

Koetter, Michael; Winter, Birte; Wöbbeking, Carl Fabian

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The price of beauty: Biodiversity effects on residential housing markets

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The Price of Beauty: Biodiversity Effects on Residential Housing Markets

Michael Koetter, Birte Winter, Fabian Woebbeking

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Authors

Michael Koetter

Halle Institute for Economic Research (IWH) –
Member of the Leibniz Association,
Department of Financial Markets, and
Otto-von-Guericke University Magdeburg
E-mail: michael.koetter@iwh-halle.de
Tel +49 345 7753 727

Birte Winter

Halle Institute for Economic Research (IWH) –
Member of the Leibniz Association,
Department of Financial Markets
E-mail: birte.winter@iwh-halle.de
Tel +49 345 7753 888

Fabian Woebbecking

Halle Institute for Economic Research (IWH) –
Member of the Leibniz Association,
Department of Financial Markets, and
Martin-Luther-University Halle-Wittenberg
E-mail: fabian.woebbecking@iwh-halle.de
Tel +49 345 7753 851

Editor

Halle Institute for Economic Research (IWH) –
Member of the Leibniz Association

Address: Kleine Maerkerstrasse 8
D-06108 Halle (Saale), Germany
Postal Address: P.O. Box 11 03 61
D-06017 Halle (Saale), Germany

Tel +49 345 7753 60

Fax +49 345 7753 820

www.iwh-halle.de

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The Price of Beauty: Biodiversity Effects on Residential Housing Markets*

Abstract

We study how and why local biodiversity affects residential property values. Leveraging remotely sensed greenness indicators and a novel dataset of granular property listings, we examine how changes in vegetation load on real estate prices. Hikes in greenness are associated with higher listing prices, fewer properties listed, and reduced liquidity in housing markets. These results suggest that price hikes in housing markets are driven by supply-side constraints instead of a “greenium” that buyers might be willing to pay due to innate preferences. Exogenous zoning shocks to foster biodiversity corroborate the presence of supply side constraints as price drivers in residential housing markets. Our findings emphasize the need to calibrate biodiversity and (social) housing policy objectives more explicitly.

Keywords: biodiversity, house prices, remote sensing, risk

JEL classification: Q51, Q57, Q58, R31

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1 Motivation

Recent evidence indicates that financial markets price biodiversity-related risks and benefits: biodiversity considerations affect equity prices (Giglio et al., 2023; Garel et al., 2024), commodity markets (Guidolin and Pedio, 2025), and investment decisions (Flammer et al., 2023). Oftentimes, however, this nascent literature remains inconclusive as to whether agents in financial markets have an innate preference for sustainable investments – thus being willing to pay a ‘greenium’ – or whether they instead price tangible benefits. In the case of biodiversity, such valuable ecosystem services include air filtration, water storage, and stormwater retention. Systems with fewer species deliver these services less reliably and are more exposed to disruption from extreme weather, habitat loss, or invasive species. But how can we disentangle whether agents price ecosystem functions like these, develop an acquired taste for diversity preferences, or merely optimize consumption of housing, subject to first principles, including housing supply frictions?

To shed light on these motives, we study whether and how local biodiversity loads on the value of residential real estate. Housing markets are particularly suited to analyzing the effects of biodiversity because enhanced biodiversity plausibly represents an amenity for which some agents may be willing to incur a premium. Alternatively, the pursuit of public biodiversity objectives, e.g., in the form of restrictive zoning policies, may load on prices because such interventions by central planners would constrain housing supply. At the same time, real estate is a pivotal financial asset in modern financial systems. It collateralizes household borrowing (Cloyne and Kleven, 2019), potentially destabilizing financial systems in case of sudden corrections of price bubbles (Mian and Sufi, 2018) that can cause long-term distortions of wealth distributions (Peydró and Uluc, 2024). Understanding whether biodiversity affects these asset prices due to fundamental value drivers or due to innate preferences is therefore relevant beyond residential real estate.

Our headline results support the view that biodiversity affects house prices by altering

the available supply of housing. We find that, in a given zip code, years with higher biodiversity than that zip code’s average are, on average, associated with higher listing prices per square meter of residential real estate. A one standard deviation increase in the biodiversity proxy associates with a price hike of 1.5% per square meter. To isolate whether higher prices can be attributed to the amenity “greenium” or a supply side constraint in housing markets, we examine quantities and a novel proxy for the liquidity of real estate markets: the duration of how long bids are posted. We find that areas that turn greener exhibit lower quantities. This pattern is consistent with tightening housing supply rather than supporting a narrative of a premium incurred by consumers who demand housing in greener areas.

To empirically test the relationship between biodiversity and real estate prices, we mobilize and combine granular, novel, and yet comparable data on both core dimensions of this question: biodiversity and residential real estate markets. First, we use the Normalized Difference Vegetation Index (NDVI), a satellite-based measure of vegetation health and density, to approximate biodiversity. Whereas NDVI is technically an indicator of vegetation greenness, it is associated with richer ecosystems (Gould, 2000; Pettorelli et al., 2011; Rocchini et al., 2022; Skidmore et al., 2003). Hence, it is widely used in ecology and biodiversity-related applications (Huang et al., 2021). More importantly, it is a proxy for biodiversity that is consistently observable across large areas and time, which we compute at the zip-code level for Germany per year. Second, we combine this granular, salient, and time-variant biodiversity information with millions of for-sale real estate listings from ImmoScout24 (2007–2021), the country’s primary online platform.¹

We recognize the potential endogeneity between biodiversity and housing prices. For example, if local housing demand rises, public and private actors may upgrade green amenities (e.g., street trees, parks, gardens), causing NDVI and prices to move together;

¹ImmoScout24 data are curated by FDZ Ruhr, see RWI-GEO-RED at RWI Real Estate Data.

households with stronger environmental preferences and higher incomes may also sort into greener areas and sustain vegetation privately. To mitigate these concerns, we use within-zip-code changes in green infrastructure and conservation zoning as plausibly exogenous shifts in effective housing supply. While designation decisions can reflect local preferences at broader planning levels, the timing and specific placement of new protections within a zip code are largely driven by ecological and administrative criteria rather than contemporaneous zip-code-level housing demand. We further account for systematic urban-rural differences (e.g., tighter supply elasticities, distinct greening policies) by sample splits. Because zoning data are available only for Baden-Württemberg, the analysis that includes zoning is restricted to that state. The city-rural comparisons are estimated on the full national zip-year panel.

Our analysis contributes to several strands of the literature. First, we contribute to the growing literature on biodiversity finance (Arlt et al., 2024; Chen et al., 2024; Coqueret et al., 2024; Cornaggia et al., 2025; Garel et al., 2024; Giglio et al., 2023, 2024; Guidolin and Pedio, 2025; Flammer et al., 2023; Liu et al., 2025; Sacher and Singla, 2025). We contribute by analyzing a so-far under-investigated asset class: residential real estate.

Second, we contribute to the research on hedonic studies that assess the impact of tree canopy cover on property prices, where the evidence is mixed. Some observe that trees in the vicinity raise property values, e.g., Czembrowski and Kronenberg (2016); Mansfield et al. (2005); Netusil et al. (2010); Ratzke (2023); Siriwardena et al. (2016).² Others find negative effects of canopy cover on housing prices (Belcher and Chisholm, 2018; Cho et al., 2008; Tyrväinen and Miettinen, 2000). Whereas these studies focus on specific cities, we add by taking a broader view, using observations from Germany.

Third, we contribute to the literature on housing markets and biodiversity (Liu et al., 2025; Sacher and Singla, 2025; Cornaggia et al., 2025). We add to Liu et al. (2025) and

²For an overview of the hedonic pricing literature and tree canopy, please refer to Li et al. (2015).

Sacher and Singla (2025) by providing evidence on biodiversity levels and real estate markets, as opposed to biodiversity risk.

Closest related to our paper is Cornaggia et al. (2025). Using U.S. property transactions linked to biodiversity measures, they find two effects. First, local biodiversity loss is associated with higher prices, consistent with the market valuing nearby build-out and land conversion. Second, regional species richness is valued as an amenity, and this premium intensifies over time and with greater public attention. We add in three ways. First, we move beyond prices to quantities and liquidity, which helps distinguish amenity-driven demand shifts from supply tightening. Second, we exploit within-zip code, over-time variation in annual satellite greenness (NDVI), rather than mainly cross-sectional variation that might mechanically correlate low biodiversity with high prices in dense areas. Third, we use variation in green-infrastructure and conservation zoning as plausibly exogenous supply shocks, yielding suggestive evidence that supply constraints account for the observed movements in prices and quantities.

2 Priors and institutional background

In this section, we begin by fixing the expectations regarding possible associations between biodiversity and real estate prices, followed by a discussion of the institutional set-up to further isolate possible mechanisms.

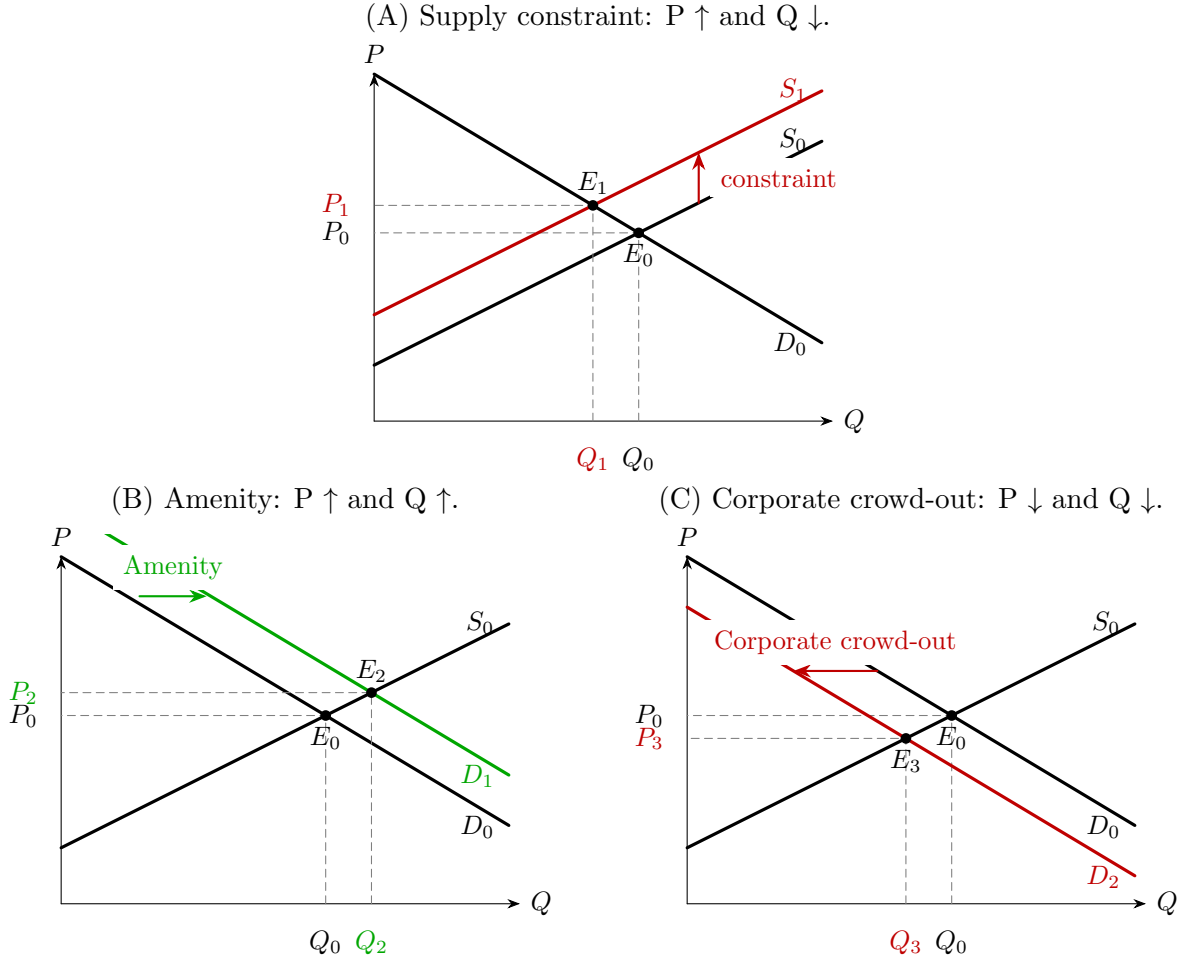
2.1 Theoretical priors

Theory yields ambiguous effects of biodiversity on housing markets because demand- and supply-side channels operate simultaneously.³ Consider therefore Figure 1, which depicts naive comparative statics of housing demand and supply to articulate the possible forces

³We remain agnostic as to the expected effect of biodiversity on liquidity, which is a priori ambiguous.

at play and the resulting empirical associations to expect against the backdrop of existing literature.

