Wildlife Management Areas, Deer Quality, and Rural Land Values:
A Spatial Hedonic Analysis of Arkansas

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Abstract

This paper validates the data and inference infrastructure for a spatial hedonic study of how public-hunting-land proximity, deer-harvest quality, and Chronic Wasting Disease (CWD) capitalize into rural Arkansas land values. The contribution is methodological: we validate the pipeline, not the amenity hypothesis, which remains untested pending market transaction data. Lacking publicly released parcel-level sales, we build it on 308,226 tax-assessed vacant-agricultural parcels across 73 counties and 20 deer-management zones, matched to fourteen spatial data sources. The dependent variable is statutory use value (Amendment 59; Ark. Code Ann. § 26-26-407), a soil-productivity-driven assessed value, not a market price. Ten identification-robustness checks span functional form, Conley spatial HAC, bootstrap, matching, leave-one-out, and a properly powered placebo-distance test. The WMA proximity coefficient ($< 1/4$ mile) is -0.082 (95% CI $[-0.130, -0.034]$), stable across counties (leave-one-out median -0.082, IQR $[-0.083, -0.081]$; 0 of 73 outside the full-sample interval) and 30% smaller under coarsened exact matching (-0.057). A placebo test relocating 191 pseudo-WMAs places the estimate in the left tail (one-sided $p = 0.01$), ruling out spatial noise but not terrain selection (WMAs occupy marginal land); it is a specification check, not identification. The negative gradient, opposite the positive-amenity prediction for sale prices, reflects WMA placement on marginal terrain: a diagnostic property of use-value assessment, not evidence that WMAs depress market land values. A staggered difference-in-differences design around Arkansas's phased CWD-zone expansion (2016, 2018, 2021) follows.

Keywords: spatial hedonic; Wildlife Management Areas; use-value assessment; amenity capitalization; Chronic Wasting Disease; rural land values
JEL classification: C21, Q24, Q26, Q51, R14

1 Introduction

Arkansas ranks among the premier deer hunting destinations in the United States, with the white-tailed deer harvest consistently exceeding 150,000 animals per year (199,863 in the 2024–25 season) [Arkansas Game and Fish Commission, 2025]; resident and nonresident sportspersons spent approximately $1.5 billion on fishing and hunting in the state in 2011 [U.S. Fish and Wildlife Service, 2014]. Hunting lease markets, outfitter operations, and recreational land purchases represent a growing share of rural land demand, particularly in regions where traditional agricultural returns are declining. Yet despite the economic significance of hunting to rural land markets, remarkably little hedonic evidence exists on how proximity to public hunting lands—specifically state-managed Wildlife Management Areas (WMAs)—capitalizes into property values.

The hedonic pricing framework of Rosen [1974] predicts that if hunters value access to quality hunting, proximity to well-managed public hunting lands should be reflected as a premium in surrounding rural property values—the positive amenity capitalization documented for open space, water bodies, and protected areas across the environmental economics literature [Cho et al., 2006, Lansford and Jones, 1995, Walls et al., 2015, Bastian et al., 2002]. In agricultural land markets, Palmquist [1989] shows that hedonic gradients on spatial attributes can be interpreted as the equilibrium valuation of those attributes for both productive and consumptive (recreational) uses. Under this theoretical prior, the coefficient on WMA proximity in a hedonic regression of rural land transaction prices should be *positive*: closer equals more valuable.

The empirical obstacle is data. Arkansas does not publicly release parcel-level transaction records, and the commercial alternatives—ATTOM Data Solutions and CoreLogic's real-estate transaction database—require institutional licensing fees that exceed available project budget. The previously standard free-to-academia option, Zillow's Transaction and Assessment Dataset (ZTRAX), was discontinued in September 2023, eliminating the principal low-cost route for academic transaction-data access. We therefore build and validate the spatial hedonic pipeline on the one parcel-level dataset that is universally available: tax-assessed agricultural values from the Arkansas GIS Office's Computer-Assisted Mass Appraisal (CAMA) snapshot, covering 308,226 vacant-agricultural (AV-classified) parcels matched to fourteen spatial data sources (soil quality, hydrology, land cover, roads, urban access, federal public lands, floodplains, gas wells, CRP enrollment, elevation, WMA boundaries, CWD zones, deer-harvest biodata, and county demographics), entering the regressions as eleven parcel-level controls plus fixed-effect-absorbed county and zone variables. These appraised use values are not market prices—they capitalize soil productivity under the state's use-value statute (detailed in Section 3) rather than reflecting demand—but they share the same parcel-level spatial structure that transaction prices will, making them a defensible proof-of-concept source for stress-testing the econometric pipeline before a full causal analysis.

This paper's contribution is methodological. We construct a spatial hedonic pipeline for Arkansas rural land values, demonstrate its econometric properties through ten identification-robustness checks (functional form, Conley spatial HAC, wild cluster bootstrap, generated-regressor bias, soil-control attenuation, CWD intensity, donut-hole exclusion, leave-one-out county, coarsened exact matching, and placebo distance), and show that the WMA $< 1/4$ mile coefficient is stable across all perturbations. The assessed-value cross-section produces a *negative* gradient—opposite the positive amenity prediction—which we attribute primarily to WMA placement on marginal terrain (bottomland hardwoods, steep Ozark hillsides, flood-prone land) combined with assessor under-reaction to recreation amenity value. This sign discrepancy is itself diagnostic: it motivates transaction-data acquisition by showing that assessed values cannot substitute for sale prices when testing amenity capitalization. The validated pipeline is designed to detect the theoretically predicted positive gradient as soon as rural sale data become available, with a staggered difference-in-differences design around Arkansas's phased CWD-zone expansion (10 counties in 2016, 15 in 2018, 17 in 2021) as the leading follow-on identification strategy [Callaway and Sant'Anna, 2021, Sun and Abraham, 2021].

The integration of deer-harvest biological data into a hedonic land-value model is, to our knowledge, novel. Age-normalized Boone & Crockett z-scores constructed from AGFC check-station records serve as a continuous measure of spatial variation in deer trophy quality that can be tested as a hedonic attribute. No prior study has used administrative wildlife harvest records as a deer quality index in a property value regression.

This paper makes three contributions. First, it builds and validates a reproducible spatial hedonic pipeline for Arkansas rural land, integrating fourteen spatial data sources onto 308,226 parcels and stress-testing the estimated gradient through ten identification-robustness checks and a four-estimator inference suite (county-clustered, Conley spatial HAC, wild cluster bootstrap, and generated-regressor bootstrap). Second, it constructs an age-normalized Boone & Crockett deer-quality index from administrative harvest records—to our knowledge the first use of such records as a hedonic attribute—and establishes what a single cross-section can and cannot identify with it. Third, it documents and diagnoses a negative assessed-value gradient that is the *opposite* of the market-price prediction, demonstrating why use-value assessments cannot substitute for transaction prices and thereby scoping the transaction-data program the pipeline is built to serve. The contribution is methodological and infrastructural: the paper does not test the amenity-capitalization hypothesis, which a use-value dependent variable cannot support.

Section 4 details the hedonic specification and inference strategy. Section 5 reports the main regression results. Section 6 presents the ten identification-robustness checks. Section 7 presents the deer-quality deep dive. Section 8 discusses interpretation, particularly the assessed-value-vs.-sale-price divergence. Section 9 summarizes limitations and the transaction-data roadmap.

2 Literature Review

2.1 Hedonic Amenity Capitalization and Public-Land Proximity

The theoretical foundation is the hedonic pricing model of Rosen [1974], which decomposes differentiated-good prices into the implicit values of their attributes, with microeconomic roots in Lancaster [1966]. Palmquist [1989] extends the framework to treat land as a differentiated factor of production, showing that hedonic coefficients on land attributes can be interpreted as marginal productivities in agricultural markets where parcels serve both productive and consumptive (recreational) functions. Applied to rural land, the hedonic equation accommodates spatial characteristics as continuous or binned distance gradients, whose functional form—linear, log-linear, or nonparametric—must be empirically determined; we estimate both continuous and binned specifications.

A substantial literature documents positive capitalization of environmental amenities. Cho et al. [2006] find that forest and open-space proximity raises farmland values with distance decay; Lansford and Jones [1995] document water-body premia within one to two miles; Walls et al. [2015] estimate positive effects of protected-area proximity on residential values. For agricultural markets specifically, Bastian et al. [2002] show that wildlife habitat and scenic amenities capitalize into Wyoming agricultural values even where production is the dominant use, and Abbott and Klaiber [2010] demonstrate that the value of open-space preservation depends on the alternative land use it displaces.

Hedonic evidence on public hunting land is scarcer. The only parcel-level comparison is Casola et al. [2022], who estimate spatially heterogeneous effects of North Carolina Game Lands on residential sale prices: proximity is positive at moderate distances but adjacency is negative, consistent with congestion or nuisance-wildlife effects. Their study uses residential properties, omits harvest-quality variables, and does not consider CWD. The sign reversal between Casola's residential setting (premium near public hunting land at moderate distances) and the rural-agricultural setting we examine (discount near WMA boundaries) is itself informative: residential markets capitalize hunting *access* as a consumption amenity, while rural farm and timber markets reflect pre-existing land *quality*. WMAs in both settings tend to occupy negatively-selected terrain, but the implied capitalization differs because the marginal buyer differs—an asymmetry we return to in Section 8 when interpreting the negative rural gradient as consistent with placement selection rather than amenity capitalization. On the income side, Hussain et al. [2013] estimate that hunting-lease income capitalizes at a 7.55% rate in Mississippi forestland sales ($1/acre lease ≈ $13.25/acre in sale price), and Munn and Hussain [2010] find that a 10% increase in trophy-deer share raises lease rates by roughly $106 per hunter on Mississippi 16th Section lands. Pope and Goodwin [1984] estimates that hunting rights broadly add 10–25% to farmland values using farm-level survey data. None of these papers jointly estimates WMA proximity, harvest quality, and CWD effects—the methodological gap this pipeline addresses.

