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What densities? Using urban density metrics to reflect meaning in policy and planning action

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Abstract. Urban density has been a pivotal concept in political discourses to address the global challenge of sustainable and equitable urban development in the past decades. Consequently, policy and planning strategies have focussed on creating denser neighbourhoods. However, empirical knowledge on the effects of such policies on produced urban form and densities created remains vague, leading to limitations of evaluating them in accordance to their sustainability goals. Therefore, this contribution introduces a regional cross-border settlement model that allows to analyse effects of land policy in urban form comparatively between France and Germany. As many policies promote urban density, we take the case of a specific French land policy, the loi SRU, that aims at generating more social housing and dense urban environments. Based on the developed settlement model, containing information on building type and block age, we test and select different density metrics to assess the evolution of urban form. We compare the share of building types as well as density across national context, building types and development ages to describe the effects of the policy.

The results highlight the general applicability of the settlement model, as we could show and interpret the share of multi-family housing being elevated in the French part, while it decreases in the German part. Further, selected density metrics show that new construction in France maintains density, while in Germany density is decreasing. Further research is required to enhance the settlement model through considering location and infill development to enhance the analytical capabilities.

Submission Type. Analysis, Dataset, Metrics

BoK Concepts. [AM] Analytical Methods

Keywords. urban form, urban metrics, land policy

1 Introduction

The term urban density is commonly used in planning and political discourses and often encouraged through land policies (e.g. Conseil constitutionnel de la Republique française, 2000; §§46, 50, 200). While the term *urban density* finds its place in many discourses, it is seldom defined as a concrete concept and thus it is often unclear what is referred to precisely. This is contrasted by a large number of very precise density metrics in the geospatial analysis discourse. These in turn, offer a high potential to support politics and urban planning behind the vague density terminology. While inconsistencies in definitions exist, it also remains unclear, whether political and planning discourses on urban sustainability actually do lead to higher densities and what specific measurable densities are useful to reflect the political and planning term *urban density*.

For geospatial analysis, it remains challenging to support land policy discourse. While studies show the applicability of various approaches to describe the effect of changes or differences in land policy on settlement structures and the evolution of density within these (Claassens et al., 2020; Götze et al., 2024; Jehling and Hecht, 2022), the capabilities of density metrics to support political and planning discourses remain to be further explored. Here, in particular, the possibilities of comparative approaches in bordering national systems appears relevant, as policies differ largely while mobility and economic interlinkages are high. Comparative approaches thus allow to minimise other effects on urban form besides applied land policies, like economic growth or demography.

Therefore, this contribution presents a cross-national urban geo-data model, that is used as a test-bed to apply urban metrics to use them for comparative analysis of land policy effects. Starting with a concrete example of a French policy that encourages higher densities trough more social housing, the research questions are explored: What effect on the share of building types does the change in policy have? What changes in urban density become visible given the new land policy? They thus aim at tracing the effect the land policy had on urban development in France by comparing it to the urban development in bordering Germany.

The cross-national urban geo-data model entails block, age, and building information, and is developed for the French-German border-region. In this contribution we present this data model, the change in land policy and show results of a comparative analysis. For this co-variational analysis, we describe the change in French land policy, which took effect in 2000, against the situation in Germany, where no such substantial changes in land policy were made and thus few changes in building type and urban densities can be expected.

2 Theory

2.1 Legal Context

Ever since the Earth Summit in 1992, sustainable urbanisation has been a key policy goal in many countries. The French land policy "*loi relative à la Solidarité et au Renouvellement Urbains"* (loi SRU) of 2000 is one of such policies. It aims at producing a) a higher share of social housing and b) denser built environments, by permitting municipalities to allow a higher urban density (Conseil constitutionnel de la Republique française, 2000; §§46, 50, 200). The hypothesis that this land policy has an effect on urban form is therefore at the core of this contribution, especially as the policy binds municipalities to its objectives. In Germany, land policy also took account for more sustainable urban development, addressing mainly urban containment through proposing various instruments. However, the federal system seems not to foresee specific requirements for municipalities to address the share of social housing or higher densities (Jehling et al., 2018).