Figure 1: Visualization of rationals for an association between biodiversity and housing prices



Shown are comparative statics for prices (P) and quantities (Q). Prices on the vertical axis (P) and quantities on the horizontal axis (Q). (A) A supply constraint shifts supply from S_0 to S_1 , raising P and lowering Q . (B) An amenity-driven demand increase shifts demand from D_0 to D_1 , raising both P and Q . (C) Corporate crowd-out (or anticipated regulation) shifts demand inward to D_2 , lowering P and Q . Dashed lines mark equilibria; colored curves highlight the shifted schedule. Parameter values are illustrative.

Consider first the supply side in Figure 1. Conservation designations and related rules can reduce developable land or raise building costs. Such policies would shift supply inward, resulting in higher prices and lower quantities. This “construction crunch” scenario is shown in Figure 1A by the shift from S_0 to S_1 . The effects would be amplified when

short-run supply is inelastic (Saiz, 2010; Quigley and Raphael, 2005; Pollakowski and Wachter, 1990; Nolte, 2020).

On the demand side, biodiversity may raise the willingness to pay via: (i) amenity and recreational benefits, which are well documented in hedonic studies of open space and urban greening (e.g., Tyrväinen and Miettinen, 2000; Irwin, 2002; Geoghegan, 2002; Atreya et al., 2016; Li et al., 2015); (ii) risk mitigation via cooling, runoff retention, or flood buffering (e.g., Schwaab et al., 2021; Liu et al., 2025); and (iii) productivity and well-being channels that increase wages and housing demand (Bratman et al., 2019; Pulido-Chadid et al., 2023). In terms of housing market outcomes, these amenity and productivity rationales imply an outward shift of housing demand and thus higher prices and higher quantities. This is illustrated in Figure 1B by the shift from D_0 to D_1 and the new equilibrium at E_2 .

Alternatively, housing demand may contract if conservation-related constraints crowd out corporate activity and reduce local investment and employment. Dampened economic activity would also depress housing demand (Bartram et al., 2022). In addition, higher costs faced by firms can compress wages (Walker, 2011; Ray and Hertel, 2025), which, in a Rosen-Roback framework, lowers the willingness to pay for housing (Roback, 1982). Finally, buyers may discount properties if they expect future regulatory costs in high-biodiversity areas (Sacher and Singla, 2025). In this case, we would expect to observe lower prices, lower quantities, and a longer time on the market, corresponding to an inward shift of demand from D_0 to D_2 and a new equilibrium at E_3 in Figure 1C.

We assess these predictions by estimating the correlations between greenness and prices, quantities, and liquidity. Considering both prices and quantities helps to distinguish demand from supply forces: an increase in prices alone is observationally equivalent to either an outward demand shift or an inward supply shift. The change in quantities is, in turn, distinct. Quantities rise only under amenity-driven demand shifts, whereas they

fall under supply constraints. We further estimate effects separately for city and non-city areas to capture differences in urban supply frictions. Moreover, we exploit within-zip-code zoning events for Baden-Württemberg as plausibly exogenous supply shifters.

2.2 Institutional Setting

In Germany, spatial planning is a multilevel system that includes federal, state, and regional authorities. The federal level sets spatial planning principles by providing a legal framework, namely the Federal Spatial Planning Act (Raumordnungsgesetz, or ROG). For instance, § 2(2) ROG calls for concentrating settlement in existing places and protecting open space through a large-scale, ecologically effective open space network. At the state level, each of Germany’s sixteen states adopts a binding spatial planning framework that must align with the federal ROG. State spatial plans guide major land-use policies, such as settlement patterns, infrastructure, and conservation. They also prioritize certain land uses, designating areas for purposes such as nature preservation or wind energy development. Regional plans further refine state-level principles into detailed land-use allocations. These allocations include, for instance, industrial, residential, agricultural, and conservation zones (Danielzyk and Münter, 2018).

We use regional planning data from Baden-Württemberg on green infrastructure and conservation zoning. Specifically, we use data on green corridors, green breaks, and nature conservation and landscape management, which function as development-restricting designations intended to maintain open space, ecological connectivity, and landscape character. The aim of these designations is the following: green breaks are intended to maintain undeveloped buffers between settlements while also preserving local climate and ecological exchange in these areas. Green corridors secure large, continuous open-space systems across municipalities to maintain soil, water, climate, species and habitat functions, as well as agriculture, forestry, and nature-based recreation. Nature conser-

vation and landscape management protect and develop areas of high importance for biodiversity, habitat networks, and landscape functions. These areas are designated in the respective regional planning regions, of which there are 96 in Germany and 12 in Baden-Württemberg. Regional plans are updated roughly every 10–15 years and are developed in close coordination with municipalities (Danielzyk and Münter, 2018).

An example of state-level and regional plans is provided in Figure 2 and Figure 3 in the Appendix. While the state-level plan (see Figure 2 in the Appendix) focuses on designating broad categories such as transportation corridors, conservation areas, and areas of supra-regional importance, the regional plan (see Figure 3 in the Appendix) delves into finer detail, specifying the exact land uses and zoning assignments for areas within the region.

Developing a regional plan is an iterative process that usually takes several years. After the regional assembly issues a formal mandate to the planning administration, the administration drafts an initial plan and carries out a Strategic Environmental Assessment (SEA). The draft and SEA report are then published for a consultation period of six to eight weeks, during which public hearings are held and written submissions are invited. All feedback is recorded in a balancing resolution (Abwägungsbeschluss) and may lead to a revised draft and further consultation. Once finalized, the plan is adopted by the regional assembly and, after a short legal objection period, enters into force and binds all lower-level planning.

Once an area is designated in the regional plan, the decision is binding for municipal land-use planning, with restrictiveness determined by the specific designation. In our Baden-Württemberg setting, we observe three regional environmental designations, namely, green corridor, green break, and nature conservation and landscape management. These are typically set as binding objectives of spatial planning and therefore constrain local development; limited, text-specific exceptions may apply and require a

formal deviation procedure.

Spatial-planning zones for green infrastructure and conservation designations typically build upon protected areas (e.g., nature reserves, landscape protection areas, or Natura 2000 sites); however, they also extend to formerly unprotected farmland, forest stands, or regional green corridors that had no formal conservation status beforehand. Prior to designation, these lands were often intensively farmed, used for timber production, or left fallow without any specific protection under the Federal Nature Conservation Act (Umweltbundesamt, 2023).

In Baden-Württemberg, the regional designations we use are adopted as binding objectives of spatial planning, typically mapped as priority areas, and therefore constrain municipal land-use planning.⁴ Regional green corridors and green breaks are to be kept free of building, with only narrowly defined, site-bound exceptions specified in the plan text.⁵ Where an exception is sought, it requires a formal deviation from the planning objective under § 6 ROG.⁶ Any project permitted remains subject to the usual environmental procedures, namely, UVPG (e.g., §§ 6, 18) and the BNatSchG avoid-mitigate-compensate rules (§§ 13–15).⁷

⁴See the state’s overview of regional planning instruments and binding effect (Ministerium für Landesentwicklung und Wohnen Baden-Württemberg, 2025); for an example where these categories are set as priority areas in the plan legend/text, see (Regionalverband Südlicher Oberrhein, 2018; Regionalverband Südlicher Oberrhein, 2017).

⁵E.g., the Verband Region Stuttgart specifies a general ban on construction for green breaks (Verband Region Stuttgart, 2025); the Regional Plan for the Southern Upper Rhine states that regional green corridors are to be kept free of settlement (PS 3.1.1) (Regionalverband Südlicher Oberrhein, 2017).

⁶(Bundesministerium der Justiz, d).

⁷(Bundesministerium der Justiz, c,b,a).

3 Data and Summary Statistics

3.1 Measuring Biodiversity

We approximate biodiversity using satellite-based remote sensing because it provides consistent, spatially continuous coverage over large areas and long periods. Biodiversity is understood here as “the total sum of all biotic variation, from the level of genes to ecosystems” (Purvis and Hector, 2000).⁸

Collecting data on biodiversity *in situ* (on-site) at comparable scales is time-consuming, limiting precise measurement across broad extents and long time spans. Remote sensors (e.g., satellites) can continuously and comprehensively approximate ecological conditions, though with trade-offs: lower spatial and temporal resolution, difficulty distinguishing species-level diversity, and potential errors from atmospheric interference or sensor calibration. Consequently, remote-sensing indicators are typically validated against *in situ* observations (Reddy, 2021; Cavender-Bares et al., 2022). Studies generally report positive correlations between *in situ* observations and remote-sensing biodiversity measures (Rocchini et al., 2022; Pettorelli et al., 2011; Gould, 2000; Skidmore et al., 2003).⁹

We employ the *Normalized Difference Vegetation Index* (NDVI) as it is widely used as an indicator for assessing vegetation greenness and photosynthetic activity (Huang et al., 2021). In particular, we use NDVI data from 2007 onward.¹⁰ NDVI is calculated using spectral bands with different wavelengths, namely the near-infrared (NIR) and red bands, capturing the high red light absorption and strong NIR reflectance characteristic of healthy green vegetation (Tucker, 1979; Rouse et al., 1974):

⁸Common biodiversity metrics include Simpson’s Index, which calculates the probability that two randomly selected individuals belong to different species (Simpson, 1949); Shannon-Wiener Index, which measures the uncertainty in predicting a randomly chosen individual’s species (Shannon, 1948); and the Evenness Index, assessing the distribution uniformity of individuals across species (Pielou, 1966).

⁹For a comprehensive overview of remote-sensing measures for biodiversity, please refer to Reddy (2021), O’Connor et al. (2015), and Cavender-Bares et al. (2022).

¹⁰Satellites that regularly cover large areas typically provide a spatial resolution from roughly 10 to 300 meters; higher-resolution aerial imagery exists for specific places and times.

$$\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}} . \quad (1)$$

NDVI ranges between -1 and 1 . Areas with high NDVI values indicate dense, healthy vegetation, whereas low values correspond to sparse vegetation, bare soil, or water surfaces. In particular, values above 0.6 are typical for dense, healthy vegetation (often forests); 0.1 – 0.5 for shrubs/grasslands; values near 0 for bare soil or built surfaces; and open water tends toward -1 (Jones and Vaughan, 2010).

