

## Comparative analysis of net land take in Portugal's Metropolitan Areas

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### Biographical note on authors

Rita Nicolau is a principal researcher at DGT (Directorate-General for Territory) and a research collaborator of CiTUA (Center for Innovation in Territory, Urbanism, and Architecture of Lisbon University). Her background is in environmental engineering (undergraduate in 1996 and PhD in 2002, by New University of Lisbon) and operational research and systems engineering (Master by Lisbon University in 1994). She is a GIS specialist accredited by the Portuguese Engineers Order.

Until 2002, she worked at the National Centre for Geographic Information in the National Spatial Data Infrastructure (SNIG) implementation.

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From 2006 to 2010, she researched at the National Institute of Health Doutor Ricardo Jorge (INSA), participating in projects concerned with the spatial analysis of mortality and morbidity and their determinants, and assessment of the impact of atmospheric pollution on human health. Since 2011, at DGT, she has participated in research projects that have entailed the analysis of urban systems, the identification and delineation of settlements and built-up structures, the delimitation of rural-urban interfaces, land use change assessment, and the creation of indicators for monitoring sustainable urban development and spatial planning in general. Her current research relates to land consumption for urban development (land take, soil sealing, developed land recycling and re-naturalisation).

Beatriz Condessa is assistant professor at IST. She obtained a degree in Environmental Engineering – Specialization in Spatial Planning (1986, New University of Lisbon, Portugal) and a PhD in Geography (1999, Barcelona University, Spain).

She has carried out research activities since 1992. Firstly, in CNIG (National Centre for Geographic Information), mainly in developing databases using GIS tools to facilitate urban management and promote public access to information. Between 1998 and 2004, she coordinated the CNIG research team on Spatial Planning.

Since 2004, in IST, she has taught and researched urban management, focused on integrating urban planning, law and urban economics. More recently, she was PI of PERCOM project (Equity and efficiency in the urbanization process: a land readjustment execution model), of LANDYDYN (Land use cover change in continental Portugal: characterization, driving forces and future scenarios) and RIPROCITY (Rivers in Cities: potential for urban sustainability).

During 2014-2015 she coordinated the master programme in Urban Studies and Territorial Management at IST. She is a GIS specialist accredited by the Portuguese Engineers Order and a member of the Portuguese Urbanists Association and the International Academic Association on Planning, Law, and Property Rights (PLPR).

### Abstract

The "No Net Land Take by 2050" target, set by the EU, has been reshaping European urban development. The main goal of this research is to compare the processes related to net land take and soil sealing in the Portuguese metropolitan regions (AML and AMP) and to assess their situation regarding the 2050 target.

During 2007-2018, the artificial land area increased by 4.9 percent in AMP and 4.6 percent in AML. Net land taken averaged 0.6 ha/day in the AMP and 0.7 ha/day in the AML. Reuse of artificial land was rarely practised, at 0.02 ha/day in the AMP and 0.03 ha/day in the AML. Given that the share of sealed artificial land in both regions was already close to 60% in 2018, thereby jeopardising urban biodiversity, to reduce net land take it is recommended that future infrastructure and housing needs be met by reusing already sealed artificial areas.

**Keywords:** Urbanisation; Reuse of developed land; Re-naturalisation of developed land; Urban land use efficiency

## 1. Introduction

Urban development in Europe is being shaped by the "No Net Land Take by 2050" target, set by the 2011 Roadmap to a Resource Efficient Europe (EC, 2011a) and reinforced by the EU Soil Strategy for 2030 (EC, 2021). In pursuit of sustainable use of soil, this strategy recommends that Member States set, by 2023, their targets aimed at net land take reduction by 2030 and report on their progress by making measurable contributions towards the 2050 target. The first draft of the Soil Monitoring Law (SML) was launched in July 2023 (EC, 2023) to ensure healthy soils across the EU by 2050. It establishes a regulatory framework for sustainable soil management, which mandates Member States to monitor land take and soil sealing.

Land take conveys the 'loss of undeveloped land to human-developed land' (EC, 2016, p.4) over a given period. In practice, it represents 'the surface of agricultural, forest, semi-natural and natural areas, wetlands and water bodies artificialized in a given period' (Nicolau and Condessa, 2024, p.1). Net land take accounts for the difference between land take and re-naturalisation of developed land, which is the reverse process of land take. A reduction in net land take is only attainable through the reuse of developed land (i.e. artificial or urban areas) or by increasing re-naturalisation, a rarely practised land use transformation (Nicolau and Condessa, 2022).

