lake with the sea, their outflow being regulated by floodgates that maintain water levels in the rice fields.

In a small proportion, water inflows also arrive from the lake's own hydrographical basin, with an area of 917.1 km^2 in both directions as groundwater sources within the limits of the Natural Park and from several ravines. The main ones are La Rambla de Poyo and La Rambla de Beniparrell; other gullies end in ditches in the orchards and rice fields that flow into the L'Albufera.

The Natural Park is surrounded by a densely populated hinterland, due to the influence of the City of Valencia and its metropolitan area. Major pressures come from the activities of a population of 1,500,000 inhabitants, of which, almost 1,000,000 live in the thirteen municipalities included within the limits of the Natural Park. Farming and intensive irrigation systems developed in and out of the limits of the Natural Park are important threats to the preservation of ecosystems and water quality.

2.2. Methodology

2.2.1. Direct pressures: spatial representation, quantification and analysis of artificial surfaces

Two detailed concrete and asphalt artificial covers for the years 1991 and 2011 were created using ARCGIS (v. 10.1) GIS vector structure. For the year 1991, an information layer was produced from a panchromatic aerial photograph of 1991(provided by the Valencia Cartographic Institute) which was converted through GIS processes into an orthophoto. The resulting product was a full extent scene that covers the administrative study area, with a final pixel definition of 1 m. This precision allows the identification of very small soil sealing entities, considering the true smallest cartographic unit as having around 8 m^2 and the minimum linear feature width of 3 m. A present day artificial surface layer was constructed using the 2011 year colour orthophoto of 0.5×0.5 metres pixel resolution (provided by the Spanish National Geographical Institute). Information extraction was performed by on screen digitising following techniques of aerial photograph interpretation for land cover-use delimitation (Taylor et al., 2000).

The resulting layers were further integrated into a GIS analytical structure together with a coverage containing municipal boundaries of the administrative study area and another one including the limits of the Natural Park. All digital maps were geographically positioned following national and regional mapping standards: Spatial reference system ETRS89 and Universal Transverse Mercator projection. Based on existing metrics (Cushman et al., 2008), landscape (spatial) structure was analysed to determine the extent and trends of anthropogenic soil sealing and the degree of fragmentation and patchiness with the specific landscape class of paved and built up surfaces for both the municipalities of the administrative area and the protected land of the Natural Park. Soil sealing and fragmentation values were extracted for each year as absolute and relative surfaces.

Map overlay techniques (Gao, 2008) between the artificial surfaces and administrative entities and Natural Park layers were performed to obtain synthetic soil sealing values for each municipality and the total protected land respectively. Cartographic Diachronic spatial analysis was undertaken at administrative level using temporary municipal soil sealing trends between 2011 and the reference date (1991) and,