While NDVI directly measures the health and density of vegetation, it can also serve as a useful proxy for biodiversity. This is because NDVI is positively correlated with *ecosystem productivity* and *ecosystem stability*, both of which are key factors in supporting biodiversity. The idea that productive ecosystems yield higher biodiversity was originally proposed by Darwin and Wallace (1858). Contemporary research supports a robust, positive correlation between ecosystem productivity and biodiversity, or, more specifically, species richness (Wang et al., 2016; Dronova et al., 2022; Ren et al., 2023; Chapin et al., 2000; Gaston, 2000; Tilman, 2000; Purvis and Hector, 2000; McCann, 2000). Theoretical explanations for this positive correlation include: (a) the selection effect, which posits that greater species diversity increases the chance of including species that contribute significantly to overall vegetation growth and accumulated organic matter, thereby enhancing productivity; and (b) complementarity, which suggests that species differences lead to more efficient resource utilization, thereby enhancing productivity (Aarssen, 1997; Huston, 1997; Loreau, 2000; Loreau et al., 2001; Tilman et al., 1997). As ecosystems with higher productivity can support a greater variety of species, NDVI, by measuring productivity, can be an effective indicator of biodiversity.

3.2 Sample Selection and Variable Construction

To measure local biodiversity, we collect monthly observations of the Normalized Difference Vegetation Index (NDVI) for each of the 8,170 German zip codes between 2007 and 2021.¹¹ The NDVI data are sourced from the Moderate Resolution Imaging Spectroradiometer (MODIS) product MOD13A1 version 6, which provides a spatial resolution of 500 meters.

We first combine all available images within a month into a Best Available Pixel (BAP) composite to extract NDVI data from the satellite imagery. Low-quality pixels, such as those masked by clouds or snow, are excluded. We then average across all BAP pixels within each zip code region. This yields monthly observations at the zip code level, which we further aggregate by calculating annual averages.

Real estate market data are sourced from ImmoScout24, the leading online real estate marketplace in Germany. This dataset is maintained by FDZ Ruhr and comprises millions of observations, including various property traits.¹² The dataset includes listing prices for properties on sale, along with detailed characteristics of these houses and apartments. Between 2007 and 2021, the dataset covers more than 25 million for-sale listings. We use the logarithm of the mean housing price per zip code for our analysis, together with the median number of bedrooms, floors, and rooms, as well as the median property age in the respective zip code. We rely on listing prices because equivalent comprehensive data on transaction prices for German real estate are not available. The dataset also includes geographic coordinates (latitude and longitude), zip codes, and state codes to locate the properties.

In addition, we construct a quantity and a liquidity measure at the zip-year level

¹¹We obtained the data on German zip codes, as provided by Deutsche Post Direkt GmbH, accessed on 22 May 2023. Excluded zip codes include those for large customers (Großkunden) and the following areas: 87491 Jungholz (Tirol), 87567 Riezlern (Kleinwalsertal), 87568 Hirschegg (Kleinwalsertal), and 87569 Mittelberg (Kleinwalsertal). © Deutsche Post Direkt GmbH.

¹²See RWI-GEO-RED/REDX: Real Estate Data and Indices.

from the listing data: quantities (average market stock) and stickiness (average time on market). To construct these, we first build listing “spells” for each advertised property. A new spell starts when the gap to the previous observation of the same listing exceeds three months, or when observable attributes change discontinuously, i.e., a change in zip code, listing type, a >20% jump in floor area, or a change of more than one room.

Using these spells, we compute the supplied quantities of residential real estate as follows. Let $Stock_{i,m}$ be the number of active spells in zip code i in month m . Our quantity measure at the zip-year level is the 12-month average stock,

$$Quantities_{i,t} = \frac{1}{12} \sum_{m=1}^{12} Stock_{i,m} , \quad (2)$$

which equals the total listing-months in i during year t divided by 12. To measure Stickiness, we track monthly spell entries and exits and compute, for the set of active listings each month, the average elapsed duration (in months) since the spell started. Stickiness for zip code i in year t is the 12-month average of this monthly mean duration. Stickiness serves as a proxy for local real estate market liquidity. If listings stay longer on the platform, stickiness increases, indicating lower market liquidity and slower local housing turnover.

Detailed annual zoning data at the zip code level is not available for all 96 regional planning regions in Germany, largely reflecting the federal structure of the Republic. However, we obtained detailed information for one of the largest German states: Baden-Württemberg. The data are obtained from the Geoportal Raumordnung Baden-Württemberg.¹³ We observe zoning information on green corridors, green breaks, and nature conservation. We then analyze year-to-year changes to identify zip codes that experience an increase in any of these designations. Based on these changes, we split the sample into “zoned” and “unzoned” zip codes. Areas that experience any increase

¹³Data as of January 2024 from Geoportal Raumordnung Baden-Württemberg ©.

during our observation window are classified as zoned zip codes, while the remainder are considered unzoned. Additionally, we construct a zoning-intensity measure that equals the increase in zoned area relative to the total zip-code area in the year of the increase, and zero otherwise.

We obtain socioeconomic and regional control variables from the Federal Statistical Office and various regional statistical offices at the administrative district level (Kreise und Kreisfreie Städte).¹⁴

Administrative districts typically comprise multiple zip codes. We use district-level controls to absorb broad regional economic and policy shocks that affect all zip codes within a district (e.g., changes in GDP or labor-market conditions), while our key explanatory variables, NDVI and zoning, vary at the zip code level. This design allows us to estimate the effect of local greenness (NDVI) on prices within a zip code while holding constant common regional dynamics across zip codes in the same district. For example, an industrial expansion may raise district GDP without directly increasing residential housing demand in the industrial area zip code itself; however, nearby residential zip codes in the same district can experience higher housing demand as the regional economy grows.

We only sample real estate listings with non-missing information on prices per square meter, biodiversity, housing characteristics, and regional controls. To address outliers, we winsorize housing prices at the 1st and 99th percentiles separately for apartments and houses for sale and exclude properties listed under multiple zip codes.

Based on these restrictions, we construct two empirical samples. First, we use the

¹⁴Regional controls are GDP growth, unemployment rate, business registrations, insolvencies, population size, the second vote share for the Green Party in the federal election, the share of total area used for settlement and traffic, and the share of agricultural area. In 2016, the basis of data collection changed for the share of settlement and traffic area as well as the share of agricultural area. We normalize these controls by dividing the zip code share by the total share of the respectively assigned area. We linearly interpolated missing values for the unemployment rate (20 missing values between 2007 and 2021) and for insolvencies (36 missing values between 2007 and 2021). For business registrations and the settlement and traffic area, observations started in 2008, so we use the 2008 values for 2007 as well.

full zip-code-year panel (2007–2021) covering all of Germany. This sample allows us to document correlations between biodiversity and housing prices. Second, we construct a zip-code-year panel for those zip codes that are located in Baden-Württemberg (2007–2021), for which we obtain detailed zoning information. This sample permits a better isolation of supply side frictions as a potential mechanism by which biodiversity loads on real estate asset prices.

3.3 Summary Statistics

Table 1 presents the summary statistics for our two empirical samples. Panel A, which is the national panel, covers 117,606 zip-year observations for housing sales between 2007 and 2021. For each zip code, we compute the average listing price per square meter across all property types (houses and apartments). Across zip-years, the average price per square meter is €1,896, with a median of €1,594. The average stock of active listings per zip code is about 15.7 listings per zip code, and the average time on the market (stickiness) is about 1.26 months. Listings have, on average, 2.95 bedrooms and 4.73 rooms. The average NDVI value is 0.62, indicating dense and healthy vegetation. Figure 4 in the Appendix visualizes the variation in NDVI values at the 25th and 75th percentiles for the sample. The imagery reveals a clear distinction in the amount of green space.

The Baden-Württemberg sample (see Table 1 Panel B) comprises 17,716 zip-years and features higher average prices (€2,186) and slightly higher average NDVI than the full sample (0.64 vs. 0.62). Comparing the Baden-Württemberg sample to the rest of Germany (Table 2), we find considerable normalized differences in prices and biodiversity. We also analyze differences across the other sample splits considered in this study. In particular, cities and non-cities exhibit substantial heterogeneity in prices, biodiversity, and quantities, whereas liquidity does not differ materially between the two groups. These patterns motivate estimating effects separately for cities and non-cities,

as the underlying housing markets appear to be different. A more detailed description of Baden-Württemberg data reveals, first, that nearly 50% of all zip codes were zoned at some point and, second, that zoned and unzoned zip codes differ considerably. In particular, they are characterized by higher housing prices, lower biodiversity, and higher quantities.

[Table 1 about here]

We observe that between 2007 and 2021, the average NDVI is increasing. This finding aligns with Eisfelder et al. (2023), who report positive NDVI trends in Europe for the period 1981 to 2018. Specifically, they find that NDVI is increasing on average by 0.15, with a more pronounced increase in central and southeastern Europe. Additionally, NDVI notably rises during spring and autumn, while it generally decreases in summer across most of Europe, except in parts of England and Spain (Eisfelder et al., 2023). We observe similar patterns in our sample, as shown in Figure 1 in the Appendix, which illustrates the trends in the average NDVI for March (left) and August (right) across NUTS3 regions during our sample period from 2007 to 2021.

[Figure 1 about here]

The spatial distribution of the zip-level NDVI trend is shown in Figure 2A. For each zip, we estimate the trend with the Theil-Sen slope (median of all year-pair slopes) following Eisfelder et al. (2023) and report it in NDVI units per decade. Darker green areas indicate regions that experienced higher positive changes in NDVI over the study period, while lighter green or yellow areas suggest lower growth or stagnation in vegetation greenness, and red areas indicate a decline in NDVI. NDVI trends vary markedly across Germany, with gains concentrated in the south and largely stable or declining patterns across central regions. The largest NDVI declines are concentrated in three types of areas: (i) lignite-mining districts (Welzow, Inden, Cottbus), (ii) urban areas (Hannover,

Wiesbaden), and (iii) forest-dieback hotspots in the Harz region (Schierke, Harsleben). We observe the largest increases in NDVI in rural areas such as Spiekeroog and Zwenkau, but also in cities, such as Frankfurt am Main, Mannheim, and Nürnberg.

Housing price and housing quantity trends also show spatial heterogeneity. Housing prices have broadly increased across Germany (Figure 2B), with the strongest increases occurring in large metropolitan cores such as Berlin, Hamburg, and the Munich area. In contrast, housing quantities declined the most, especially around major cities (Figure 2C).

[Figure 2 about here]

Figure 3 shows the same zip-level trend estimates as in Figure 2, but restricted to Baden-Württemberg. Zips that received green-infrastructure or conservation zoning during 2007-2021 are outlined in black. We observe that zoning changes are spatially clustered. Specifically, planning regions that updated their regional land-use plans tend to show increases in most zip codes. Nearly half of all zip codes experienced a zoning increase over the period. Importantly, both zoned and non-zoned zip codes exhibit variation in NDVI, prices, and quantities.

[Figure 3 about here]

4 Property Prices and Biodiversity

4.1 Empirical Methodology

The unit of analysis to study whether within-zip-code changes in biodiversity affect housing prices and quantities is the zip-year level. We start from listing-level data and compute the average asking prices and total listing counts for each of the 8,170 German zip codes. We aggregate for two reasons. First, our measure of biodiversity (NDVI) varies only at the zip-code-level, so aggregating aligns the level of our outcome with the level of our

key explanatory variable and prevents zip codes with many listings from being overrepresented when estimating the NDVI effect. Second, the resulting zip-code panel structure allows for a fixed-effects specification with zip-code and time fixed effects.