Soil sealing is considered the most intense form of land take, as it causes a total and irreversible loss of ecosystem services and functions provided by soil (Scalenghe and Marsan, 2009; EC, 2011b; Tobias et al., 2018). To prevent cities' biodiversity from declining, some experts (Decoville and Feltgen, 2023) advocate keeping soil sealing levels within urban areas below 40 percent, a threshold supported by a study on urban plant diversity loss caused by soil sealing in a rapidly urbanising Chinese city (Yan et al., 2019). Nonetheless, research applied to the Paris Metropolitan Area (Tardieu et al., 2021) showed that the level of soil sealing is insufficient to predict a large part of the variations in ecosystem services at the landscape level. Therefore, their authors argue that planning decisions affecting ecological functions on which the well-being of urban citizens depends should be based on regular assessments of these services.

To limit land take and soil sealing, the Soil Strategy (EC, 2021) also proposes the adoption of a hierarchy in land use planning that prioritises the reuse of developed land. Whenever land take cannot be avoided, measures should be implemented to compensate for the loss of ecosystem services (e.g. re-naturalisation of artificial areas, development of green infrastructure).

This research aims to compare the processes related to net land take and land take driving forces between Portuguese metropolitan regions (Área Metropolitana de Lisboa - AML and Área

Metropolitana do Porto - AMP) to assess their progress towards meeting the 2050 target. In addition to sensitising decision-makers and public authorities to the European goal, the research also intends to support the setting of regional and local land take targets, which do not exist to date, and the definition of reduction strategies for land take. Although the Portuguese National Spatial Planning Policy Programme recognises the need to protect the soil as a natural capital asset and to control land artificialisation, these objectives have not yet been translated into quantitative targets (national, regional and local) that can contribute to the successful implementation of a "no net land take" policy.

## **2. Materials and Methods**

### **2.1. Methods and Data**

The study assessed land use changes between 2007 and 2018 and the degree of soil sealing in 2018, based on Portuguese land use/cover maps known as COS (Costa et al., 2023), municipal boundaries maps for 2018 (both produced by the Directorate-General of Territory - DGT), and the Imperviousness Density (IMD) layer produced by Copernicus Land Monitoring System (CLMS, 2023). Annual population estimates launched by Statistics Portugal were employed to analyse population dynamics. COS are vector maps with a minimum mapping unit of one hectare and the IMD 2018 is a raster product with a spatial resolution of 10 metres.

The research assumed that the COS classes relating to artificial surfaces represent developed or urban land, including both sealed and unsealed areas, and that the remaining COS classes represent undeveloped or non-urban land.

The sealing level of each spatial unit and its artificial land was assessed in three stages. First, pixels covering the spatial unit and its artificial land were identified; Next, the product of the IMD value by the surface area of each pixel was totalled for all pixels of interest; Finally, the percentage of the area of interest that was sealed was calculated.

The processes described by the study regard surface areas per spatial unit over a specific period. Due to the unequal sizes of spatial units, the study reports them in  $\text{m}^2/\text{year}\cdot\text{km}^2$ , which allows comparison of the same process across different spatial units, or in  $\text{ha}/\text{day}$ , which only enables comparing processes relating to the same spatial unit between different periods.

### **2.2. Study Area**

The study examines two NUTS III regions of mainland Portugal (Figure1) during 2007-2018 and at the end of this period: the Lisbon Metropolitan Area (AML) and the Porto Metropolitan Area (AMP). The AML is the most populous area in the country, with almost 2,9 million inhabitants (2021). It is subdivided into 18 municipalities, one of which (Lisboa) is the largest city in Portugal. The AMP covers 17 municipalities and is the second most populous region in the country (nearly 1,8 million inhabitants in 2021). In 2018, almost half (47 %) of the mainland's population was concentrated in the AML and the AMP, justifying these regions having the highest proportions of their surface area covered by artificial land (25.1 % in AMP and 21.7 % in AML). Although the AML has over a million more inhabitants than the AMP, in 2018 the artificial land per capita was higher in the AMP ( $297 \text{ m}^2/\text{inhabitant}$ ) than in the AML ( $230 \text{ m}^2/\text{inhabitant}$ ), which shows that the latter region is denser than the AMP. According to the Municipal Plans in force in 2018 and the population estimates for that year, the availability per inhabitant of parks, gardens and forests in areas classified as urban in the AML ( $39 \text{ m}^2/\text{inhabitant}$ ) was much lower than in the AMP ( $83 \text{ m}^2/\text{inhabitant}$ ).