2.2 Context of Urban Morphology Metrics

A wide range of urban morphology metrics is commonly used in the geospatial analysis discourse to directly measure or derive properties of urban elements (buildings, blocks, neighbourhoods or districts). There are many publications available that give a good overview on which urban morphology metrics are used in the wider field (Biljecki and Chow, 2022; Fleischmann et al., 2021; Labetski et al., 2023; Zhang et al., 2023). We test and apply such metrics for the analysis of changes of density across time. Our selection of metrics deemed suitable for calculating urban density is presented in Table 1, as well as the references where they are used and at which spatial level these metrics assess urban density.

Table 1. Potential urban density metrics for analysing effects of land policy

Metric	Level	References
Distance to next neighbour	Building	(Chen et al., 2024; Zheng et al., 2024)
Number of direct neighbours (walls touching)	Building	(Hartmann et al., 2024; Jehling and Hecht, 2022)
Number of neighbours in radius 50 m	Building	(Hartmann et al., 2024; Kong et al., 2024)
Median distance to neighbours in radius 50 m	Building	(Bhuyan et al., 2023; Memduhoğlu et al., 2024)
Sum of building area	Block	(Hartmann et al., 2024; Li et al., 2022)
Sum of building volume	Block	(Hartmann et al., 2024; Yanhua Xie et al., 2015)
Number of buildings	Block	(Chen et al., 2024; Li et al., 2022; Yanhua Xie et al., 2015)
Mean of building area	Block	(Chen et al., 2024; Hartmann et al., 2024; Li et al., 2022)
Mean of building volume	Block	(Hartmann et al., 2024)
Mean distance to next neighbour	Block	(Chen et al., 2024; Memduhoğlu et al., 2024)

3 Methodological Framework

3.1 A regional scale cross-border settlement model

Based on homogenised geospatial data from official national data sources, a regional scale cross-border settlement model is set up. This helps to address the focus in the research question on residential development that the loi SRU addresses, as well as building ages and land take patterns. To delimitate the study area, we selected the area of two homogenous 45-minute driving-time isochrones around the two economic and cultural poles of Strasbourg in France and Karlsruhe in Germany. Together, they form a region along an approx. 100 km long mutual national border. The settlement model is based on buildings and parcel data. A number of classification approaches are applied to derive information on building and block level that allows us to compare and assess the evolution of urban form.

3.1.1 Building Development Block Separation

Building development blocks, i.e. groups of parcels that are likely to have been developed at a similar time and within proximity, are identified with the help of address, building, and street network data. First, street-parcels are excluded, leaving islands of parcels between the streets. Next, building data that overlap the parcels are used to sub-divide building islands into building blocks based on proximities of buildings using a Delaunay triangulation. Next, address data is used to separate building groups into neighbouring streets. Thus, helping to indicate for potential differences in structure and age. To address the heterogeneity of land parcel data geometries, the groups of parcels are then buffered to integrate neighbouring parcels without buildings and group them together based on their overlap.

3.1.2 Building Type Classification

Using a supervised classification approach (Hecht et al., 2015), building type information is assigned to the polygons of approximately 2 million buildings in the study area. We use a random forest classification based on urban metrics such as building height, footprint, or proximity to neighbours. To train the classification model, we use a dataset of 20.000 buildings that were classified by hand. Following Jehling and Hecht (2022), the settlement structure is described via 12 building types, which are then grouped as multi-family housing (MFH), single-family housing (SFH) as well as non-residential public buildings and industrial/commercial buildings for the analysis of urban density.

3.1.3 Building Block Age Classification

To show the evolution of urban form, the age of a building block is determined by using the Global Human Settlement Layer (GHSL) (Ehrlich et al., 2021). The dataset provides built-up surface data in 5-year time steps on a 100m x 100m grid given the percentage of urbanised land. Using historic aerial imagery, a sample of more than 100 building development blocks for each 5-year time-step since 1990 is pre-classified to select a fitting threshold value to classify building block age based on relative changes in the percentage of urbanised land. With this we estimate the development block age into eight time-epochs; pre 1990, 1990-1994, 1995-1999, 2000-2004, 2005-2009, 2010-2014, 2015-2019, 2020-2024.