To assess the impact of biodiversity on property prices, we first analyze the association between biodiversity, namely the average NDVI, and property prices and quantities using the following empirical specification:

$$\mathbf{Y}_{i,t} = \beta_0 + \beta_1 \text{Biodiversity}_{i,t} + \beta_2 \mathbf{Z}_{i,t} + \beta_3 \mathbf{X}_{i,t} + \alpha_t + \gamma_i + \epsilon_{i,t} , \quad (3)$$

where $\mathbf{Y}_{i,t}$ alternatively denotes (i) the natural logarithm of the average asking price per square meter in zip code i during year t , (ii) the average number of active listings in zip code i in year t , and (iii) the average liquidity, i.e., the average duration a listing remains on the market in zip code i in year t . Our proxy for $\text{Biodiversity}_{i,t}$ is the average annual NDVI in zip code i in year t . The vector $\mathbf{Z}_{i,t}$ contains median property-specific controls in zip code i in year t . Regional controls at the administrative district level are captured by $\mathbf{X}_{i,t}$ (see footnote 14) to account for local economic conditions and political preferences that may jointly affect biodiversity and housing market outcomes. For instance, higher GDP growth may be associated with increased construction activity and land conversion, which can reduce biodiversity while simultaneously increasing property values. In addition, median housing characteristics (e.g., dwelling size and number of rooms) help absorb compositional changes in the housing stock that may be correlated with both prices per square meter and local greenness. For example, a higher median number of rooms per dwelling typically reflects larger units, which might be correlated with lower prices per square meter and with greener, less dense neighborhoods.

In all regressions, we include year fixed effects, α_t , and zip code fixed effects, γ_i . Year fixed effects (α_t) capture common shocks across all zip codes in a given year, such as

changes in national interest rates or macroeconomic conditions that might drive variation in housing prices or quantities. Zip code fixed effects, γ_i , absorb any unobserved time-invariant local characteristics that systematically affect prices or quantities. These include the time-invariant component of biodiversity, as well as other baseline amenity endowments, neighborhood composition, distance to employment centers, topography, and persistent local policies. By including these fixed effects, β_1 is identified from deviations in biodiversity within a zip code from its own average level over the sample period, net of year shocks that are common to all zip codes in the country.

In some specifications, we replace α_t with state \times year fixed effects that allow for state-specific time variation, which might include state business cycles, state policies, statewide weather, or conservation programs. With state \times year fixed effects, β_1 is identified from changes in NDVI within zip codes over time that deviate from other zip codes in the same state and year, net of shocks common to all zip codes in that state-year. We cluster standard errors at the zip code level to allow the error terms to be correlated across years within the same zip code.

We estimate (3) for three outcomes: the natural logarithm of the average price per square meter, quantities, and stickiness. This allows us to obtain suggestive evidence on the amenity vs. supply side constraint rationales. If more greenness over time reflects demand-side amenity valuation, we expect higher prices along with higher quantities. If greenness increases instead capture supply constraints, such as land preserved from development that restricts new construction, we expect higher prices and lower quantities. The resulting comparative statics are illustrated in Figure 1.

4.2 Headline Results

The headline results are reported in Table 3. Columns (1) and (2) exhibit point estimates pertaining to the specification of house prices as the dependent variable in Equation 3,

including zip code and year fixed effects. We estimate that zip codes that become greener over time experience, on average, higher housing prices per square meter. These findings are robust to including zip code and state×year fixed effects in column (2). A standard deviation increase in NDVI (0.09) within a zip code is associated with an approximately 1.5% increase in the price per square meter (columns (1)–(2)). To illustrate the economic magnitude of this effect, consider a zip code where the NDVI rises from the 25th to the 75th percentile of the sample distribution, corresponding to a hike from 0.58 to 0.68¹⁵. The point estimates imply that such a change is associated with 1.7–1.8% higher listing prices per square meter. At the sample mean of about €1,900/m², this estimate corresponds to an increase of around €30/m², or roughly €3,000 for a typical 100 m² dwelling.

[Table 3 about here]

In the next two columns, we employ housing quantities as the dependent variable. In general, we observe a negative association between a zip code becoming greener over time and housing quantities (columns (3) and (4)). Again, these findings remain robust if we control for shocks common to all zip codes in a given state-year. Specifically, a standard deviation increase in NDVI is associated with about 0.8 to 2.0 fewer active listings, i.e., a 5–13% decline relative to the mean (15.7) (columns (3)–(4)). Effects on market liquidity, approximated by the average time a listing remains on the market (Stickiness), are reported in columns (5) and (6). Empirically, the estimated effects are small and not robust across specifications. The coefficient in column (5) is positive but only marginally significant and becomes indistinguishable from zero when state×year fixed effects are specified in column (6). Overall, we do not find systematic evidence that changes in greenness affect how quickly properties sell; the main margins of adjustment appear to be prices and quantities rather than liquidity.

¹⁵See Figure 4 in the Appendix for an illustration.

Taken together, the combination of higher prices and lower quantities is most consistent with the *construction crunch* narrative in greener zip codes, as depicted in Figure 1A, rather than innate preferences for biodiversity that command a “greenium”.

4.3 Supply Side Frictions: Sample Splits

The headline results suggest that, on average, greening zip codes are associated with increases in prices and a reduction in quantities, a pattern that is most consistent with tightening supply depicted in Figure 1A. However, this specification still averages over very different housing markets and institutional environments. In particular, (i) supply elasticities differ sharply between dense cities and the rest of the country, and (ii) the biodiversity proxy employed here, NDVI, is itself shaped by land-use regulation and green-infrastructure planning. If the association between greenness and housing outcomes is truly driven by supply-side frictions, we expect it to be stronger precisely where buildable land is scarce or newly constrained.

To test this proposition, we proceed in two steps. First, we split the national panel into city and non-city zip codes and re-estimate the headline specification separately (subsubsection 4.3.1). This specification allows us to assess whether the greenness-price-quantity relationship differs between more densely populated, high-priced urban markets in comparison to arguably more elastic non-urban markets. Second, we exploit variation in explicit green-infrastructure and conservation zoning in Baden-Württemberg (subsubsection 4.3.2). Comparing zip codes that received such zoning in the sample period between 2007 and 2021 to those that never did, aids to isolating whether the headline pattern is concentrated where formal planning decisions directly restrict development, as implied by a supply-constraint interpretation.

4.3.1 City vs. Non-City Areas

We expect housing markets in large cities to differ fundamentally from those in non-city areas.¹⁶ In cities, demand is spatially concentrated, buildable land is scarce, and planning constraints and neighborhood externalities are more salient. As a result, short-run housing supply is typically much less elastic: adding new units often requires re-densification, redevelopment, or costly height extensions rather than simple greenfield construction.

A second motivation is measurement. The employed greenness proxy (NDVI) behaves systematically differently in dense urban cores: levels are mechanically lower and dynamics are different because built-up surfaces dominate the pixel, while relatively small pockets of green space (street trees, pocket parks, courtyards) can generate noticeable changes over time. The same change in NDVI may therefore reflect very different underlying processes in cities (e.g., rooftop greening, park upgrades, or the conversion of brownfields into parks) than in rural or suburban areas (e.g., afforestation or conservation of larger open spaces). In particular, increases in NDVI within cities may often be associated with greening of underused or shrinking areas, rather than with tighter constraints on residential construction.

For these reasons, we re-estimate Equation (3) separately for zip codes in Germany’s ten largest cities¹⁷ and for all remaining zip codes. This split allows us to explore heterogeneity in the biodiversity-housing market relationship between large cities and the rest of the country. In particular, to assess how the *construction-crunch* pattern documented in the headline findings differs between city and non-city areas.

The results in Table 4 confirm the headline pattern for non-city areas. Within-zip increases in NDVI are associated with higher prices per square meter and lower quantities.

¹⁶See, for example, Koetter et al. (2025) on evidence that staggered changes in real estate transaction taxes affected real estate prices in urban and rural areas significantly differently in Germany.

¹⁷Berlin, Hamburg, Munich, Cologne, Frankfurt(M), Stuttgart, Düsseldorf, Leipzig, Dortmund, Essen.

These results for housing prices are robust to controlling for state×year fixed effects. The magnitude of the coefficient resembles the headline results as well and remains similar across specifications (columns (1) and (2)). A one standard deviation increase in NDVI (0.07) is associated with about a 1.4–1.5% increase in listing prices per square meter. On the quantity side, we find a robust negative association between NDVI and the number of listings. This result is consistent with the earlier construction-crunch interpretation in which local greening is accompanied by tighter effective housing supply.

[Table 4 about here]

In the ten largest cities, by contrast, higher biodiversity is associated with declines in both quantities and prices. This finding could indicate that NDVI in large cities captures greening-by-shrinkage/overgrowth or greening on non-market parcels. Outside of big cities, more green space might coincide with binding land constraints, yielding the construction-crunch pattern. Instead, in big cities, NDVI increases might align with vacancy, demolition fallows, or public-realm greening. Think, for example, of a relatively disadvantaged zip code at the edge of a large city. These peripheral neighborhoods may attract less in-migration than central, well-connected areas; therefore, housing demand is weak, and prices and listing activity gradually decline. At the same time, the maintenance of public spaces is scaled back, some small plots fall vacant, and leftover strips of land or informal green spaces are allowed to “grow wild.” Trees and shrubs become denser, vacant lots re-naturalize, and unkempt parks become bushier. Through the lens of the satellite-based NDVI measure, all such narratives would render the zip code greener, possibly explaining the price reversal despite falling quantities.

The NDVI coefficients on quantities become substantially more negative once we include state×year fixed effects (columns (4) and (8)). This pattern suggests that, in the specification without state×year fixed effects, common state-level shocks that increased

both greenness and listing volumes attenuate the negative within-zip relationship, biasing the coefficient toward zero.

4.3.2 Zoned vs. Unzoned Areas

A concern remains that NDVI is not only a driver of housing outcomes but also an outcome of local preferences and policies. Municipalities may become greener in response to rising demand, and environmentally minded, higher-income households may self-select into greener areas. Such forces may still bias the headline relationships estimated above, despite saturating the specification with controls and fixed effects.

To sharpen the supply-side interpretation, we therefore turn to explicit green-infrastructure and conservation zoning in Baden-Württemberg. The considered zoning designations, regional green corridors, green breaks, and areas for nature conservation and landscape management, are planning instruments that restrict or strongly condition future development and are adopted in discrete revisions of regional plans. Whereas the broad orientation of these plans reflects regional preferences, the exact timing and location of new designations within a regional planning region are largely driven by ecological and planning criteria, rather than contemporaneous, zip-code-specific housing demand.

We split the Baden-Württemberg sample into zip codes that ever experience an increase in such zoning during the sample period (“zoned”) and those that never do (“un-zoned”). We then re-estimate the headline specification (Equation 3) for each sub-sample. The stronger relationship between biodiversity and the housing market in zoned zip codes provides further suggestive evidence in favor of the construction-crunch narrative.

Table 5 reports the results for the zoned zip codes in columns (1) and (2) and for the unzoned zip codes in columns (3) and (4). Consistent with the headline results, an increase in NDVI is associated with higher prices and lower quantities in zoned areas. In the unzoned group, coefficients are small and statistically insignificant. This concentra-

tion of effects, where supply frictions increase, also corroborates the construction crunch hypothesis. Greenness coincides with designations that reduce developable capacity (or potentially raise development costs), yielding higher prices and lower quantities.

[Table 5 about here]

Zoning changes are plausibly exogenous to short-run, zip-code-specific housing market fluctuations, because they are mainly driven by ecological and planning criteria. However, they are still policy choices rather than the outcome of a randomized experiment. For example, a fast-growing municipality that anticipates high future demand and attracts higher-income, environmentally minded households may decide to protect its remaining open spaces by designating them as regional green corridors. In such a case, stronger demand and tighter regulation coincide spatially. The zoning split, therefore, does not deliver a fully causal estimate. However, the stark difference between zoned and unzoned areas, combined with the alignment of the zoned results with our headline pattern, mitigates a pure sorting- or demand-driven greening explanation and supports a supply-side interpretation.