Identification is the common challenge. Public-hunting lands are not randomly placed: agencies establish WMAs on marginal terrain (bottomland, steep slopes, flood-prone areas), creating mechanical negative correlation between WMA proximity and agricultural value. Walls et al. [2015] address this with boundary discontinuity designs; we rely on county and deer-zone fixed effects to absorb area-level confounders and complement with ten identification-robustness checks (Section 6), while acknowledging that cross-sectional identification remains limited until transaction data enable difference-in-differences designs.

2.2 Wildlife Disease Economics and Arkansas Context

Chronic Wasting Disease (CWD), a fatal prion disease of cervids, has emerged as a significant wildlife-management concern since its expansion beyond endemic areas in the early 2000s. Bishop [2004] documents a roughly 5% decline in Wisconsin deer hunting permit demand and approximately $10 million in lost license revenue after CWD detection in 2002. Erickson et al. [2019] extend this finding to a longer window, estimating a 5.4% decline in Wisconsin license demand representing $96 million in consumer-surplus loss over 2002–2015, with effects attenuating as hunters habituated. Zimmer et al. [2012] surveys Alberta hunters and finds that CWD detection altered hunter behavior and trip choices, although perceived health risk remained low. Poudyal et al. [2025] provide the first peer-reviewed hedonic estimate of CWD capitalization into land markets, finding that on-property CWD detection reduces Tennessee and Mississippi hunting-lease rates by 22% ($1.84/acre/year) with no significant effect for nearby-property detection. No study has yet estimated CWD effects on sale prices—a gap that requires transaction data, temporal variation in CWD status, and a credible control group.

Arkansas provides both the setting and the identifying variation. The state's diverse physiographic regions—the flat, productive Mississippi Delta; the rugged Ozark Plateau; the Ouachita Mountains—generate substantial heterogeneity in agricultural land value and hunting quality, with WMA placement patterns that reflect this geography: Delta WMAs (Bayou Meto, Dagmar, Rex Hancock–Black Swamp) manage waterfowl and deer in bottomland hardwoods, while Ozark WMAs (Gene Rush, Piney Creeks, Wedington) occupy steep forested terrain. The Arkansas CWD timeline—initial detection in Newton County in February 2016, phased zone expansion to 15 counties in 2018 and 17 in 2021—supplies the staggered treatment assignment needed for the Callaway and Sant'Anna [2021] or Sun and Abraham [2021] difference-in-differences estimators, once transaction data become available.

3 Study Area and Data

3.1 Study Area and Sample

The study area covers all 75 Arkansas counties (approximately 53,000 square miles), encompassing 191 WMA boundaries managed by the AGFC, the 17 CWD management-zone counties as of 2024–25, and the state's 20 deer management zones organized into six Deer Management Units (DMUs). Figure 1 displays the WMA, CWD, and deer-zone boundaries. The cross-classified DMU–zone–county structure—deer zones cross county lines, with all 20 zones spanning multiple counties and 59 of the 73 sampled counties spanning multiple zones—provides natural fixed-effect groups for absorbing zone-level variation in hunting regulation and habitat quality, distinct from (not nested within) the county fixed effects.

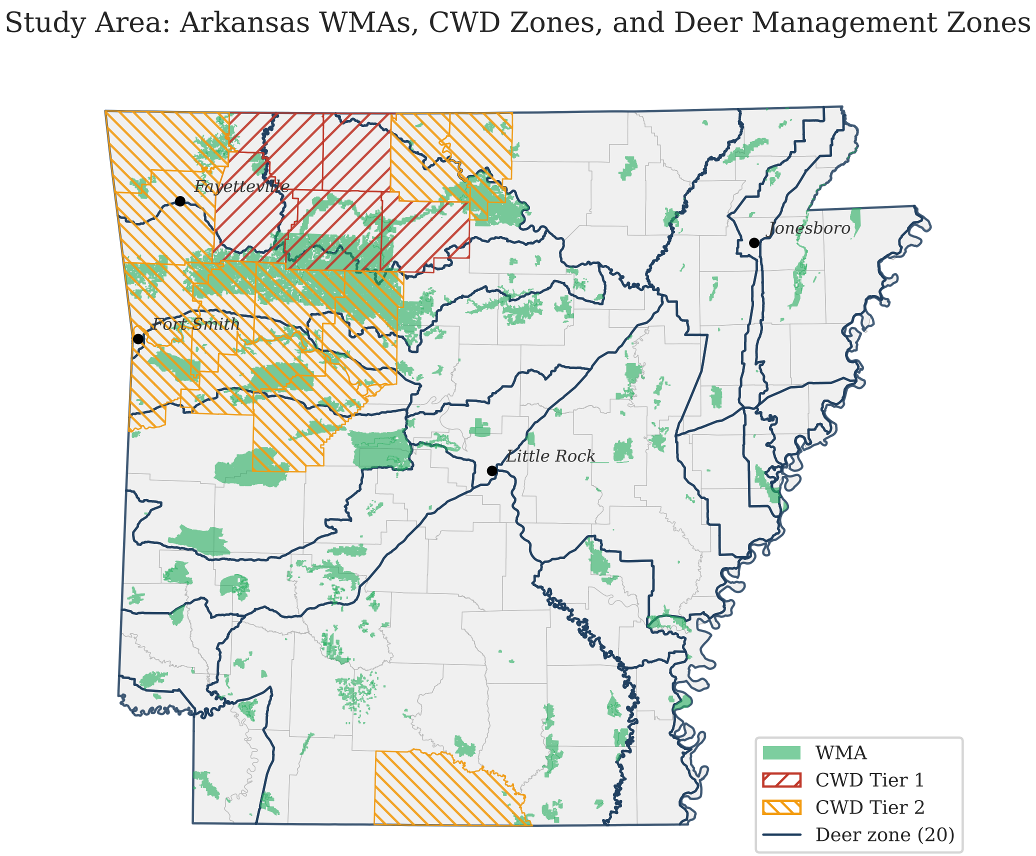


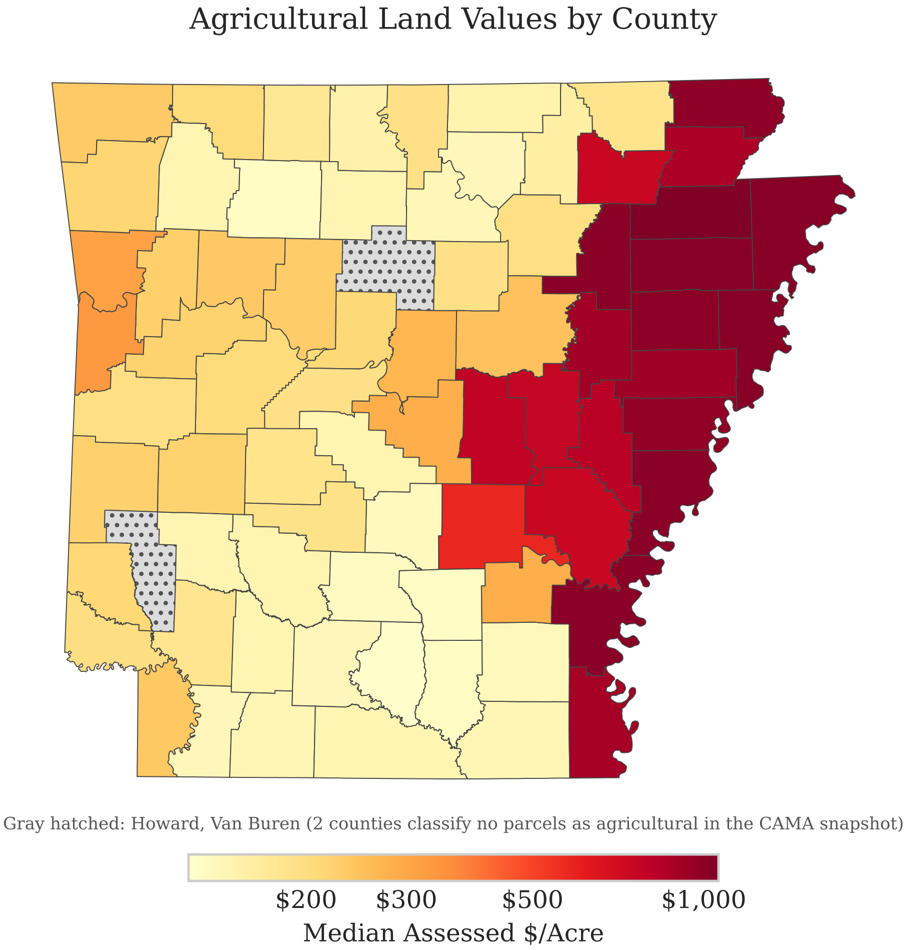
Figure 1: Study area map: Wildlife Management Areas (WMAs, green), CWD management-zone boundaries (Tier 1 red hatched, Tier 2 orange hatched), and the 20 deer management zones (dark blue outlines) across Arkansas's 75 counties.