3.2 Land Policy and Urban Form

3.2.1 Share of housing types

To relate the changes in settlement development to changes in land policy, i.e. the first research question, the settlement model is used to select sub-groups of buildings and blocks. Buildings of the MFH and SFH classes belonging to different epochs are further assessed. The focus is laid on MFH as this category of buildings typically accommodate social housing (Lévy-Vroelant et al., 2014). The share of buildings of this type in France is set against the share of buildings of the same type in the German part of the study area, where no policy changes to incentivise MFH were put in place.

3.2.2 Changes in Urban Density

Deriving effects on urban form through the loi SRU, traced through the addressing of research question 1, further effects of the policy on urban density are looked at through geospatial metrics. We tested the urban metrics of Table 1. For our research question on changes in urban density, the metrics “Median distance to neighbours in radius 50 m“ and “Sum of building volume” allowed for a good interpretability and are presented in the following.

3.2 Data and Software Availability

The data sources for buildings (BDTopo®) and parcels (Plan Cadastral Informatisé (PCI)) in France are available via Open Licence compatible with CC-By. The building data in Germany (ALKIS®) is openly available under the licence "dl-de/by-2-0". For parcel data (FS-DE), specific agreements have to be signed with BKG or federal states to access data freely for scientific purposes. The described steps were done using QGIS 3.34.5 and R 4.4.0 for data preparation and analysis and ArcGIS Pro 3.4.0 for calculation of urban metrics using built-in functions and tools. The software ArcGIS Pro 3.4.0 is available through licensing via the manufacturer ESRI. The data on the settlement model can be made available by the authors upon request.

4. Results

4.1 Cross-National Settlement Model

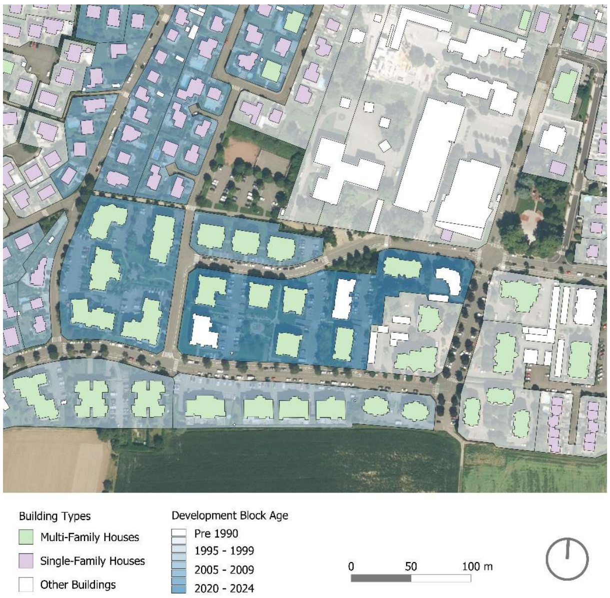

Figure 1. Identified buildings with blocks of MFH constructed under loi SRU (2000-2020) (author's own, sources: BDTopo® and OrthoExpress®).

As the basic result, we derive a cross border settlement model. Figure 1 gives an impression of the spatial scale and semantic enrichment of data on building and block level in the model. The automated classification approach for the building classification applied to the 2 million buildings brought an overall accuracy of 0.83 for the 12 types, which can be considered sufficient for the analysis of three main classes.

4.2 Impacts on Share of Housing Types

To address the first research question, Figure 2 gives the share of MFH to SFH in the two countries. The change over time for the German and French parts of the case study areas is provided. While in both countries the share of MFH is declining since the 1990ies, it stabilises and increases in France after the introduction of loi SRUin 2000. In contrast to this reuptake of MFH in France as opposed to SFH, the share of SFH is constantly increasing in Germany.