4.4 Zoning Intensity and Housing Market Responses

To further exploit the heterogeneity in how strongly individual zip codes are affected by planning decisions, we venture next from a simple “ever zoned” vs. “never zoned” comparison to a measure of zoning intensity. When a regional plan is revised, almost all zip codes in the respective planning region typically receive some additional green-infrastructure or conservation designation. Yet, the amount of newly zoned land differs across zip codes. To capture this heterogeneity, we construct an annual zoning-intensity measure equal to the additionally zoned area divided by the total area of the zip code. The variable is zero in years without zoning expansions. Including this measure alongside

NDVI allows us to distinguish between the long-run association of greenness with housing outcomes and the short-run response to a discrete tightening of development rights.

Formally, for zip code i in year t in Baden-Württemberg we estimate

$$\mathbf{Y}_{i,t} = \beta_0 + \beta_1 \text{Biodiversity}_{i,t} + \beta_2 \text{Zoning}_{i,t} + \beta_3 \mathbf{Z}_{i,t} + \beta_4 \mathbf{X}_{i,t} + \alpha_t + \gamma_i + \epsilon_{i,t} , \quad (4)$$

where $\mathbf{Y}_{i,t}$ again denotes the logarithm of the average price per square meter, quantities, and stickiness, respectively. $\text{Biodiversity}_{i,t}$ is the average annual NDVI in zip code i and $\text{Zoning}_{i,t}$ is the share of the zip-code area newly subject to green-infrastructure or conservation zoning in year t . The vectors $\mathbf{Z}_{i,t}$ and $\mathbf{X}_{i,t}$ collect property-level and regional controls, and γ_i and α_t are zip-code and year fixed effects.

We estimate Equation 4 separately for all zip codes in Baden-Württemberg (columns (1)–(6) in Table 6) and for a subsample that excludes zip codes in Stuttgart (columns (7)–(12) in Table 6), the only one of Germany’s ten largest cities located in Baden-Württemberg. Adding the zoning-intensity measure allows us to isolate the contemporaneous adoption-year response to new zoning while controlling for the level of NDVI. Controlling for NDVI is important, as greener areas may be systematically more likely to receive green-infrastructure or conservation designations.

Comparing columns (1) and (7), which resemble the headline results in Equation 3 for zip codes in Baden-Württemberg, we find that the coefficient on NDVI is small and statistically insignificant when all zip codes are included. It turns positive and marginally significant, though once we exclude Stuttgart. This mirrors the city vs. non-city results reported before: large cities exhibit different greenness-price dynamics, so pooling the zip codes of Stuttgart with the rest of Baden-Württemberg attenuates the average NDVI-price association. When we add the zoning-intensity variable in columns (2) and (8), the findings are very similar with and without Stuttgart: the contemporaneous price response loads almost entirely on zoning intensity, while the NDVI coefficient becomes small and

statistically insignificant. A natural interpretation is that prices react immediately when development rights are tightened, and the zoning variable captures this discrete legal change. Once we condition on zoning intensity, little additional systematic price variation remains to be explained by short-run movements in NDVI, which adjust only gradually.

[Table 6 about here]

Turning to quantities in columns (3), (4), (9), and (10), we find that NDVI remains negatively associated with the number of active listings, whereas zoning intensity in year t is positively associated with quantities. This pattern is consistent with a distinction between short-run and medium-run effects. In the year of a major zoning expansion, projects that are already in the pipeline or landowners who anticipate future restrictions may bring additional units to the market, generating a temporary increase in observed listings where zoning intensity is high. Over time, however, as newly protected areas re-naturalize and the effective stock of developable land shrinks, NDVI captures the resulting decline in active listings. The non-city subsample shows very similar results.

Taken together, the zoning-intensity results reinforce the supply-side interpretation. Over time, a higher NDVI is associated with higher prices and lower quantities, while in the adoption year, zoning shocks are capitalized into prices and, if anything, temporarily raise quantities rather than offset the longer-run decline. Although demand-side forces such as the sorting of greener-preferring households or demand-induced greening remain possible, they would typically predict rising prices along with higher quantities and faster turnover, which is not what we observe once we account for zoning intensity.

5 Conclusion

This paper studies how biodiversity relates to housing markets by combining a large panel of real estate listings for Germany (2007-2021) with remotely sensed greenness (NDVI).

Leveraging a zip-code-by-year design with rich controls and fixed effects, we document two main results. First, within a given zip code and year, higher greenness is associated with higher residential prices per square meter. Second, greener zip codes exhibit lower market quantities and, if anything, slightly longer time on the market, a pattern more in line with supply tightening than with a demand premium.

Taken together, the evidence points to a *construction crunch* narrative. As areas become greener, especially where regional zoning constrains developable land, the effective housing supply tightens, and prices rise. The urban reversal suggests that greenness gains in dense cores often occur on non-residential or transitional land (public-realm greening, corridors, demolition sites, or temporary fallows), which weakens how greenness is priced in owner-occupied sales.

These findings have policy implications that differ by context. Where conservation designations overlap with developable land, especially in suburban or peri-urban areas, protecting land reduces housing capacity, which tends to raise prices and lower inventory. In those places, pairing conservation with targeted supply measures in less sensitive locations, such as selective upzoning, modest density increases outside protected corridors, and predictable mitigation and compensation procedures, can balance ecological goals and affordability.

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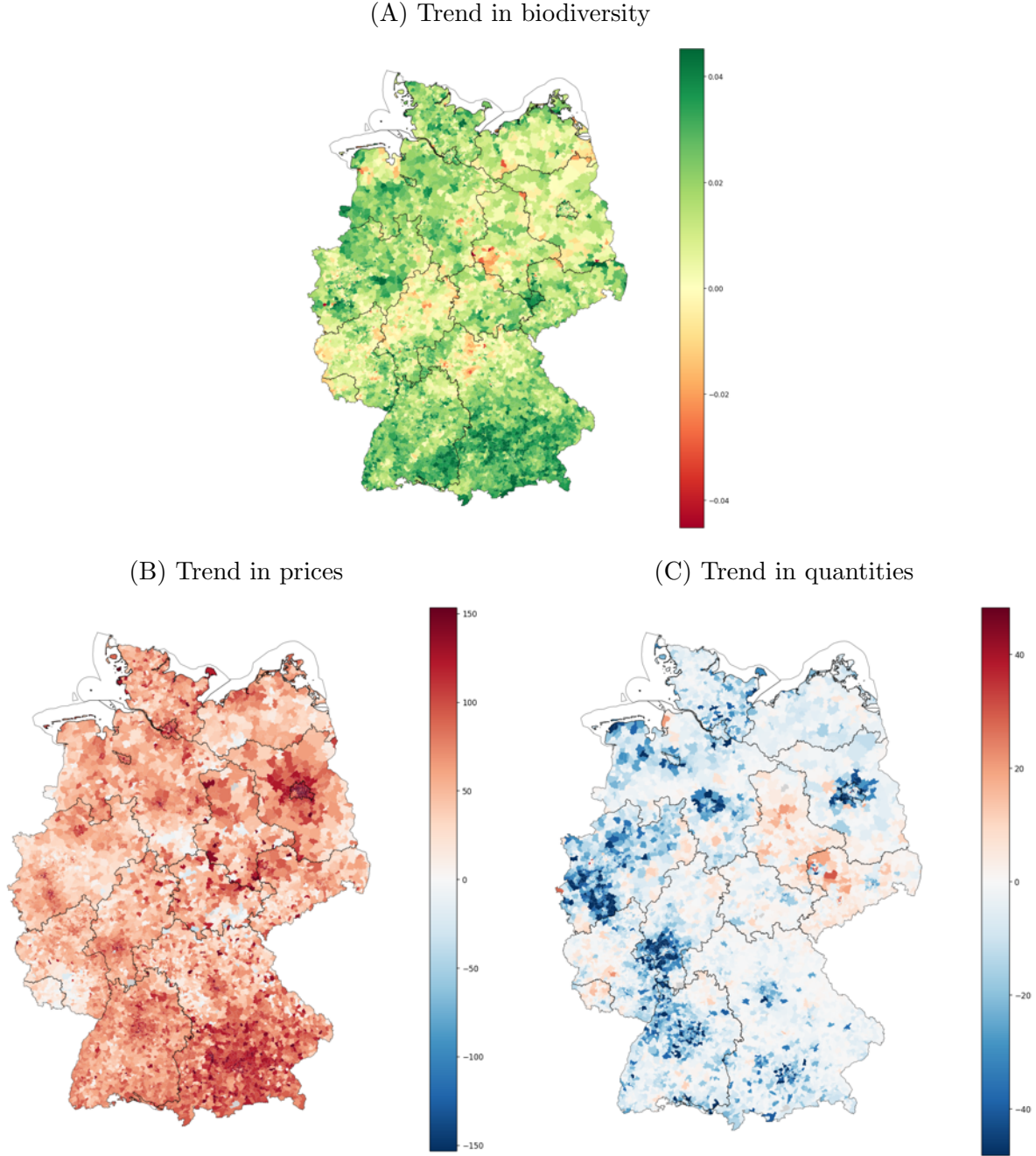
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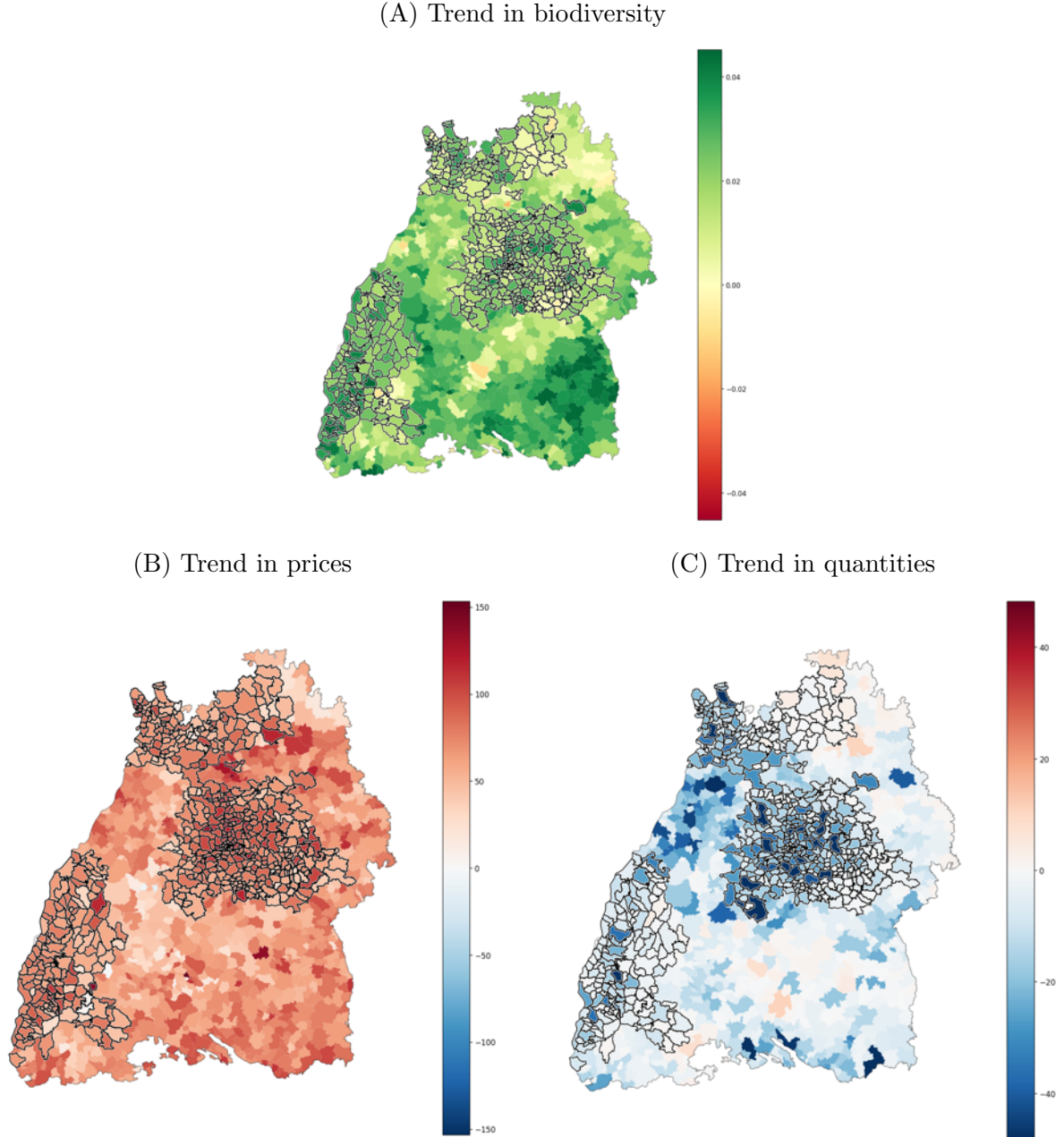
Figures and Tables

