Anthropogenic drivers of land take – a panel spatial analysis for Bavarian municipalities

Extended Abstract

Land take is defined as the conversion of natural and semi-natural areas (e.g., agricultural land) into artificial land used for industry, housing and infrastructure (European Environment Agency, 2025). It normally goes in hand with soil sealing, defined as the permanent covering of the soil surface by impermeable materials such as concrete and asphalt and therefore puts enormous pressure on habitats and soil functions including water infiltration, carbon storage, nutrient cycling, and biodiversity habitat provision. Beyond ecological degradation, land take (or in particular soil sealing) exacerbates urban heat island effects, increases flood risks, and diminishes the overall resilience of landscapes to climate change impacts. Given these multifaceted consequences, limiting land take has become a policy priority of the EU, manifested for example in the Commission's soil strategy aiming at no net land take (NNLT) by 2050 (European Commission, 2021).

In line with this target, land take in Germany must be reduced to net zero by 2050, mainly by higher compactness of cities, more efficient land uses outside the cities and a stronger focus on renaturation. However, despite some remarkable success between the years 2000 and 2015, where land take could have been reduced by about 50% (Umweltbundesamt, 2022), figures are now stagnating at about 58 ha of land a day.

The drivers behind this process are complex and often intertwined, ranging from demographic pressures and economic growth to governance frameworks and policy incentives. Understanding these drivers is crucial for designing effective mitigation strategies. However, the literature still faces challenges in capturing the localized, temporal, and spatial heterogeneity of land take, particularly at administrative levels where land use decisions are often made. Germany, however, offers a compelling observational unit due to its strong tradition of local self-government, where municipalities wield substantial authority over land use planning, building permits, and local infrastructure development.

We take advantage from this fact and employ a STIRPAT model (Stochastic Impacts by Regression on Population, Affluence, and Technology) to analyze main human anthropogenic drivers of land take caused by human activities at the level of municipalities. While the STIRPAT framework has been widely applied to investigate factors driving CO_2 emissions or air pollution its use in soil sealing research remains limited. Even fewer studies incorporate spatial dependencies that arise naturally in geographically contiguous units, where spillover effects and spatial autocorrelation can influence land take dynamics.

Utilizing the STIRPAT framework and the Spatial Durbin Error Model (SDEM), this study analyzes the anthropogenic drivers of land take across 1,600 municipalities in Bavaria, Germany, from 2014 to 2022. The Moran test for spatial autocorrelation indicates a spatial dependency among residuals. So, the following equation is estimated:

$$y = X\beta + WX\gamma + u, u = \lambda Wu + \varepsilon \quad (1)$$

where y is the vector of the dependent variables (impact *I*) for *n* municipalities, X the *n* x *k* matrix of explanatory variables, β the vector of elasticities, W the weight matrix (representing the spatial interaction effects of the dependent variable with the dependent variable in neighboring municipalities), ρ the spatial autoregressive coefficient (measuring the effect of the spatial correlation between one municipality and other neighboring municipalities), γ the exogeneous spatial lag parameter, u denotes errors, ε residuals and λ is the parameter reflecting spatial correlation among errors.

By accounting for spatial dependence through inverse-distance and contiguity weighting, this study offers novel insights into how public affluence and building permission interact to drive land take across local jurisdictions. The findings indicate that increasing land take is positively related to population growth, economic development and building permissions. Moreover, they confirm that land take is very much a local topic, largely affected by municipal trends and political decision-making.

To begin with, public affluence shows positive impacts on land take and thus existing findings are confirmed. However, literature defines affluence typically as income or GDP per capita indicating the level of affluence of private households or regions. In contrast to, the results of this paper demonstrate that (also) public affluence (i.e., revenue from sales tax) is a suitable indicator for explaining land take. Most likely wealthier municipalities have higher financial capabilities, which in turn allows for more intensive land use decisions (development of residential, commercial and infrastructural area). Of course, land consumption due to private buildings also depend on private investments. Nevertheless, municipalities hold control over spatial planning and land use development must be consistent with the local zoning plan.

Interestingly, the findings show an ambiguous effect of public affluence on land take. The effect on land consumption turns negative at a specific level of public affluence. Thus, in line with the EKC hypothesis the relationship between affluence and environmental degradation follows an inverted U-shape. Once a municipality reaches a certain limit of wealth, decisions on land take are maybe taken more carefully as environmental issues may gain in importance versus (further) economic growth. While this effect is mostly discussed for the relationship between income and GHG emissions (e.g., Naveed et al. 2022 or Bibi and Jamil, 2021), related research on land take shows that the hypothesis is also valid for land take (e.g., Borruso et al. (2025) for land take in Italian municipalities).

Additionally, results indicate that the decreasing effect of public affluence on land take is especially transmitted by indirect effects. One reason could be that a higher land consumption of neighboring areas can serve as a deterrent example for one's own area.

Further, the findings show that the share of building permissions of one municipality (compared with all other municipalities) positively affects land take. Obviously, the number of building permissions increases land take. But the variable can also be interpreted as the strictness of a municipality regarding the decisions on building permissions. The higher the share, the lower the strictness and the more permissive the decisions regarding building

permissions are made. Further, the effect of buildings transmissions is also transmitted by indirect effects. Building permissions can act like a signal for development diffusion and thus increase land take in neighboring areas.

Moreover, results show the spatial dependence of land take and thus confirm the former observation that public affluence, EKC effects and building permissions influence the land take of neighboring municipalities. This is in line with empirical findings suggesting that residential and commercial development is more likely if surrounded areas undergo a similar development (Zhou and Kockelman, 2008). There can be manifold (unobserved) reasons why land take of one municipality influences land take of neighboring municipalities (reflected in the spatial dependence of the error terms). For example, the existence of intermunicipal networks and authorities (e.g., intercommunal projects or district offices) or the simple visibility effect of land use decisions made by surrounding municipalities.

Although these results should be interpreted within the specific context of the study area rather than as broad generalizations, they emphasize the necessity of multi-regional land take reduction policies. Land take is not determined solely by a municipality's internal demographic, economic, and political factors; this may be explained by close interrelation of municipalities due to urban sprawl, trade or daily commuting. Thus, the reduction of land consumption is difficult to achieve through isolated municipal actions.

Land take reduction should reflect on fostering the diffusion of environmental preferences across regions and strengthening land management. For instance, incentives could be provided when fiscal increases in core affluent areas are utilized for non-diffusive development, such as intensive (compact) development in peripheral neighborhoods. Additionally, stricter building permission standards should be implemented to suppress additional land take between adjacent areas, spreading land restraint as a chain effect across the region. Finally, increasing the costs associated with building permission across adjacent areas could serve as a practical mechanism.

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