The spatial backbone is 2,111,591 parcel centroids from the Arkansas GIS Office (PARCEL_CENTROID_CAMP, September 2025 snapshot) with CAMA attributes (assessed land value, acreage, parcel type, county). The statewide data is distributed as point centroids rather than polygon boundaries; all distance computations therefore measure from the centroid to the nearest WMA boundary edge. For large parcels near WMA boundaries, centroid distance may overstate the true nearest-edge distance. The *boundary_adjacent_wma* control (Section 4.2) partially addresses this by flagging parcels whose polygon boundary touches a WMA, and the donut-hole robustness test (Section 6) confirms the gradient survives after dropping the highest-leverage near-boundary parcels. The analysis sample restricts to 308,226 vacant-agricultural (AV) parcels between 5 and 5,000 acres, trimmed at the 1st and 99th percentiles of land value per acre ($86/ac and $1,250/ac). The 5-acre minimum excludes 42,900 sub-agricultural-scale parcels (residential lots, garden plots, assessment artifacts); the 5,000-acre cap is non-binding (zero AV parcels exceed it). Section 6 reports a sample-filter sensitivity test confirming that the WMA proximity gradient is unchanged across alternative acreage minimums (1, 5, 10 acres) and trim thresholds (none, 1/99, 2.5/97.5, 5/95). Vacant-agricultural is the cleanest dependent variable for proximity-gradient estimation: parcels with agricultural improvements (AI, AM types) conflate land value with structure value in the CAMA assessed total. The dependent variable is the natural log of appraised land value per acre; Figure 2 maps county-mean values. Summary statistics are in Table 1; the full variable dictionary and data-acquisition pipeline are in Appendix B.

What the dependent variable measures. Arkansas appraises agricultural, pasture, and timber land at *use value* rather than market value, as mandated by Amendment 59 to the state constitution and codified at Ark. Code Ann. § 26-26-407: the county assessor capitalizes the typical net income the soil can produce, using NRCS soil-productivity classes and a statutory capitalization rate set annually by the Arkansas Assessment Coordination Division, and market (sale) value is explicitly excluded as a basis. The dependent variable is therefore the appraised *use* value of land per acre—an administrative function of soil productivity and county, not a market price. The data bear this out: parcel-level NCCPI alone explains $R^2 = 0.13$ of ln(value/acre), county fixed effects alone explain $R^2 = 0.52$, and the two together with ln(acres) reach $R^2 = 0.56$. The negative WMA gradient should accordingly be read as a property of the use-value schedule—WMAs occupy lower-productivity soil that the schedule prices lower—rather than as evidence about market demand. This is the central reason the proof-of-concept cannot test the amenity-capitalization hypothesis: a use-value dependent variable contains, by construction, no market signal for the pipeline to recover. The hypothesis test requires transaction prices, where the predicted sign is positive.

The analysis sample is built in sequential steps: 2,111,591 statewide parcel centroids → 357,611 vacant-agricultural (AV) parcels → 314,711 after the 5–5,000 acre filter (the 5-acre minimum drops 42,900 sub-agricultural-scale parcels) → 314,533 after requiring positive land value per acre → 308,266 after trimming the 1st and 99th percentiles of value per acre → 308,226 in the final regression sample, after the deer-zone spatial join, dropping the two counties with fewer than 30 AV parcels, and requiring non-missing parcel-level controls.

Because the size floor and value trim could in principle remove WMA-adjacent parcels differentially, we checked the WMA-distance composition of the dropped parcels. The sub-five-acre slivers and the trimmed parcels are only marginally nearer WMAs than the analysis sample: 5.5% and 6.1% lie within 1/4 mile of a WMA, respectively, versus 4.6% of kept parcels (median distances 5.4 and 5.8 versus 5.8 miles). This small proximity skew does not drive the gradient—the acreage-minimum sensitivity in Section 6, which retains the sub-five-acre parcels at a one-acre floor, leaves the <1/4 mile coefficient within the $[-0.064, -0.099]$ range reported there.



Agricultural Land Values by County

Gray hatched: Howard, Van Buren (2 counties classify no parcels as agricultural in the CAMA snapshot)

Figure 2: Mean assessed land value per acre by county. Higher values (darker shading) concentrate in the Delta agricultural region and near metropolitan Northwest Arkansas and Pulaski counties.

Table 1: Summary Statistics (N = 308,226 AV-only parcels)

Variable	Mean	SD	Min	Max
Dependent variable and parcel-level attributes (N = 308,226 parcels)				
Assessed land value/acre ($)	322	342	86	1,250
ln(land value/acre)	5.36	0.83	4.46	7.13
Distance to WMA (km)	11.44	9.49	0.00	56.3
Parcel acreage	60.2	87.2	5.0	1,308
nccpi_weighted_avg (parcel)	0.47	0.20	0.00	0.88
is_forest	0.45	0.50	0	1
is_wetland	0.09	0.29	0	1
in_100yr_floodplain	0.15	0.36	0	1
in_national_forest	0.0002	0.014	0	1
boundary_adjacent_wma	0.04	0.20	0	1
ln(dist. paved road, km)	0.21	1.10	−3.00	3.16
ln(dist. urban area, km)	3.68	1.12	−3.00	5.00
ln(dist. water body, km)	−1.07	0.97	−3.00	1.87
ln(dist. federal land, km)	2.42	1.40	−3.00	4.40
Zone-level attribute (20 zones, repeated per parcel)				
mean_bc_zscore (zone-level)	0.033	0.25	−0.23	0.73

County-level controls used only in Model 5 (*crp_pct_county_area*, *in_cwd_zone*, *ln_population*, *ln_median_income*, *mean_nccpi*, *elevation_km*, *in_fayetteville_shale*, *pct_prime_farmland*) are summarized in Table 6.

Figure 3 displays the dependent-variable distribution before and after the 1st/99th percentile trim. The distribution is bimodal, reflecting the Delta/Ozark physiographic split in Arkansas agricultural land values: a lower mode near ln(value/ac) ≈ 4.5 (marginal Ozark and Ouachita land) and a higher mode near ln(value/ac) ≈ 7.0 (productive Delta row-crop ground). The trim cuts remove roughly 2% of AV parcels concentrated at both extremes of the raw assessed-value distribution.

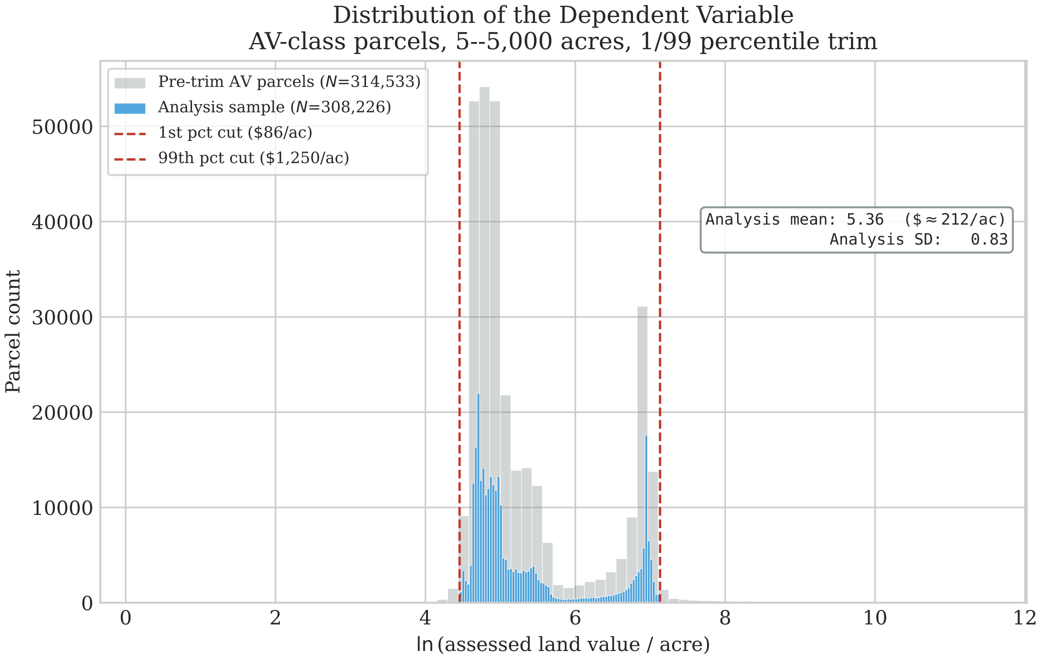


Figure 3: Distribution of the dependent variable, ln(assessed land value / acre). Gray: pre-trim AV-class parcels (N = 314,533). Blue: the canonical analysis sample (N = 308,226). Dashed red lines at \$86/ac and \$1,250/ac. The bimodal shape reflects the Delta/Ozark physiographic split.

Marginality classification. For the placement-endogeneity discussion in Section 8, we operationalize a parcel as *marginal agricultural land* when its parcel-level *nccpi_weighted_avg* (the SSURGO area-weighted National Commodity Crop Productivity Index, scaled 0–1) is below the statewide median of 0.489 on the AV-trimmed regression sample. This threshold approximates NRCS Land Capability Classes 6–8 and isolates bottomland hardwood, steep Ozark, and flood-prone soils—the land types historically targeted for WMA acquisition under Pittman-Robertson and subsequent state programs. An alternative threshold of NCCPI $<$ 0.40 (close to the AV-sample 25th percentile) yields qualitatively identical placement-bias patterns. Section 8 reports the share of WMA-adjacent versus non-adjacent AV parcels that fall below each threshold.

Centroid-distance measurement error. Parcel-to-WMA distance in this paper is measured from the parcel centroid to the nearest WMA boundary edge. For large parcels the centroid distance can substantially overstate the true minimum edge-to-edge distance between the parcel polygon and the WMA. Using the AR GIS Cadastre parcel polygons cached by the WMA-adjacency download (covering parcels within 500 m of any WMA, approximately 111,308 AV-sample parcels), we compute the gap between the centroid-to-WMA-boundary distance and the true polygon-to-WMA-boundary distance. Across the 12,323 AV parcels flagged $boundary\_adjacent\_wma = 1$, the median gap is 193 m, the 90th percentile is 404 m, the 99th percentile is 817 m, and the maximum is 1,599 m. The gap scales with parcel size as expected: for parcels in the smallest acreage quartile (median 12 ac), the median gap is 103 m; in the largest quartile (median 234 ac), the median gap is 307 m and the 90th percentile is 658 m. The categorical <1/4 mile bin (radius 402 m) is therefore conservative—true polygon adjacency reaches deeper than centroid distance suggests—and the $boundary\_adjacent\_wma$ dummy in Model 3 is the cleaner adjacency control because it is constructed from polygon-to-WMA proximity rather than centroid distance. The donut-hole robustness test (Section 6) further confirms the gradient is not driven by the boundary-measurement issue.