Figure 2: Zip-level trends in biodiversity (NDVI), housing prices and housing quantities in Germany (2007–2021)



Each map reports a zip-specific time trend estimated on annual data for 2007–2021 using the Theil-Sen estimator, i.e., the median of all pairwise slopes of the variable on calendar year for that ZIP. This yields a robust slope in “per year” units; we multiply by 10 to express the trend *per decade*. We require at least 8 usable years per ZIP; areas with fewer observations are shown in grey. State borders are overlaid for reference. (A) Biodiversity (NDVI). Value = Theil-Sen slope in *NDVI units per decade*; green = greening, red = browning. (B) Prices. Estimated on $\log(\text{price}/\text{m}^2)$ and converted to % per decade via $100 \exp(10\hat{s}) - 1$ (e.g., $+50 \approx +4.1\%/yr$). (C) Quantities. Estimated on *levels* of inventory; value = *units per decade* (Theil-Sen slope $\times 10$). For example, $+12$ means roughly 12 additional units per decade.

Figure 3: Zip-level trends in biodiversity (NDVI), housing prices and housing quantities in Baden-Württemberg (2007–2021)



Each map reports a zip-specific time trend estimated on annual data for 2007–2021 using the Theil-Sen estimator, i.e., the median of all pairwise slopes of the variable on calendar year for that ZIP. This yields a robust slope in “per year” units; we multiply by 10 to express the trend *per decade*. We require at least 8 usable years per ZIP; areas with fewer observations are shown in grey. Zip codes that ever recieved a zoning designation during 2007–2021 are outlined with a black boarder. (A) Biodiversity (NDVI). Value = Theil-Sen slope in *NDVI units per decade*; green = greening, red = browning. (B) Prices. Estimated on $\log(\text{price}/\text{m}^2)$ and converted to % per decade via $100 \exp(10\hat{s}) - 1$ (e.g., $+50 \approx +4.1\%/yr$). (C) Quantities. Estimated on *levels* of inventory; value = *units per decade* (Theil-Sen slope $\times 10$). For example, $+12$ means roughly 12 additional units per decade.

Table 1: Summary statistics

Variable	N	Mean	SD	p25	p50	p75
Panel A: Germany						
Price per sqm	117,606	1,896.70	1,130.47	1,180.39	1,594.38	2,244.68
Log Price per sqm	117,606	7.41	0.52	7.07	7.37	7.72
Quantities	117,606	15.66	20.76	3.42	9.08	20.58
Stickiness	117,606	1.26	0.21	1.13	1.23	1.34
Biodiversity	117,606	0.62	0.09	0.58	0.64	0.68
Panel B: Baden-Württemberg						
Price per sqm	17,716	2,186.49	892.96	1,571.15	1,971.90	2,589.07
Log Price per sqm	17,716	7.62	0.38	7.36	7.59	7.86
Quantities	17,716	14.68	17.23	3.92	8.75	19.17
Stickiness	17,716	1.28	0.20	1.16	1.25	1.36
Biodiversity	17,716	0.64	0.08	0.60	0.65	0.69
Zoning Indicator	17,716	0.46	0.50	0.00	0.00	1.00
Zoning	17,716	0.02	0.16	0.00	0.00	0.00

This table reports the summary statistics for houses and apartments for sale in Germany over different samples. Panel A covers the panel data for Germany during the period 2007 to 2021. Panel B reports the panel data for Baden-Württemberg for houses on sale during the period 2007 to 2019. The price per square meter is winsorized at the 1% and 99% levels. Biodiversity is measured as the average NDVI where the listing is located. Higher NDVI values indicate greener and healthier vegetation, reflecting higher biodiversity. Detailed definitions of variable constructions and data sources are provided in the Appendix Table 1.

Table 2: Summary statistics and mean differences for city, zoning, and regional subsamples

City vs. Non-City								
Variable	City ($N = 9096$)			Non-City ($N = 112707$)			Comparison	
	Mean	Median	SD	Mean	Median	SD	Raw diff.	Norm. diff.
Price per sqm	3442.630	2978.052	1850.128	1748.315	1523.552	939.995	1694.315	1.155 ⁺
Log price per sqm	8.003	7.999	0.539	7.345	7.329	0.488	0.658	1.279 ⁺
Biodiversity	0.488	0.501	0.104	0.635	0.643	0.073	-0.148	-1.645 ⁺
Quantities	33.207	23.750	40.234	14.034	8.000	17.318	19.173	0.619 ⁺
Stickiness	1.253	1.235	0.136	1.264	1.228	0.222	-0.011	-0.061

Zoned vs. Non-Zoned								
Variable	Zoned ($N = 8214$)			Not Zoned ($N = 9635$)			Comparison	
	Mean	Median	SD	Mean	Median	SD	Raw diff.	Norm diff
Price per Sqm	2384.338	2134.960	948.261	2013.602	1812.100	807.758	370.736	0.421 ⁺
Log price per sqm	7.706	7.666	0.373	7.538	7.502	0.365	0.167	0.454 ⁺
Biodiversity	0.633	0.636	0.084	0.654	0.660	0.073	-0.021	-0.266 ⁺
Quantities	17.041	10.250	19.785	12.469	7.333	14.330	4.571	0.265 ⁺
Stickiness	1.286	1.259	0.190	1.277	1.248	0.211	0.008	0.041

Baden-Württemberg vs. Germany (excluding Baden-Württemberg)								
Variable	Baden-Württemberg ($N=17849$)			Germany (excluding Baden-Württemberg) ($N=103\,944$)			Comparison	
	Mean	Median	SD	Mean	Median	SD	Raw diff.	Norm diff
Price per sqm	2184.212	1970.072	894.492	1821.501	1499.465	1154.353	362.712	0.351 ⁺
Log price per sqm	7.615	7.586	0.378	7.356	7.313	0.533	0.260	0.561 ⁺
Biodiversity	0.645	0.651	0.079	0.621	0.635	0.086	0.024	0.289 ⁺
Quantities	14.573	8.667	17.209	15.621	9.000	21.109	-1.048	-0.054
Stickiness	1.281	1.253	0.201	1.260	1.225	0.219	0.021	0.099

Raw mean differences between groups are reported in column “Raw diff.” Normalized differences are reported in column “Norm. diff.” A “+” indicates normalized differences exceeding 0.25 in absolute value, following the rule-of-thumb threshold in Imbens and Rubin (2015). Detailed definitions of variable constructions and data sources are provided in the Appendix Table 1.

Table 3: Biodiversity effects on real estate prices and quantities

	Log square meter price		Quantities		Stickiness	
	(1)	(2)	(3)	(4)	(5)	(6)
Biodiversity	0.174*** (5.65)	0.159*** (4.58)	-9.215*** (-3.87)	-22.345*** (-7.05)	0.067* (1.87)	0.025 (0.63)
Observations	117603	117603	117603	117603	117603	117603
R^2	0.914	0.919	0.752	0.768	0.212	0.222
Housing__Controls	Yes	Yes	Yes	Yes	Yes	Yes
Region__Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year__FE	Yes	Yes	Yes	Yes	Yes	Yes
State__FExYear__FE	No	Yes	No	Yes	No	Yes
Zipcode__FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code

This table shows the results of the headline specification in Equation 3. The Normalized Difference Vegetation Index (NDVI) approximates biodiversity on the zip-code level. We construct monthly quantities at the zip level from listings by first building “spells” for each listing. A new spell starts when the gap to the previous observation of the same listing exceeds three months or when observable attributes change discontinuously (zip, listing type, >20% jump in square meters, or >1-room change). The variable *Quantities* is the 12-month average of monthly stock in a zip-year; it equals total listing-months in that year divided by 12. The variable *Stickiness* measures the average duration of listings in a zip-year. We compute monthly stock duration by tracking entry and exit events of spells for each month. Thereby, we can compute for the set of active listings the average elapsed duration since entry. All specifications include median listing controls per zip code, regional controls, year fixed effects, and zip-code fixed effects. Listing controls are the median of the house age, number of rooms, and number of bedrooms per zip code. Regional controls are GDP growth, the unemployment rate, business registrations, insolvencies, population size, the share of votes for the Green Party, the share of total area used for settlement and traffic, and the share of total area used for agriculture. State x Year fixed effects are included in column (2), (4), and (6). We omit the city dummy because it is constant within a zip code and therefore collinear with zip code fixed effects. We cluster standard errors at the zip code level. T-statistics are in parentheses. Detailed definitions of variable constructions and data sources are provided in the Appendix Table 1. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: Real estate responses in urban and rural areas

	Non Cities				Cities			
	Log Square Meter Price		Quantities		Log Square Meter Price		Quantities	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Biodiversity	0.209*** (6.51)	0.205*** (5.69)	-4.004** (-2.54)	-13.815*** (-7.86)	-0.359*** (-3.84)	-0.357*** (-3.27)	-35.021* (-1.87)	-77.084*** (-2.77)
Observations	108600	108600	108600	108600	9003	8988	9003	8988
R^2	0.901	0.905	0.810	0.824	0.953	0.958	0.596	0.616
Housing__Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region__Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year__FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State__FExYear__FE	No	Yes	No	Yes	No	Yes	No	Yes
Zipcode__FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code

This table extends the headline specification in Equation 3 by estimating separate regressions for non-city and city zip codes. Cities are zip codes belonging to Germany's ten largest cities: Berlin, Hamburg, Munich, Cologne, Frankfurt am Main, Stuttgart, Düsseldorf, Leipzig, Dortmund, and Essen. Columns (1)–(4) restrict the sample to non-city zip codes; columns (5)–(8) to city zip codes. Within each group, the dependent variable is log price per square meter in columns (1), (2), (5), and (6), and quantities in columns (3), (4), (7), and (8). We use the Normalized Difference Vegetation Index (NDVI) to approximate biodiversity on the zip-code level. We construct monthly quantities at the zip level from listings by first building “spells” for each listing. A new spell starts when the gap to the previous observation of the same listing exceeds three months or when observable attributes change discontinuously (zip, listing type, >20% jump in square meters, or >1-room change). The variable *Quantities* is the 12-month average of monthly stock in a zip-year; it equals total listing-months in that year divided by 12. All specifications include median listing controls per zip code, regional controls, year fixed effects, and zip-code fixed effects. Listing controls are the median of the house age, number of rooms, and number of bedrooms per zip code. Regional controls are GDP growth, the unemployment rate, business registrations, insolvencies, population size, the share of votes for the Green Party, the share of total area used for settlement and traffic, and the share of total area used for agriculture. State x Year fixed effects are included in column (2), (4), (6), and (8). We cluster standard errors at the zip code level. T-statistics are in parentheses. Detailed definitions of variable constructions and data sources are provided in the Appendix Table 1. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Effects of supply constraints in real estate markets: zoned vs. unzoned areas