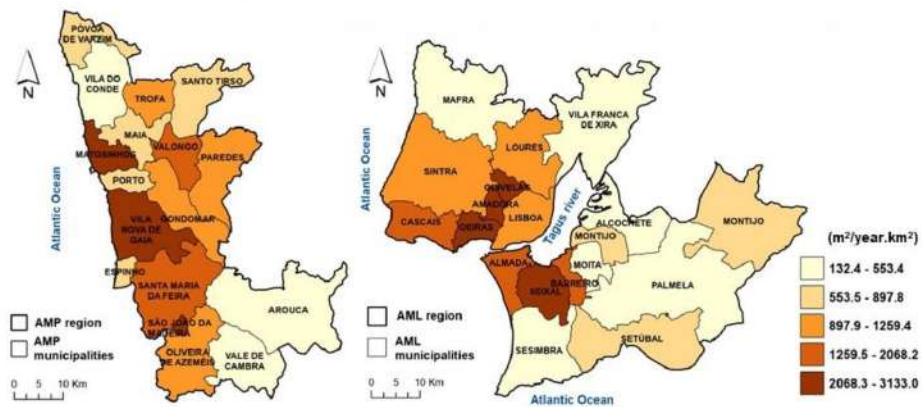


Figure 3 – Net land take rate by AMP and AML municipalities, 2007-2018 (m<sup>2</sup>/year.km<sup>2</sup>)

### 3.2. Reuse of Artificial Land

The reuse of artificial land was also little practised in both regions during 2007-2018, averaging 0.02 ha/day in AMP and 0.03 ha/day in AML (i.e. 28 m<sup>2</sup>/year.km<sup>2</sup> and 38 m<sup>2</sup>/year.km<sup>2</sup>, respectively).

Despite this trend and the fact that three municipalities did not apply this process (Vale de Cambra and Arouca in the AMP, and Moita in the southern AML), two AML municipalities (Amadora and Lisboa) stood out for having the highest rates of land reuse (289 m<sup>2</sup>/year.km<sup>2</sup> and 267 m<sup>2</sup>/year.km<sup>2</sup>, respectively) (Figure 4).

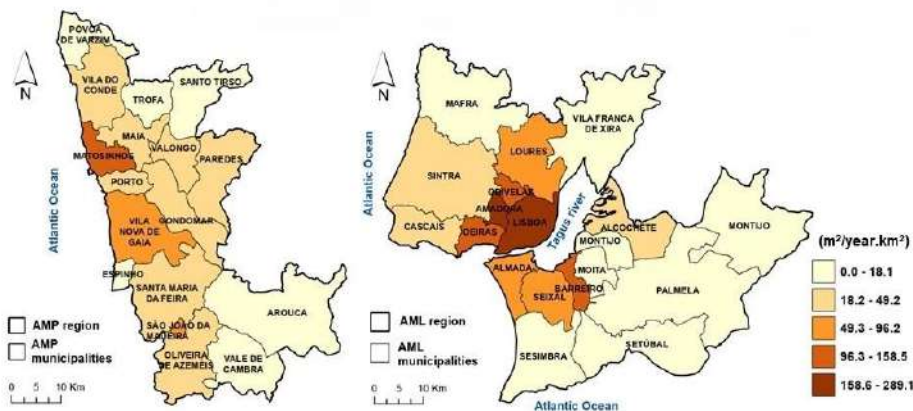


Figure 4 – Artificial land reuse rate by AMP and AML municipalities, 2007-2018 (m<sup>2</sup>/year.km<sup>2</sup>)

### 3.3. Urban Soil Sealing

In 2018, the degree of imperviousness of the artificial land was 56 percent in the AMP and 58 percent in the AML. At the municipal level (Figure 5), it ranged from 28 to 69 percent in both regions. Only two municipalities in the AMP (Arouca and Vale de Cambra) had levels of urban

soil sealing below 40 percent, which is recommended by some experts (Decoville and Feltgen, 2023) to prevent cities' biodiversity from declining. In the same year, the availability of unsealed artificial land per capita was 132 m<sup>2</sup>/inhabitant in AMP and 97 m<sup>2</sup>/inhabitant in AML.

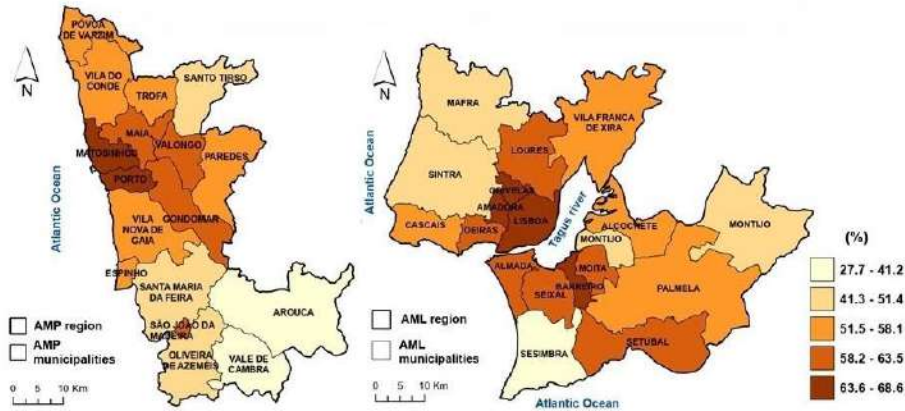


Figure 5 – Soil sealing level within the artificial land by AMP and AML municipalities, 2018 (%)