3.2 Spatial Controls and Deer-Quality Construction

Fourteen spatial data sources are integrated through programmatic acquisition scripts (full inventory and variable mapping in Appendix B). These include AGFC WMA boundaries (yielding the distance, inside-WMA, and bin variables), Census TIGER/Line roads (paved-road distance), Census Urban Areas 2020 (metro distance), NLCD 2021 (forest and wetland cover), the National Hydrography Dataset (water feature distance), the FEMA National Flood Hazard Layer (floodplain), USGS PAD-US (federal public-land distance and national-forest flag), USGS 3DEP (elevation), Arkansas Oil and Gas Commission well permits (Fayetteville Shale flag), USDA NASS Census of Agriculture (CRP enrollment), USDA SSURGO soils (parcel-weighted NCCPI via spatial join), AGFC harvest reports (CWD zone status, detection counts, seasons-in-zone), AGFC biodata (Boone & Crockett z-score), and Census ACS 5-year data (population, income). Parcel-level variables are computed by spatial overlay or nearest-feature query; county-level variables are matched by FIPS; deer-zone variables aggregate to the 20 AGFC management zones (as of the 2020–21 season; prior to that season, AGFC maintained 25 zones before consolidating several A/B subzones—e.g., merging Zones 1A, 6, and 6A into Zone 6—into their parent zones). The analysis uses the current 20-zone configuration throughout. County-level controls (county-mean NCCPI, elevation, log population, etc.) are excluded from county-fixed-effects models to avoid collinearity; they appear only in Model 5, which substitutes county controls for fixed effects (Section 4.2).

The deer trophy-quality index is a Boone & Crockett (B&C) z-score constructed from 145,538 AGFC check-station records (2009–10 through 2024–25). For each age class $a \in \{1.5, 2.5, 3.5, 4.5, 5.5+\}$, the statewide mean $\bar{s}_a$ and standard deviation σ_a of gross B&C scores are computed (excluding the 2013–14 season, which had a formula error). Each buck's score is standardized within age class as $z_{ij} = (s_{ij} - \bar{s}_{a(j)})/\sigma_{a(j)}$ and the zone-season mean is $\overline{z}_{zt} = n_{zt}^{-1} \sum_{j \in (z,t)} z_{ij}$. The score is the gross (pre-deduction) B&C score; typical versus non-typical frame classification is not recorded in the AGFC biodata, but gross scores capture overall antler development regardless of frame type and the distinction is material only near record-book thresholds (∼160 inches), which fewer than 1% of harvested bucks reach. The normalization is essential because older bucks produce systematically higher raw scores (Figure 18, Appendix B); a zone-level $\overline{z}_{zt} = +0.5$ means harvested bucks scored half a standard deviation above the statewide norm for their age class. Each parcel inherits its deer zone's z-score, implying 20 unique values (one per zone) and treating within-zone variation as measurement error; the generated-regressor bootstrap in Section 6 quantifies the inferential consequences.

Figure 4 displays the geographic distribution of the check-station records by county of harvest. Coverage is statewide but concentrated in the Ozark counties where fall harvest volume is highest (Madison, Newton, Searcy, Baxter each exceed 4,000 records), providing dense support for the zone-level B&C z-score in the hunting-intensive regions of the state. Some constituent counties in southern Delta zones have 50–200 records per year, limiting precision of county-level quality estimates but still yielding adequately-sized zone-season cells (median zone-season cell $n = 142$).

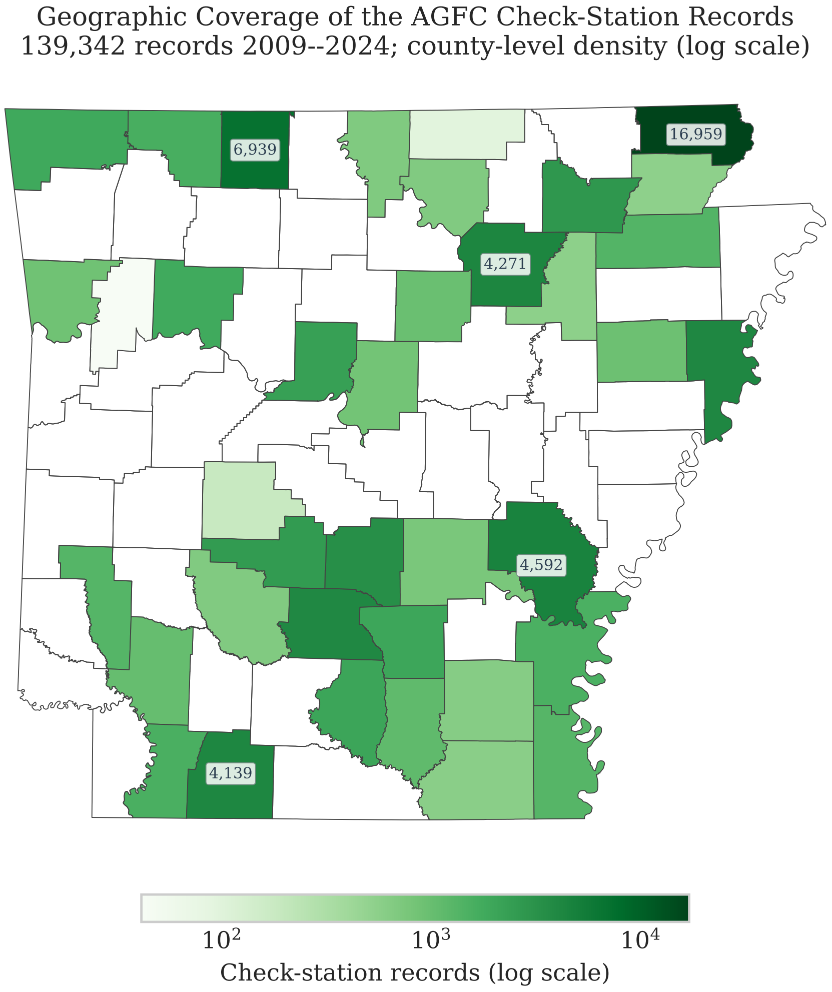


Figure 4: Geographic coverage of the AGFC check-station biodata. County-level density (log scale) of 139,342 records with valid county identifiers, 2009–2024 seasons. Top-five counties account for roughly 26% of statewide coverage.

3.3 CWD Timeline

CWD zone status is compiled from AGFC annual harvest reports. Arkansas's first CWD detection was in a captive elk in Newton County (February 2016). Zone expansion followed a staggered timeline (Table 2), providing the treatment variation needed for a future difference-in-differences design. Cumulative detections through FY25 total 2,036 positive deer; Newton County alone accounts for 970 positives (47.6%), and the top five counties for 89.0%—reflecting both the disease epicenter and concentrated surveillance effort (Figure 5). Details on testing volume and prevalence trends are in Appendix C.

Table 2: CWD Management Zone Expansion in Arkansas

Season	Counties in Zone	Key Changes
2016–17	10	Initial zone: Boone, Carroll, Johnson, Logan, Madison, Marion, Newton, Pope, Searcy, Yell
2018–19	15	Added Benton, Crawford, Franklin, Sebastian, Washington
2021–22	17	Added Baxter, Union; two-tier system (Tier 1 = core, Tier 2 = peripheral)
2024–25	17	No change

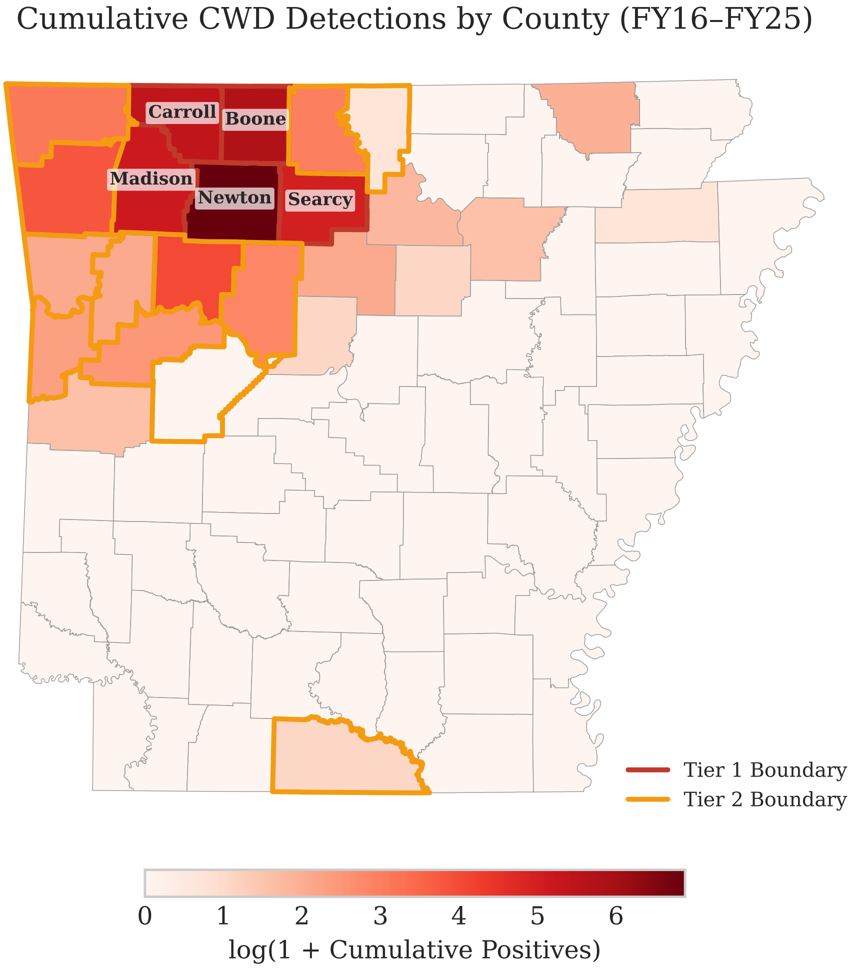


Figure 5: Cumulative CWD detections by Arkansas county through FY25. Newton County accounts for 970 of 2,036 positives (47.6%).