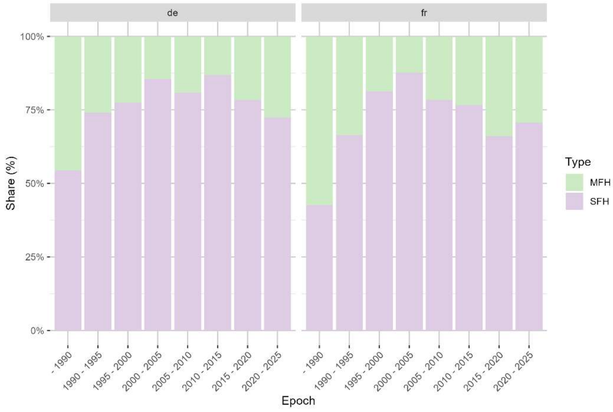

Figure 2. Share of residential building types over time: MFH and SFH (author's own).

4.3 Comparing Urban Density Across Epochs

Figure 3 shows the Nearest Neighbour Distances at the building level for residential MFH and SFH, i.e. the distance in meters to its closest neighbour across the epochs. For both housing types and in both countries the distance between buildings increases and historic, pre-1990 buildings have the closest neighbours. Between the two countries, an increase can be seen in France, meaning that buildings tend to be built more spread out. In between, the two building types, SFH appear to be generally more distant to other buildings then MFH, with a stronger increase in this trend in France that appears to be regressing as opposed to Germany.

Figure 4 shows the Building Volume per Block Area, closest to the commonly used Floor-Area-Ratio (FAR) metric. A general trend of decreasing densities can be seen across both countries and building types. While French residential building types tend to have lower volumes per block area on the buiding block, the rate appears to be shrinking less strongly. However, both countries and building types are decreasing in density as per building volume to block area ratio.

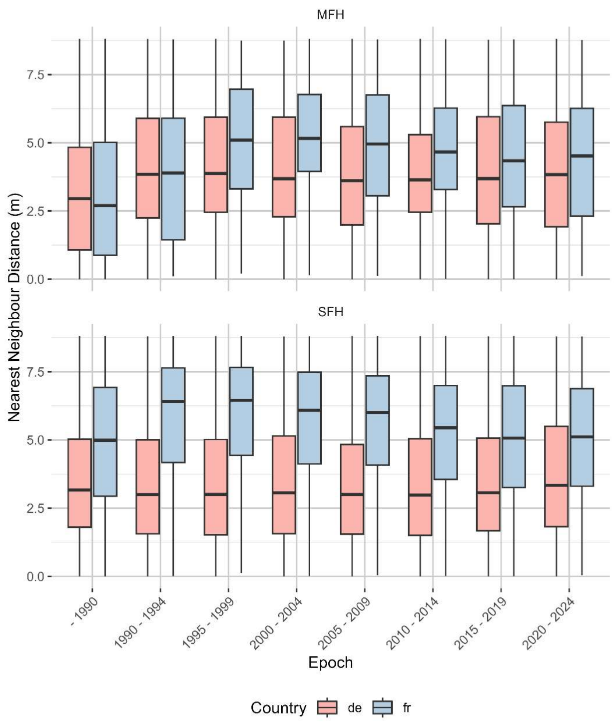

Figure 3. Nearest Neighbour Distances of residential buildings (MFH and SFH) per epoch (author's own).