	Zoned Areas		Unzoned Areas	
	Log Square Meter Price	Quantities	Log Square Meter Price	Quantities
	(1)	(2)	(3)	(4)
Biodiversity	0.216** (2.34)	-17.328* (-1.93)	-0.027 (-0.28)	-3.313 (-0.72)
Observations	8188	8188	9527	9527
R^2	0.933	0.818	0.891	0.831
Housing__Controls	Yes	Yes	Yes	Yes
Region__Controls	Yes	Yes	Yes	Yes
Year__FE	Yes	Yes	Yes	Yes
Zipcode__FE	Yes	Yes	Yes	Yes
Cluster	Zip Code	Zip Code	Zip Code	Zip Code

This table extends Equation 3 by estimating separate regressions for zip codes that were ever zoned versus never zoned during 2007–2021. Zoned zip codes are those that, in any year of our sample, experienced an increase in green-infrastructure and conservation zoning; Unzoned zip codes never did. Columns (1) and (2) restrict the sample to zoned zip codes; columns (3) and (4) to unzoned zip codes. Within each group, the dependent variable is log price per square meter in columns (1), (3), and quantities in columns (2), (4). We use the the Normalized Difference Vegetation Index (NDVI) to approximate biodiversity on the zip-code level. We construct monthly quantities at the zip level from listings by first building “spells” for each listing. A new spell starts when the gap to the previous observation (of the same listing) exceeds 3 months or when observable attributes change discontinuously (zip, listing type, >20% jump in square meters, or >1-room change). The variable *Quantities* is the 12-month average of monthly stock in a zip-year; it equals total listing-months in that year divided by 12. All specifications include median listing controls per zip code, regional controls, year fixed effects, and zip-code fixed effects. Listing controls are the median of the house age, number of rooms, and number of bedrooms per zip code. Regional controls are GDP growth, the unemployment rate, business registrations, insolvencies, population size, the share of votes for the Green Party, the share of total area used for settlement and traffic, and the share of total area used for agriculture. We cluster standard errors at the zip code level. T-statistics are in parentheses. Detailed definitions of variable constructions and data sources are provided in the Appendix Table 1. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

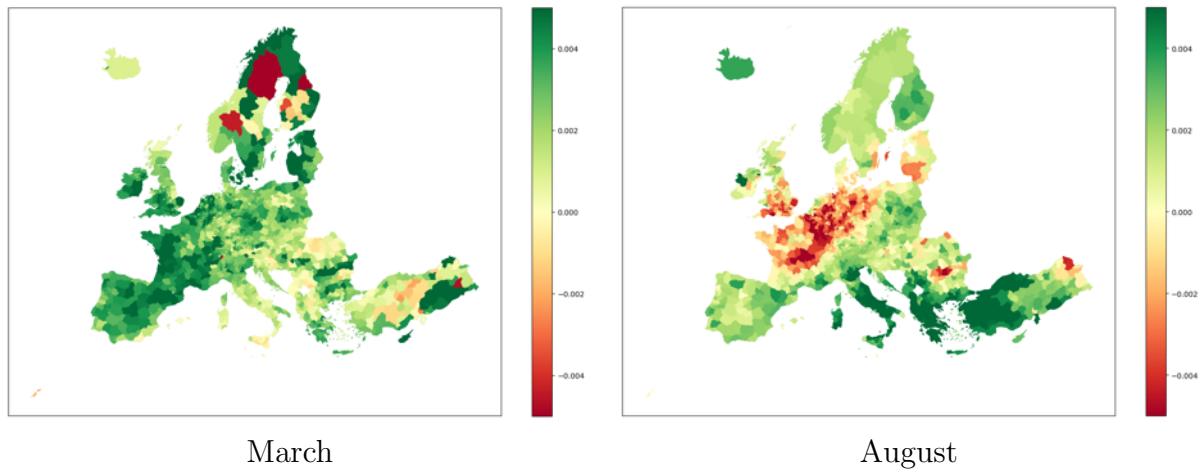
Table 6: Baden-Württemberg: Biodiversity and Zoning Intensity.

	Baden-Württemberg						Non Cities Baden-Württemberg					
	Log Square Meter Price		Quantities		Stickiness		Log Square Meter Price		Quantities		Stickiness	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Biodiversity	0.095 (1.39)	0.087 (1.28)	-9.690** (-2.04)	-10.871** (-2.29)	0.211** (2.06)	0.208** (2.04)	0.119* (1.73)	0.112 (1.63)	-11.770** (-2.47)	-12.692*** (-2.66)	0.218** (2.06)	0.216** (2.04)
Zoning		0.015*** (2.73)		2.464*** (5.30)		0.005 (0.66)		0.016*** (2.87)		2.276*** (4.80)		0.004 (0.56)
Observations	17715	17715	17715	17715	17715	17715	17205	17205	17205	17205	17205	17205
R^2	0.915	0.915	0.822	0.822	0.211	0.211	0.909	0.909	0.823	0.823	0.211	0.211
Housing...Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region...Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year...FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Zipcode...FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code	Zip Code

This table augments Eq. 3 by adding a measure of zoning intensity. For a zip-year, Zoning is non-zero only when green-infrastructure and conservation zoning expands; it equals the additionally zoned area divided by the total area of the zip code. Columns (1)–(6) use all zip codes in Baden-Württemberg; columns (7)–(12) exclude city zip codes (i.e., the non-city subsample; in Baden-Württemberg this primarily removes Stuttgart). Within each group, the dependent variable is log price per square meter in columns (1), (2), (7), (8), quantities in columns (3), (4), (9), (10), and stickiness in (5), (6), (11), (12). Biodiversity is our proxy for biodiversity, the Normalized Difference Vegetation Index (NDVI) on the zip-code level. We construct monthly quantities at the zip level from listings by first building “spells” for each listing, i.e., a new spell starts when the gap to the previous observation (of the same listing) exceeds 3 months or when observable attributes change discontinuously (zip, listing type, >20% jump in square meters, or >1-room change). The variable Quantities is the 12-month average of monthly stock in a zip-year; it equals total listing-months in that year divided by 12. The variable Stickiness measures the average duration of listings in a zip-year. Monthly stock duration is computed following a standard flow-stock identity: for each month, we keep track of entry and exit events of spells, which allows us to compute for the set of active listings the average elapsed duration since entry. All specifications include median listing controls per zip code, regional controls, year fixed effects, and zip-code fixed effects. Listing controls are the median of the house age, number of rooms, and number of bedrooms per zip code. Regional controls are GDP growth, the unemployment rate, business registrations, insolvencies, population size, the share of votes for the Green Party, the share of total area used for settlement and traffic, and the share of total area used for agriculture. We cluster standard errors at the zip code level. T-statistics are in parentheses. Detailed definitions of variable constructions and data sources are provided in the Appendix Table 1. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

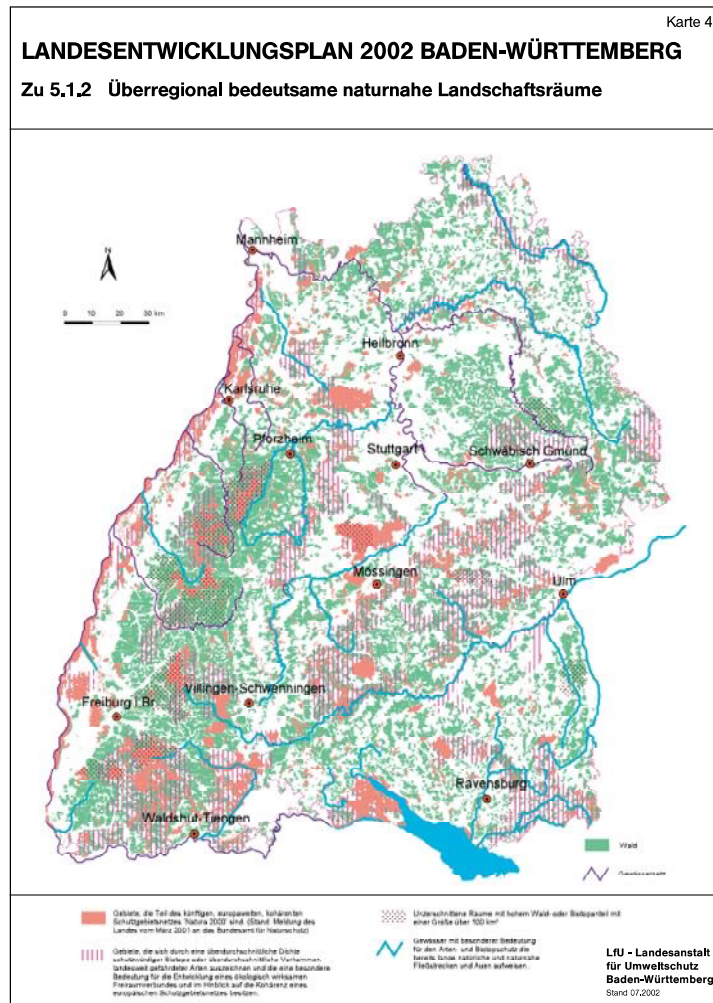
Appendix

Appendix Figure 1: NDVI change between 2007 and 2021 for Europe's NUTS3 regions.



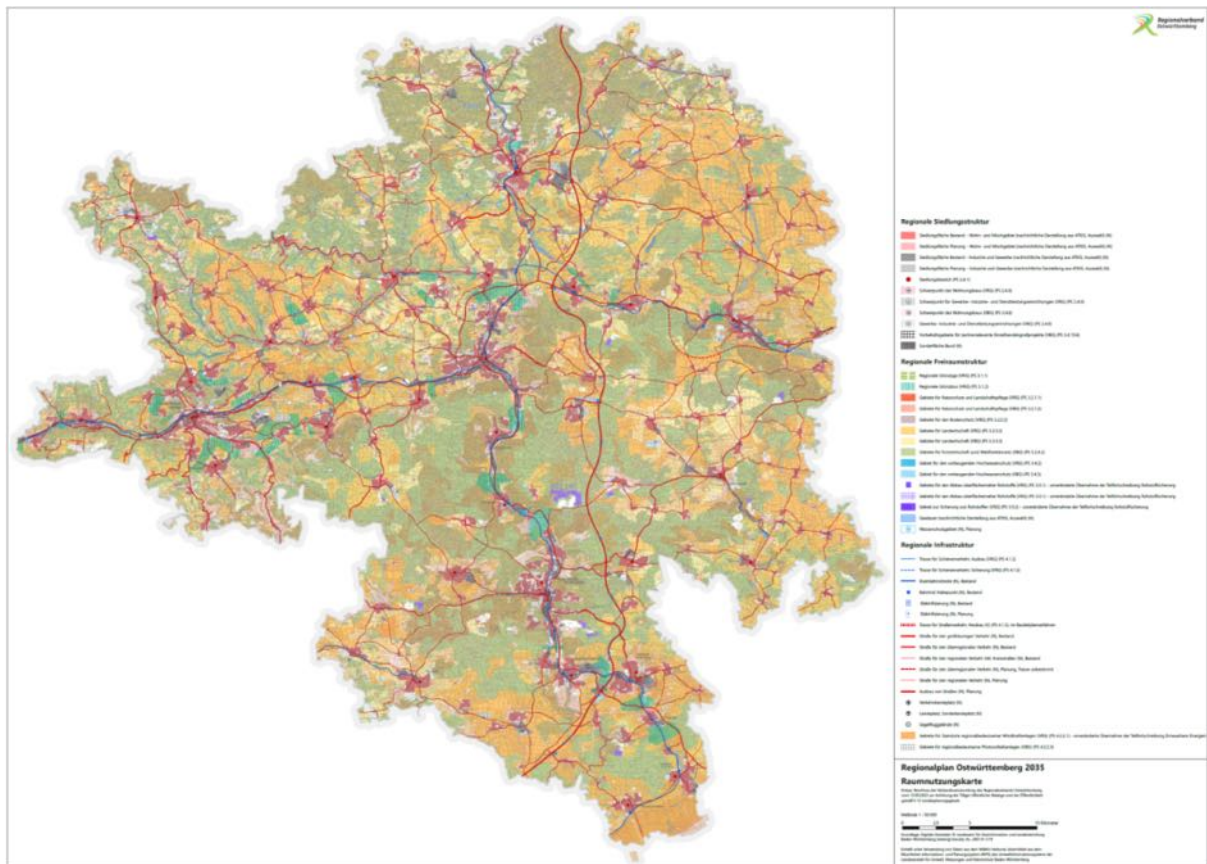
The maps show estimated trends in vegetation greenness (NDVI) between 2007 and 2021 at the NUTS3 level. For each NUTS3 region and month (March on the left, August on the right), we regress the NDVI observations from 2007 onward on a linear time trend and plot the estimated slope coefficient. Positive (negative) values indicate increasing (declining) NDVI over time.