4 Methodology

Complete variable definitions are in Appendix B.

4.1 Hedonic Model

The base specification is a semi-log hedonic price function:

$$\ln(\text{price}_i) = \alpha + \beta \cdot \mathit{dist\_wma}_i + \mathbf{X}_i'\boldsymbol{\gamma} + \delta_c + \epsilon_i \tag{1}$$

where price_i is assessed land value per acre for parcel i, $\mathit{dist\_wma}_i$ is the Euclidean distance (km) from the parcel centroid to the nearest WMA boundary, $\mathbf{X}_i$ is a vector of parcel-level spatial controls, δ_c are county fixed effects, and ϵ_i is the error term. All percentage effects are computed using the exact transformation $(\exp(\hat{\beta}) - 1) \times 100$. The extended bin specification replaces continuous distance with categorical distance bins:

$$\ln(\text{price}_i) = \alpha + \sum_{b=1}^{6} \phi_b \cdot \mathbf{1}[\mathit{wma\_dist\_bin}_i = b] + \theta \cdot \mathit{inside\_wma}_i + \mathbf{X}_i'\boldsymbol{\gamma} + \delta_c + \delta_z + \epsilon_i \tag{2}$$

with bins <1/4 mile, 1/4–1/2 mile, 1/2–1 mile, 1–2 miles, 2–3 miles, and 3–5 miles, and >5 miles as the reference. The indicator $\mathit{inside\_wma}_i$ flags parcels whose centroids fall within a WMA boundary; the coefficients δ_z are deer-zone fixed effects.

Table 3 reports the parcel distribution across the seven bins. Roughly 44% of the sample lies within five miles of a WMA boundary—enough support for a nonparametric distance gradient—and the near-WMA bins contain 14,215, 8,012, and 13,860 parcels in the <1/4, 1/4–1/2, and 1/2–1 mile bands respectively, all large enough to deliver precise bin coefficients.

Table 3: Distribution of the Analysis Sample Across WMA Distance Bins

WMA distance bin	Parcels (N)	Share of sample (%)	Cumulative share (%)
<1/4 mile	14,215	4.6	4.6
1/4–1/2 mile	8,012	2.6	7.2
1/2–1 mile	13,860	4.5	11.7
1–2 miles	26,712	8.7	20.4
2–3 miles	25,811	8.4	28.7
3–5 miles	48,203	15.6	44.4
>5 miles (ref.)	171,413	55.6	100.0
Total	308,226	100.0	

4.2 Specification and Inference

County fixed effects (δ_c, 73 of Arkansas's 75 counties; Howard and Van Buren are absent from the AV sample because their assessment systems classify no parcels as vacant-agricultural) absorb all time-invariant county-level characteristics—soil quality, topography, labor markets, tax regime, assessor practices—and deer-zone fixed effects (δ_z, 20 zones) absorb zone-level variation in hunting regulation and physiography. County-level variables (elevation, soil productivity, CRP enrollment, CWD-zone status, population, median income, prime-farmland share, Fayetteville Shale overlay) are linear combinations of the county dummies and so cannot be identified separately from δ_c; they therefore appear only in Model 5, which substitutes them for county FE.

Spatial correlation in land values violates the independence assumption underlying conventional standard errors. The primary inference uses *county-clustered* standard errors (73 clusters, which allow arbitrary within-county correlation); *HC1* White standard errors are reported for comparison (and are typically ∼3–5× smaller, indicating substantial within-county correlation); and Conley [1999] spatial HAC standard errors across 25/50/75 km bandwidths provide a third check that allows correlation to decay smoothly with distance rather than snap to county boundaries. Because the 73-cluster count is borderline for asymptotic cluster-robust inference, we also report wild cluster bootstrap p-values with $B = 999$ Rademacher weights [Cameron et al., 2008] in Section 6. For the deer-quality z-score in Model 6, which is constructed from a first-stage aggregation of harvest records and is therefore a generated regressor, we report a stratified bootstrap that propagates first-stage sampling error into second-stage inference [Pagan, 1984]; details in Section 6.5.

4.3 Model Specifications

Three models form the main-text baseline. Model 1 estimates Equation (1) with continuous WMA distance and county FE on the AV-only sample. Model 2 adds deer-zone FE to isolate the within-zone gradient. Model 3 replaces continuous distance with the six distance bins (Equation (2)), allowing a nonlinear gradient. Table 4 enumerates these baselines plus five additional variants used in Section 6 or in the appendices.

Table 4: Model Specifications

Model	FE	Distance	Sample	Purpose
M1	County	Continuous	AV	Baseline hedonic
M2	County + Zone	Continuous	AV	Within-zone gradient
M3	County + Zone	Bins	AV	Nonlinear gradient (main)
M4	County	ln(distance)	AV	Log-distance spec
M5	Zone + cty controls	Continuous	AV	Substitute controls for FE
M6	County	Cont. + z-score	AV	Quality replaces zone FE
M7	County	Cont. + z × dist	AV	Quality × distance
M8	Zone + cty controls	Bins × CWD	AV	CWD × proximity
M9	County + Zone	Bins × region	AV	Physiographic heterogeneity

The stability of the WMA gradient across these specifications (Section 6) demonstrates that the core result is not an artifact of any particular modeling choice; it identifies which specifications are cross-sectionally feasible (all bin specifications) versus which require the temporal variation in transaction data for credible identification (continuous-distance interactions, CWD dynamics).

5 Results

5.1 WMA Proximity Gradient

Table 5 reports WMA proximity coefficients for the three main specifications on the AV-only sample (N = 308,226). The distance-bin specification (Model 3) produces a robust, monotonic negative gradient concentrated within two miles of the WMA boundary; full regression output is in Appendix A.

Table 5: WMA Proximity Coefficients, Main Specifications (AV-Only, $N = 308{,}226$)

	Model 1 (County FE)	Model 2 (+Zone FE)	Model 3 (Bins)
dist_to_wma_km	−0.0023	+0.0016	—
	(0.0029)	(0.0012)	
<1/4 mile (*<¼ mile*)			−0.0820***
			(0.0243)
1/4–1/2 mile			−0.0786***
			(0.0225)
1/2–1 mile			−0.0488*
			(0.0199)
1–2 miles			−0.0367*
			(0.0179)
2–3 miles			−0.0277
			(0.0152)
3–5 miles			−0.0079
			(0.0137)
inside_wma_flag[2]	−0.1468***	−0.1302***	—
	(0.0287)	(0.0220)	
boundary_adjacent_wma	−0.0978***	−0.0640***	−0.0310**
	(0.0198)	(0.0170)	(0.0112)
County FE	Yes	Yes	Yes
Deer Zone FE	No	Yes	Yes
R^2	0.6651	0.7161	0.7162

County-clustered SEs in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Model 3 reference category: >5 miles. All models include parcel-level controls: *ln_dist_paved_km*, *ln_dist_ua_km*, *is_forest*, *is_wetland*, *ln_dist_any_water_km*, *in_100yr_floodplain*, *ln_dist_federal_km*, *in_national_forest*, *ln_acres*, *nccpi_weighted_avg*.

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[2] The inside-WMA indicator is correlated with—but not collinear with—the <1/4 mile distance bin (inside-WMA parcels are a strict subset of <1/4 mile, since $dist\_to\_wma\_km = 0$ implies the centroid lies inside a WMA polygon). We omit it from Model 3 for parsimony, but doing so folds the 1,571 inside-WMA inholdings (dist. = 0) into the <1/4 mile bin, where they are 11.1% of the 14,215 parcels. Including *inside_wma_flag* in Model 3 partitions the near-boundary effect into an inholding component ($inside\_wma\_flag = -0.120$, $t = -4.87$) and an adjacency-only component (the <1/4 mile bin among

In Model 3, the four bins within two miles are statistically significant at the 5% level and the gradient is monotonically decreasing: parcels within 1/4 mile are assessed 7.9% lower than parcels beyond 5 miles ($\exp(-0.0820) - 1 = -0.079$), or roughly −$25 per acre at the sample mean of $322/acre; the discount decays to 7.6% at 1/4–1/2 mile (−$24/ac), 4.8% at 1/2–1 mile (−$15/ac), 3.6% at 1–2 miles (−$12/ac), 2.7% at 2–3 miles (−$9/ac, marginally significant at $p = 0.07$), and becomes statistically indistinguishable from zero in the 3–5 mile bin. Model 3 also estimates a separate boundary-adjacency effect: parcels whose polygon directly touches a WMA boundary carry an additional 3.0% discount (−0.031, $p = 0.006$) over and above the bin effect, indicating that direct adjacency captures a margin not absorbed by centroid-distance binning alone. Model 2's continuous-distance coefficient is small and statistically indistinguishable from zero (+0.0016, $p = 0.18$); the bin specification's monotone pattern shows the gradient is concentrated near the boundary rather than smooth across the full distance range. The *inside_wma_flag* coefficient ranges from −0.147 in Model 1 to −0.130 in Model 2 (implied effects of −$44 to −$39 per acre at the sample mean), consistent with vacant-agricultural parcels inside WMA boundaries being assessed primarily on their (low) agricultural productivity. Figure 6 displays the Model 3 bin coefficients with 95% confidence intervals.