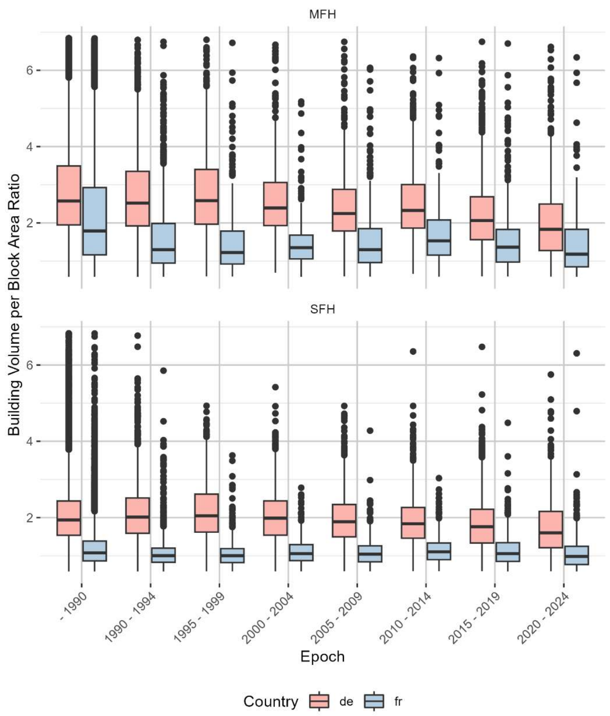

Figure 4. Building Volume per Block Area Ratio of residential buildings (MFH and SFH) per epoch (author's own).

5. Discussion

The approach shows that the settlement model allowed for a nuanced discussion of effects on land policy on urban form. Following Götze et al. (2024) and Jehling and Hecht (2022) we applied a co-variational approach to connect land policy and urban form, by reducing effects of other factors. The stronger increase of MFH in the French study area (ref. Figure 2) after the introduction of loi SRU, suggests an effectiveness of the policy in achieving its goals.

The application of urban metrics on density (Chen et al., 2024; Hartmann et al., 2024; Memduhoğlu et al., 2024; Zheng et al., 2024) demonstrates value to gain deeper insights in changes in urban form reflecting land policies. Here, metrics with a clear relation to building regulation, i.e. maximum densities through FAR or minimum distance to other buildings proofed suitable for an interpretation. However, given the tracing of positive effects in achieving the policy's goals through production of MFH, the evaluation of the policy through density metrics proofed to be countering this finding with decreasing urban density metrics in France. That means that even though more MFH were built in France, the ones that were built proofed to achieve increasingly lower densities than comparable buildings in neighbouring Germany.

For the analysis we contrasted the evolution of the French and German part of the region but also of different building types. While this allowed for a first inference on the relation between the land policy loi SRU on urban from, the results also show that further spatial context needs to be considered. Densities from the urban core to the peripheral areas of the region could provide valuable insights. Here, we expect strong differences within the region that could be made visible through describing the location of buildings and blocks through centrality measures (e.g. Gil, 2017).

Regarding the operationalisation of land policy, data availability requires us to have a broad understanding of social housing and all MFH were considered, not only the ones that were specifically built under the loi SRU or providing social housing. In the contrasting German case, where we argue for no changes towards more MFH, we indeed see a strong persistence of SFH construction as found in other approaches (e.g. Eichhorn et al., 2024). However, research also shows that MFH is often developed within existing urban structures as infill. With the resolution of the data and methodological approaches we use to derive the building epoch (Ehrlich et al., 2021), these small changes cannot be shown and require further investigation. That means while the presented model provides insights into the built urban form in precise time-steps, it is not without limitations and imprecisions, especially when it comes to identifying demolition and reconstruction, as the building data only contains current buildings.

6. Conclusion

In this research, we addressed the discrepancies in the term *urban density* as used in political and planning discourses by tracing the measurable change in urban density using a geo-data model. Given the specific case of the loi SRU, the approach showed that the land policy has an impact on what is being built (i.e. the what; MFH), but limited effect on changes within the building types (i.e. the how). Thus the approach answering the research questions by suggesting mixed results on the effects of the loi SRU. While after its introduction more MFH appear to be built, the approach also shows that according density metrics decreased in comparison to MFH in Germany. The approach has shown that metrics can support the political and planning discourse of urban density in political and planning realms, even with methodological limitations of a large-scale building model. Further applications therefore require to be more specific with regard to density metrics as well as selection of buildings built under specific land policies within a geographical context that needs to be described through further geospatial approaches.

Declaration of Generative AI in writing

The authors declare that they have not used Generative AI. All intellectual and creative work, including the analysis and interpretation of data, is original and has been conducted by the authors without AI assistance.

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