Appendix Figure 2: State level spatial plan for Baden-Württemberg.



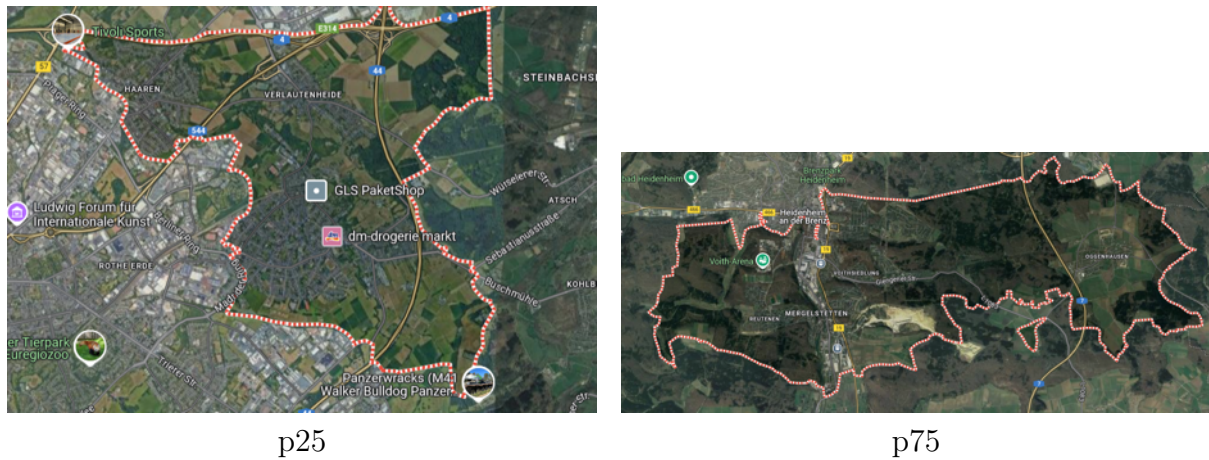
The map shows state-level priority landscape areas for Baden-Württemberg that structure the open-space network. Green indicates forest; blue lines the general water network; thick blue waterways mark rivers/floodplains of special conservation value; red areas are part of the future EU Natura 2000 network (status: March 2001); magenta hatching marks areas with a high density of valuable biotopes or occurrences of state-wide threatened species (important for ecological connectivity); stippled/dotted areas denote large, undissected spaces ($>100 \text{ km}^2$) with a high forest/biotope share. Source: Wirtschaftsministerium Baden-Württemberg, Landesentwicklungsplan 2002 Baden-Württemberg—Map 4 “Überregional bedeutsame naturnahe Landschaftsräume”, LfU Baden-Württemberg, July 2002; available at the state portal (accessed 10 Nov 2025).

Appendix Figure 3: Regional level spatial plan for Ostwürttemberg.



The map depicts regional open-space structure. Regional Green Corridors (Regionale Grünzüge, VRG; PS 3.1.1, shown as solid light-green areas), Green Breaks (Grünzäsuren, VRG; PS 3.1.2, shown as green hatched bands), and Priority/Reservation Areas for Nature Conservation & Landscape Management (Gebiete für Naturschutz und Landschaftspflege, VRG/VBG; PS 3.2.1.1/3.2.1.2, shown as dark-green hatching for VRG and lighter green hatching/outline for VBG). VRG denotes Vorranggebiet (priority area with exclusion of conflicting uses); VBG denotes Vorbehaltsgebiet (reservation area to be given particular consideration). Source: Regionalverband Ostwürttemberg, based on digital geodata LGL Baden-Württemberg (Az. 2851.9-1/19) and datasets from the WIBAS network via the RIPS system.

Appendix Figure 4: Examples of NDVI differences between the 25th and 75th percentiles.



This figure shows example zip codes at the 25th (left panel) and 75th (right panel) percentiles of the NDVI distribution. The red borders delineate the respective zip-code boundaries; greener areas correspond to higher NDVI values. Source: Google Maps.

Appendix Table 1: Variable definitions

Variable	Definition	Unit	Mean	SD	Source
Biodiversity _{<i>i,t</i>}	Proxy for biodiversity, namely the Normalized Difference Vegetation Index (NDVI) for zip <i>i</i> and year <i>t</i> , averaged over the zip's area.	Index ∈ [-1, 1]	0.62	0.09	Satellite imagery (MODIS: MOD13A1 version 6).
Price per sqm _{<i>i,t</i>}	average listing price per square meter in zip <i>i</i> , year <i>y</i> for all properties (houses and apartments) on sale.	Euro	1,896.70	1,130.47	RWL-GEO-RED
Log price per sqm _{<i>i,t</i>}	Natural logarithm of average listing price per square meter in zip <i>i</i> , year <i>y</i> for all properties (houses and apartments) on sale.	ln(EUR/m ²)	7.41	0.52	RWL-GEO-RED
Quantities _{<i>i,t</i>}	12-month average stock of active listings (spells) in zip <i>i</i> and year <i>y</i> : $Quantities_{i,t} = \frac{1}{12} \sum_{m=1}^{12} Stock_{i,m}$, where $Stock_{i,m}$ is the number of active listing spells in month <i>m</i> (i.e., total listing-months in <i>i</i> during <i>t</i> divided by 12).	Listings	15.66	20.76	Own computation based on RWL-GEO-RED
Stickiness _{<i>i,t</i>}	Average time on market (months) for active listings in zip <i>i</i> and year <i>t</i> : each month <i>m</i> , compute the mean months since spell start across active spells, then average these 12 monthly means over the year.	Months	1.26	0.21	
MedianAge _{<i>i,t</i>}	Median house age of listings in zip <i>i</i> , year <i>t</i> .	Years	33.91	29.03	RWL-GEO-RED
Rooms _{<i>i,t</i>}	Median number of rooms of listings in zip <i>i</i> , year <i>t</i> .	Count	4.73	1.31	RWL-GEO-RED
Bedrooms _{<i>i,t</i>}	Median number of bedrooms of listings in zip <i>i</i> , year <i>t</i> .	Count	2.95	0.89	RWL-GEO-RED
GDP Growth _{<i>r,t</i>}	Year-over-year GDP growth for region <i>r</i> in year <i>t</i> . Regions are the administrative district level (Kreise und Kreisfreie Städte)	% (e.g., 1 = 1%)	2.98	3.94	VGRdL (Regionalatlas)
Unemployment _{<i>r,t</i>}	Registered unemployment rate in region <i>r</i> (Kreise/kreisfreie Städte) in year <i>t</i> .	% (e.g., 1 = 1%)	5.70	2.90	Bundesagentur für Arbeit, via Regionalatlas Deutschland.
Business Registration _{<i>r,t</i>}	Annual business registrations (Gewerbeanmeldungen) per 10 000 inhabitants in region <i>r</i> (Kreise/kreisfreie Städte) and year <i>t</i> . Applications for corporate insolvency (beantragte Unternehmensinsolvenzen) per 10 000 taxable enterprises (steuerpflichtige Unternehmen) in region <i>r</i> (Kreise/kreisfreie Städte) and year <i>t</i>	Count per 10 000 inhabitants	82.15	21.77	Gewerbeanzeigenstatistik (Destatis/Länder), via Regionalatlas Deutschland.
Insolvencies _{<i>r,t</i>}		Count per 10 000 taxable enterprises	66.06	37.56	Insolvenzstatistik (Destatis), via Regionalatlas Deutschland

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(continued)

Variable	Definition	Unit	Mean	SD	Source
Population _{<i>r,t</i>}	Residents per square kilometer in region <i>r</i> (Kreise/kreisfreie Städte) in year <i>t</i> .	Inhabitants per km ²	596.46	925.38	Bevölkerungsfortschreibung (Destatis/Länder), via Regionalatlas Deutschland.
Green Votes _{<i>r,t</i>}	Share of valid second votes (Zweitstimmen) for Bündnis 90/Die Grünen in region <i>r</i> (Kreise/kreisfreie Städte) in year <i>t</i> . For non-election years <i>t</i> , we carry forward the most recent result.	% (e.g., 1 = 1%)	9.08	3.92	Die Bundeswahlleiterin, via Regionalatlas Deutschland
Settlement Traffic _{<i>r,t</i>}	Share of total land area in region <i>r</i> classified as settlement and transport (<i>Siedlungs- und Verkehrsfläche</i>) in year <i>t</i> .	Share of region area	0.0024	0.002	Land-use statistics (ALB/ALKIS), via Regionalatlas Deutschland
Agriculture _{<i>r,t</i>}	Share of total land area in region <i>r</i> classified as agriculture in year <i>t</i> .	Share of region area	0.0025	0.0009	Land-use statistics (ALB/ALKIS), via Regionalatlas Deutschland
Zoned _{<i>i</i>}	Indicator for zip codes <i>i</i> that ever experienced an increase in green-infrastructure or conservation zoning between 2007 and 2021.	Indicator	0.46	0.50	Geoportal Raumordnung Baden-Württemberg
Zoning _{<i>i,t</i>}	Zoning-intensity measure. It equals the increase in zoned area relative to the total zip-code area in the year of the increase, and zero otherwise.	Share of zip code area	0.02	0.16	Geoportal Raumordnung Baden-Württemberg

This table summarizes the variables used in the analysis. For each variable we report its unit, mean, standard deviation, and data source. Means and standard deviations are calculated over the full German panel from 2007 to 2021, except for the zoning variables, for which we only consider the Baden-Württemberg zip codes. GDP Growth is taken from the Arbeitskreis “Volkswirtschaftliche Gesamtrechnungen der Länder” (VGRdL), via *Regionalatlas Deutschland* (Statistische Ämter des Bundes und der Länder). For *Settlement Traffic* and *Agriculture*, ALB-based series are used up to the ALKIS switchover; from 2015/2016 onward, ALKIS-based series are used.

Halle Institute for Economic Research –
Member of the Leibniz Association

Kleine Maerkerstrasse 8
D-06108 Halle (Saale), Germany

Postal Address: P.O. Box 11 03 61
D-06017 Halle (Saale), Germany

Tel +49 345 7753 60
Fax +49 345 7753 820

www.iwh-halle.de

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