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non-inside parcels), and moves the <1/4 mile bin coefficient from −0.0820 to −0.0635 ($t = -2.43$)—a 23% attenuation that leaves the gradient negative, monotone, and significant. We report −0.0820 as the headline (comparable across all robustness perturbations) and the adjacency-only −0.0635 as its inholding-adjusted counterpart.

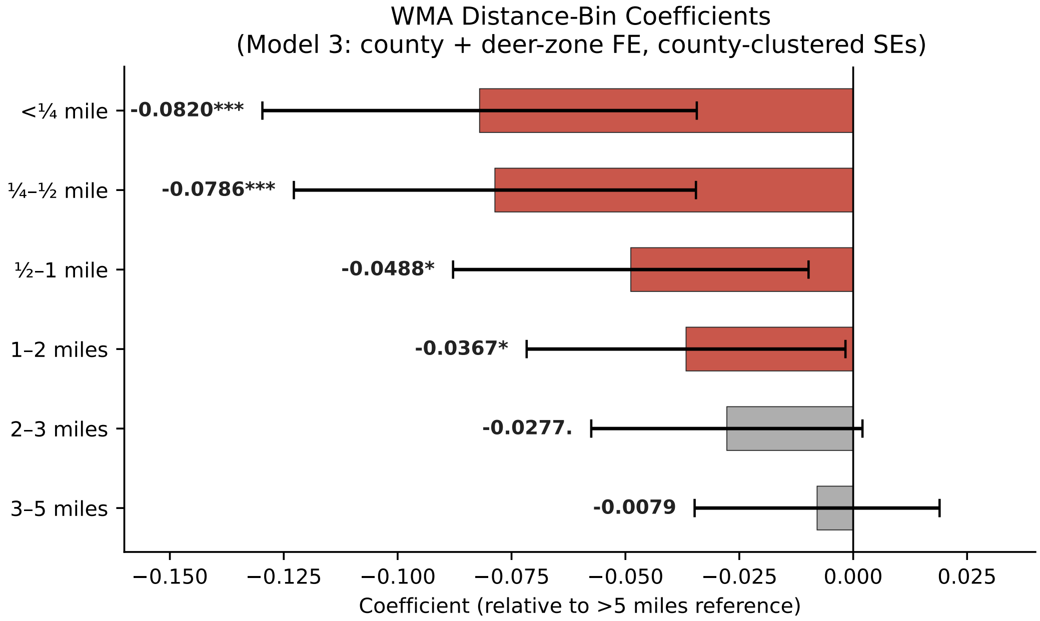

Figure 6: Model 3 distance-bin coefficients with 95% county-clustered confidence intervals. Reference category is >5 miles.

Figure 7 re-expresses the same coefficients in dollar units at the \$322/acre sample mean, applying the exact transformation $(\exp(\hat{\beta}_b) - 1) \cdot \overline{\mathrm{AV}}$ with 95% delta-style CIs from the bin-specific clustered SEs. The implied effects range from $-\$25$/ac at the boundary to $-\$3$/ac at the 3–5 mile bin, where the CI crosses zero.

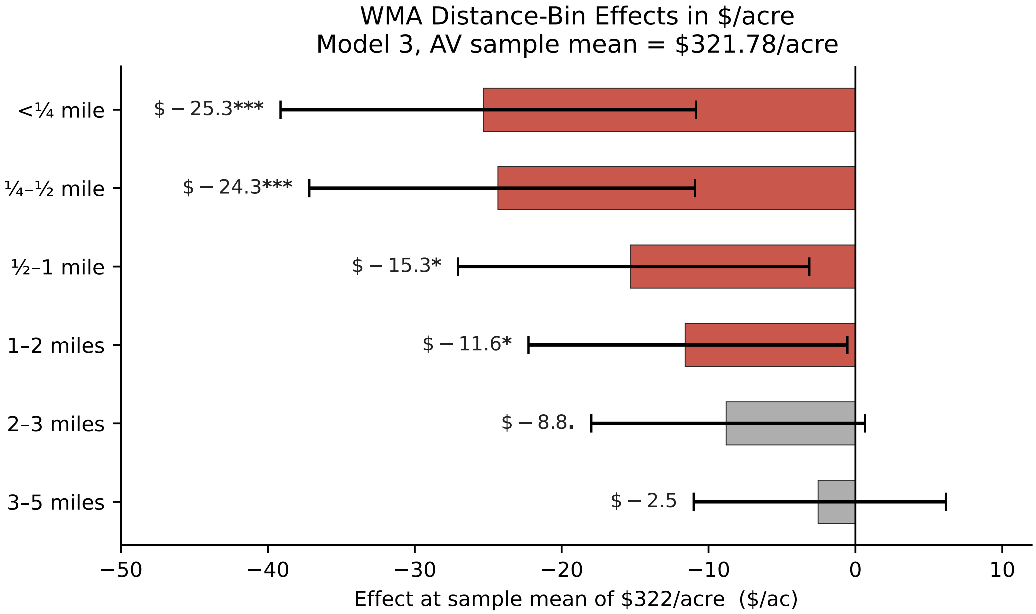

Figure 7: Model 3 distance-bin coefficients translated into $/acre at the AV sample mean of $322/acre. Point estimates are $(\exp(\hat{\beta}_b) - 1) \cdot \overline{\text{AV}}$; whiskers are the analogous 95% CI endpoints from the bin-specific county-clustered SEs.

5.2 Standard Error Comparison

Figure 8 compares the four variance estimators across key coefficients. The pattern is consistent: HC1 standard errors are the smallest (most optimistic), county-clustered SEs are substantially larger (about 4× at the median across the key coefficients shown; 3.24× for the headline $<1/4$ mile bin), and Conley HAC SEs fall between the two.

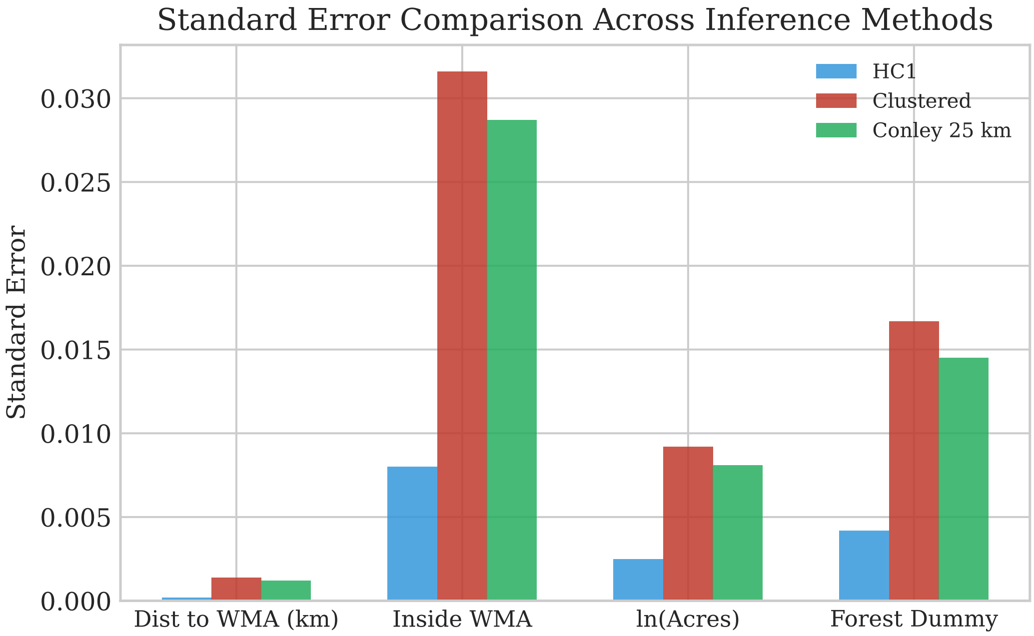

Figure 8: Standard error comparison across variance estimators for key WMA proximity coefficients. HC1 (white) produces the smallest SEs; county-clustered (gray) is about 4× larger at the median (3.24× for the <1/4 mile bin); Conley 25km (blue) and 50km (red) fall in between.

Under the primary county-clustered standard errors, the continuous-distance coefficient is statistically indistinguishable from zero in *both* Model 1 (-0.0023, $p = 0.42$) and Model 2 ($+0.0016$, $p = 0.18$); the apparent "sign flip" between the two is a movement between two near-zero estimates and we do not interpret it as a substantive within-zone gradient. The proximity result rests on the bin specification (Model 3), which does not depend on the continuous-distance term. (For completeness, the median ratio of Conley 25km to county-clustered SEs is 0.88× in Model 1, indicating county clustering is slightly conservative relative to a smooth spatial correlation structure.)

For the distance bin coefficients in Model 3, all bins within 2 miles remain significant at conventional levels under all four variance estimators, providing strong evidence that the proximity gradient is robust to the assumed spatial correlation structure.

5.3 Deer Quality

Model 6 replaces the 20 deer zone fixed effects with a continuous zone-level mean B&C z-score (*mean_bc_zscore*), estimated on the AV zone-matched subsample (N = 308,226). Under clustered OLS, the coefficient is +1.055 (clustered SE 0.224, $t = 4.71$). Because the z-score is a generated regressor (constructed from a first-stage aggregation of harvest records), the OLS standard error understates uncertainty, so we treat a Pagan (1984) stratified bootstrap—resampling first-stage harvest records within zone and re-estimating Model 6 ($B = 200$; full details in Section 6.5)—as the headline inference. The bootstrap distribution has mean +0.80 and 95% CI $[+0.29, +1.22]$: propagating first-stage sampling error attenuates the central estimate by about a quarter relative to OLS while still excluding zero. Reading the bootstrap mean, a one-SD (0.25-unit) increase in zone-level deer quality is associated with roughly +0.20 log points (about 22%) higher assessed land values (physiographic heterogeneity in Appendix D). The OLS estimate sits inside the bootstrap CI, so the two are consistent once first-stage error is propagated. Second, a permutation test ($B = 200$) randomly reassigns the 20 zone-level z-score values across the 20 zones and refits Model 6 under each placebo; the OLS coefficient lies far outside the placebo distribution (placebo SD 0.35, two-sided $p < 0.001$), so the zone-level deer-quality signal is not explainable by random zone reassignment. The z-score varies at the zone level and absorbs zone-level characteristics correlated with deer quality—physiographic region, forest cover, soil type, climate, urban proximity. The R^2 gap between Model 2 (zone FE, 0.7161) and Model 6 (z-score, 0.6823) is 0.034, so the z-score summarizes but does not replicate the full zone FE set. Figure 9 maps the z-score by zone.