### 3.4. Artificial Land and Population Dynamics

During 2007-2018, the artificial land area expanded by 4.9 percent in the AMP and 4.6 percent in the AML (Figure 6), while the resident population of the AMP decreased by 2.4 percent, that of the AML increased by 2.5 percent. The expansion of artificial land was coupled with a population loss in most of the municipalities in the AMP and a group of five in the AML (Lisboa, Almada, Barreiro, Moita and Setúbal).

Population growth was only faster than that of artificial land in Maia (in the AMP) and eight AML municipalities (Cascais, Mafra, Vila Franca de Xira, Odivelas, Alcochete, Montijo, Palmela and Sesimbra), which experienced a decrease in artificial land per capita that is considered desirable to achieve the European target (EC, 2016).

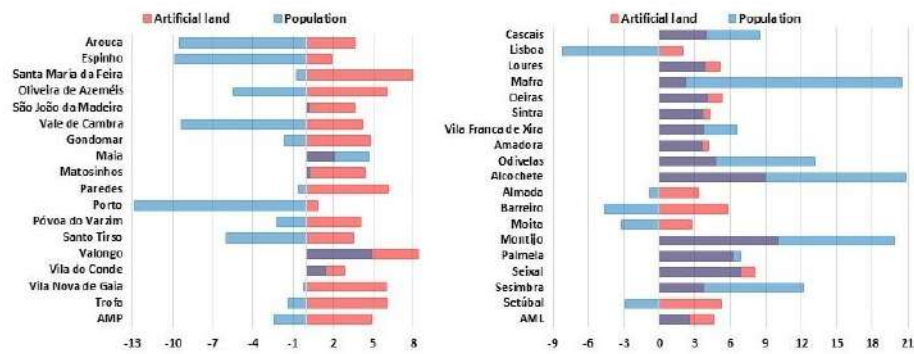


Figure 6 – Growth in resident population and artificial land by region and municipalities of AMP (left) and AML (right), 2007-2018 (%)

#### 4. Discussion and Conclusions

During 2007-2018, the expansion of the artificial surface area in Portuguese metropolitan regions was mainly intended for infrastructure (expansion of transport networks, industrial and commercial sites and areas under construction). This increase (4.9 % in the AMP and 4.6 % in the AML) was in absolute terms almost double that of the resident population (-2.4 % in the AMP and 2.5 % in the AML). Although the AMP has seen a population loss in this period, the 2021 Census indicates that its inhabitants and those of the AML continue to grow, which leads to an increase in demand for housing.

To meet the European target by 2050, the net land take rates during this period (0.7 ha/day in the AMP and 0.6 ha/day in the AML) have to drop. To this end, in addition to publicising the European target among regional and local decision-makers, stricter control mechanisms must be implemented to reduce the consumption of non-artificial land and increase the reuse of artificial land, which has been under-implemented (0.03 ha/day in AML and 0.02 ha/day in AMP).

As the share of sealed artificial land in both regions was already close to 60 percent in 2018, a level that according to some experts compromises urban biodiversity (Yan et al., 2019; Decoville and Feltgen, 2023), to obtain net land take reductions, it is recommended that future infrastructure and housing needs must be met by reusing already sealed artificial areas. However, intensifying land use in these areas can reduce urban resilience and must be compensated for by increasing the surface covered by green spaces and other nature-based solutions (EC, 2012).

In line with the recommendations of the EU Soil Strategy (EC, 2021), the authorities of both AMP and AML should also define quantitative targets (regional and local) for net land take reduction by 2030 and monitor its progress.

Meeting the 2050 target requires intra-urban densification without neglecting the unique features of each city (Nicolau and Condessa, 2024), such as its availability of brownfields, vacant lots and underused areas (Schiller et al., 2021) and ecosystem services (Tardieu et al., 2021), as well as legal, economic, environmental, and social aspects, which have not been addressed in this study. Given that a single strategy that can be applied universally to achieve this target does not exist (Decoville and Feltgen, 2023), defining a policy for its fulfilment demands a more in-depth analysis encompassing those aspects and the specificities of each city.

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