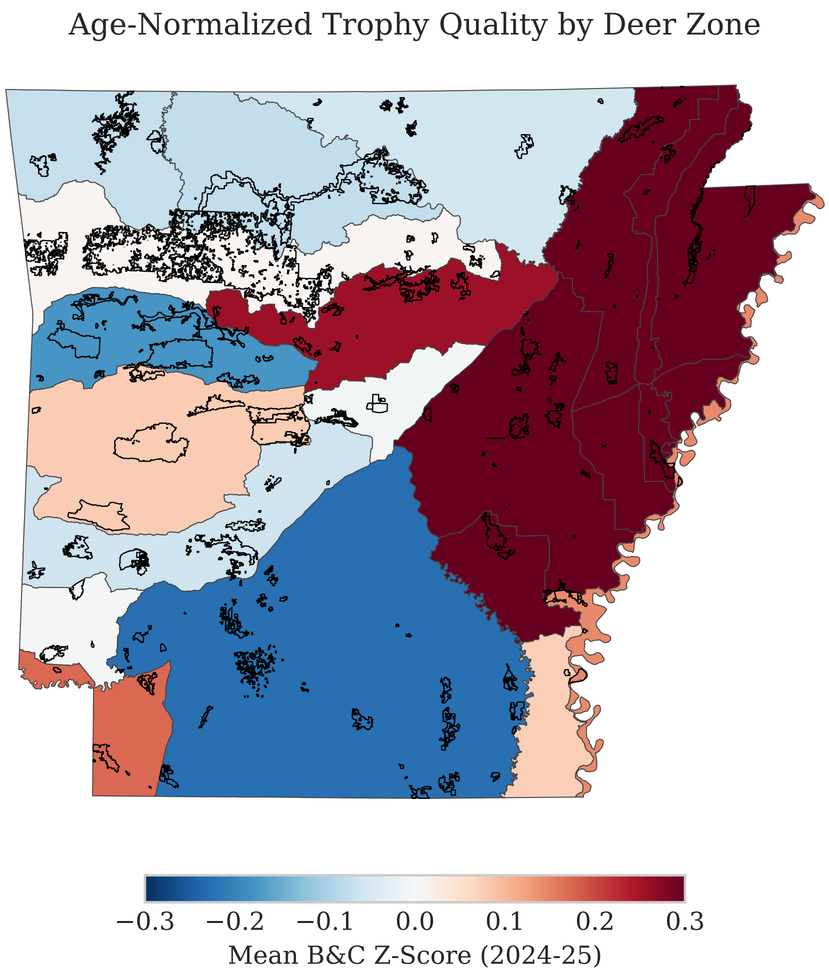

Figure 9: Mean Boone & Crockett z-score by deer management zone (2024–25 season). Higher scores (darker red) indicate above-average age-adjusted antler development. The highest z-scores are in the Mississippi Alluvial Valley and Crowley's Ridge zones, reflecting high-protein forage access; the Ozark Plateau zones score near the statewide norm after age normalization.

5.4 County-Level Controls

Model 5 replaces county fixed effects with explicit county-level control variables, allowing identification of county-level determinants of land values. Table 6 presents the results.

Table 6: County-Level Control Coefficients (Model 5)

Variable	Coefficient	SE (clustered)	p-value
crp_pct_county_area[1]	−0.043	0.014	0.002**
in_cwd_zone	−0.009	0.022	0.682
in_fayetteville_shale	−0.017	0.059	0.767
elevation_km	−0.720	0.163	<0.001***
mean_nccpi	+0.450	0.192	0.019*
ln_population	+0.030	0.013	0.019*
ln_median_income	−0.061	0.056	0.283
pct_prime_farmland	+0.005	0.002	0.002**

Model 5, which substitutes county-level controls for county fixed effects, surfaces several significant county-level predictors. Elevation is strongly negative (-0.72, $p < 0.001$): a 1-km increase in mean county elevation (roughly the Delta-to-Ozark contrast) is associated with 52% lower assessed values, consistent with the placement-on-marginal-terrain mechanism documented in Section 8. County soil productivity (*mean_nccpi*, +0.45, $p = 0.019$) and the prime-farmland share (+0.005 per percentage point, $p = 0.002$) are significant positive predictors at the county level even after parcel-level NCCPI is controlled for (+0.48 in this spec), indicating that both within- and between-county soil variation predict value. CRP enrollment is significantly negative (-0.043 per percentage point, $p = 0.002$), consistent with CRP enrollment concentrating in counties with marginal farmland. Population has a small positive effect (+0.030, $p = 0.019$); median household income, the Fayetteville Shale indicator, and the CWD zone status are individually insignificant.

5.5 CWD Effects

CWD zone status in Model 5 yields a coefficient of -0.009 ($p = 0.68$)—directionally negative but small (under a percent discount, well within sampling noise). Combined with the CWD × continuous-distance interactions reported in Table 7 (-0.0022, $t = -1.13$, $p = 0.26$ under county FE; -0.0029, $t = -2.32$, $p = 0.02$ under county + deer-zone FE), the conclusion is that CWD zone status does not robustly modulate the WMA proximity gradient in the cross-section. The marginally significant zone-FE estimate is consistent with the placement-selection story (CWD counties cluster in the Ozarks where WMA-adjacent parcels are systematically marginal) rather than a disease-specific effect on land values.

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[1] The variable *crp_pct_county_area* is measured in percentage points, so the coefficient represents the effect of a one-percentage-point increase in county conservation enrollment share.

When CWD is interacted with the deer-quality z-score, the strength of the interaction depends substantially on whether deer-zone fixed effects are included. Table 7 reports four specifications under two fixed-effect structures: county FE only and county + deer-zone FE. Under county FE alone, the CWD × z-score interaction is -2.08 ($t = -9.00$, $p < 0.001$): in non-CWD counties the within-zone deer-quality slope is $+1.60$, and in CWD counties it reverses to $+1.60 - 2.08 = -0.48$, an apparent "CWD eliminates the deer-quality premium" pattern. Once deer-zone FE are added, however, this interaction collapses to -0.37 ($t = -1.40$, $p = 0.16$), no longer statistically significant. The mechanism is straightforward: CWD-designated counties cluster in the Ozark Plateau where zone-level z-scores are near the statewide norm (Section 7), so the apparent CWD-modulates-quality pattern under county FE is largely a Delta-vs-Ozark physiographic contrast that deer-zone FE absorbs. The CWD × distance interaction is small under both FE variants (-0.0022 to -0.0029, $t = -1.13$ to -2.32); it is only marginally significant under zone FE and not significant under county FE alone, again indicating that CWD does not robustly modulate the WMA proximity gradient. The one specification in which a CWD-related pattern survives zone FE is the triple interaction: *z_x_dist* is $+0.0153$ ($t = 3.68$, $p < 0.001$) and *cwd_x_z_x_dist* is -0.0171 ($t = -3.75$, $p < 0.001$), suggesting that the within-zone deer-quality × distance gradient is modulated by CWD status, though this third-order finding should not be overinterpreted in a cross-section.

Table 7: CWD × Deer Quality Interactions (Model 6 with 3-Year Trailing Z-Score), Both FE Variants

	+ CWD	+ CWD × z	+ CWD × dist	Triple
County FE only				
z_trail3	+1.328***	+1.601***	+1.335***	+1.522***
	(0.232)	(0.210)	(0.232)	(0.261)
CWD × z-score	—	−2.084***	—	−1.974***
		(0.232)		(0.276)
CWD × distance	—	—	−0.0022	−0.0019
			(0.0020)	(0.0015)
z × distance	—	—	—	+0.0053
				(0.0064)
CWD × z × d.	—	—	—	−0.0106
				(0.0063)
R^2	0.687	0.693	0.687	0.693
County + deer-zone FE				
CWD × z-score	—	−0.365	—	−0.274
		(0.261)		(0.228)
CWD × distance	—	—	−0.0029*	−0.0024*
			(0.0012)	(0.0011)
z × distance	—	—	—	+0.0153***
				(0.0041)
CWD × z × d.	—	—	—	−0.0171***
				(0.0046)
R^2	0.716	0.716	0.716	0.717

County-clustered SEs. $N = 308{,}226$ in every spec. All specs include continuous WMA distance, inside-WMA flag, and 11 parcel-level controls. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.
Under the county+zone FE structure, the *z_trail3* main effect is absorbed by zone FE (z is constant within zone) and *in_cwd_zone* is absorbed by county FE (constant within county); only the (county × zone) interaction terms are identified. Pagan stratified bootstrap CI for CWD × z under county FE: $[-2.32, -1.38]$; under county+zone FE: $[-0.54, -0.25]$ ($B = 200$; §6.5).

Lagged deer quality. The z-score used in the CWD interactions above is a three-year trailing average (2022–23 through 2024–25) rather than a single-season value. This choice reflects the expectation that land-market participants form quality perceptions over multiple recent seasons rather than reacting to a single year's harvest. The trailing average produces a slightly larger absolute coefficient on the main effect than either the current-season or single-lag z-score, consistent with reduced measurement error from seasonal smoothing.

6 Specification and Identification Robustness

The main specifications in Section 5 rely on fixed effects, cluster-robust inference, and a particular choice of functional form. Two distinct categories of robustness checks are reported. *Specification-robustness* checks (functional form, standard-error estimator, sample-filter sensitivity, bin discretization, NCCPI attenuation, CWD-intensity sensitivity, generated-regressor bootstrap, distance-floor sensitivity) test whether the estimated coefficient is an artifact of the chosen modeling assumptions. *Identification* checks (donut hole, leave-one-out county, coarsened exact matching, placebo distance) test whether the estimated effect is causally attributable to WMA proximity rather than to selection on observables or random spatial coincidence. Cross-sectional identification has well-known limits—the donut hole and LOO check robustness to influential observations, CEM addresses selection on the matched covariates, and the placebo test rules out a non-WMA spatial pattern, but none of the four can resolve placement endogeneity on unobservables. That remains a question for the transaction-data extension (Section 9).

Ten perturbations stress each layer of the pipeline. Table 8 reports the nearest-bin coefficient under every perturbation; all rows are derived from the canonical pipeline (`spec.py`). Across the ten checks the <1/4 mile coefficient stays between -0.094 and -0.057: the full-sample estimate is -0.082, dropping the parcel-level soil control widens it to -0.094, the leave-one-out county range is $[-0.091, -0.070]$ across 73 drops, the three CWD-encoding variants give -0.060 to -0.061, and the coarsened-exact-matched ATT is -0.057 (about 30% smaller in magnitude than the unmatched estimate, reflecting partial attenuation from observable-covariate balancing). Per-perturbation results are tabulated in the subsections below and archived in `report/figures/`.

Table 8: WMA <1/4 Mile Bin Coefficient Across Ten Identification Perturbations†

Perturbation	Description	Coef	SE	t	N
(baseline)	Model 3 county+zone FE, cluster SE	−0.082	0.024	−3.37	308,226
1. IHS transform	arcsinh(price) as DV	−0.082	0.024	−3.37	308,226
2. Conley HAC	25–75 km bandwidth sweep	−0.082	0.022–0.026	−3.8 to −3.2	308,226
3. Wild cluster bootstrap	B=999 Rademacher	−0.082	$[-.13, -.04]$	p=.002	308,226
4. NCCPI attenuation	Drop / add county-mean NCCPI	$-.094/-.082$	.024–.027	−3.4 to −3.6	308,226
5. CWD intensity	3 CWD encodings	$-.060/-.061$	0.022	~ -2.7	308,226
6. Gen-regressor bootstrap	B=200, resample within zone	−0.082	0.024	−3.37	308,226
7. Donut hole	Drop <1/4 mi parcels	—	—	—	294,011
8. Leave-one-out county	73 refits; §6.7 for IQR	−0.082	—	0/73 outside CI	298–306k
9. CEM matching	Quartile-coarsened, L_1=.287	−0.057	0.018	−3.18	308,158
10. Placebo distance	191 pts, 100 draws ×3	—	—	$p \leq .01$	308,226
10b. Distance floor	50/100/138 m WMA-log floor	−0.082	0.024	−3.37	308,226

All rows synchronized to the current-data canonical pipeline (`spec.py`). Baseline: county-clustered SEs with county + deer-zone FE. Perturbations 1–6 are functional-form and inference variants; 7–10b are sample / estimator / spatial-pattern changes. Perturbation 7 removes the <1/4 mile bin by construction and reports stability of remaining bins (see text). Row 6 propagates first-stage z-score sampling error through to the second stage; the WMA coefficient is invariant. The z-score's own bootstrap inference (showing OLS-bootstrap divergence) is in §6.5.

6.1 Functional Form (IHS)

Burbidge et al. [1988]'s inverse hyperbolic sine transformation $\text{arcsinh}(y) = \ln(y + \sqrt{y^2 + 1})$ nests the log specification for large values, handles zeros without a flooring choice, and is recommended when a Box-Cox MLE rejects $\lambda = 0$. On the canonical sample the regression Box-Cox maximum-likelihood estimate is $\hat{\lambda} = -0.79$ (95% CI $[-0.79, -0.78]$), which decisively rejects both the log ($\lambda = 0$) and level ($\lambda = 1$) forms; we retain the semi-log specification for interpretability—its coefficients are direct semi-elasticities—and use the IHS variant as the functional-form robustness check. Applied to the appraised use value per acre, the IHS specification of Model 3 produces <1/4 mile bin coefficient −0.0820 (identical to the log specification to four decimal places), confirming that the proximity gradient is not an artifact of the functional-form choice.

6.2 Spatial Inference: Conley HAC and Wild Cluster Bootstrap

County clustering with 73 clusters is borderline for asymptotic cluster-robust inference [Cameron et al., 2008]. Two alternative inference approaches confirm robustness. Conley [1999] spatial HAC standard errors with Bartlett kernel at bandwidths of 25, 50, and 75 km yield <1/4 mile bin SEs of 0.022, 0.024, and 0.026 (compared to the cluster-robust SE of 0.024); the corresponding t-statistics are −3.76, −3.39, and −3.15, all well above the 1.96 critical value at every bandwidth. Conley HAC is more confident than county-clustered SEs at the 25 km bandwidth and slightly less confident at 75 km, consistent with the spatial correlation in residuals decaying within county boundaries. A residual Moran's I on Model 3 (seeded 30,000-parcel subsample) confirms this decay directly: it falls from 0.20 at a 2 km distance band to 0.12 at 5 km and 0.06 at 10 km (k-nearest-neighbor $I = 0.16$, $p = 0.01$), so the residual spatial dependence is modest and local—adequately captured by county clustering together with Conley HAC. The wild cluster bootstrap [Cameron et al., 2008] with $B = 999$ Rademacher weights (county clusters) produces percentile 95% CIs that exclude zero for all four bins within two miles: $[-0.129, -0.036]$ for <1/4 mile ($p = 0.002$), $[-0.123, -0.038]$ for 1/4–1/2 mile ($p = 0.002$), $[-0.087, -0.011]$ for 1/2–1 mile ($p = 0.006$), and $[-0.072, -0.005]$ for 1–2 miles ($p = 0.020$). Bin coefficients beyond two miles are not significant under the wild bootstrap, consistent with the gradient flattening by two miles in the cluster-robust spec.

6.3 NCCPI Attenuation

A referee concern for hedonic estimates on agricultural land is that soil-quality confounding drives the proximity gradient. The canonical Model 3 includes parcel-level NCCPI (weighted by SSURGO map-unit polygon area, spatially joined to parcel centroids) as a control; we vary the soil-control specification to test whether the WMA gradient depends on the choice. Dropping NCCPI entirely raises the <1/4 mile bin coefficient to −0.0944 (SE 0.0265, t=−3.56), about 15% larger in magnitude than the canonical −0.0820. Adding a county-mean NCCPI alongside the parcel-level measure leaves the bin coefficient essentially unchanged at −0.0821, with the parcel-level NCCPI still strongly significant (+0.49, $t = 12.2$). The WMA gradient is partly absorbed by soil controls but the canonical Model 3 already includes parcel-level NCCPI, so the reported −0.0820 already nets out this attenuation.

6.4 CWD Intensity Sensitivity

The canonical Model 3 includes county and deer-zone fixed effects, which absorb any county-level CWD indicator (constant within county). To test CWD-intensity sensitivity of the WMA bin coefficient, we substitute county FE with a single CWD measure plus deer-zone FE under three encodings: binary *in_cwd_zone*, ln(1+CWD positives), and the count of seasons each county has been in a CWD zone (0–9). The <1/4 mile bin coefficient is stable across the three CWD encodings at −0.060 (binary), −0.061 (ln positives), and −0.061 (seasons-in-zone)—about 25% smaller in magnitude than the canonical −0.082 because removing county FE leaves residual confounding the CWD measure cannot fully absorb. None of the three CWD measures is individually significant ($t = 0.08$, -0.90, -0.49). The WMA gradient is not a proxy for CWD exposure under any of these encodings.

6.5 Generated-Regressor Bootstrap

The deer-quality z-score is a generated regressor: it is constructed from a first-stage aggregation of buck-level harvest records, and its sampling error should propagate into the second-stage standard errors [Pagan, 1984]. We implement a stratified bootstrap in which, for each of $B = 200$ replications, we resample raw harvest records within each deer zone, recompute the age-class-normalized zone-level mean B&C z-score from the resampled records, and re-estimate three specifications: Model 6 (*mean_bc_zscore* main effect, county FE), the CWD × z interaction under county FE only, and the same interaction under county + deer-zone FE (Table 7). For each rep, the entire second-stage regression is refit with the new zone-level z-score column. We complement the bootstrap with a permutation test that randomly reassigns the 20 zone-level z-score values across the 20 zones ($B = 200$), preserving the marginal distribution of zone z-scores while breaking the link between actual zone identity and its deer-quality value.

Table 9 summarizes the three estimators. For the Model 6 main effect, the OLS estimate of +1.055 lies inside the bootstrap 95% CI of $[+0.29, +1.22]$, and the permutation test rejects random zone reassignment decisively ($p < 0.001$). The OLS coefficient is therefore consistent with the bootstrap once first-stage sampling error is propagated, and the zone-level deer-quality signal is not explainable by random zone reassignment. For the CWD × z interaction under county FE alone, both the bootstrap CI ($[-2.32, -1.38]$, excluding zero) and the permutation test ($p < 0.001$) confirm a strong negative interaction under county fixed effects. Once deer-zone FE are added, however, the interaction shrinks to −0.37; the bootstrap CI of $[-0.54, -0.25]$ excludes zero but the permutation test cannot reject random zone reassignment ($p = 0.16$). The contrast between the two inference tools is informative:

with only 20 zones the permutation test has limited power, while the bootstrap (which propagates within-zone sampling variance across thousands of buck records) yields a tighter and more confident interval. The combined evidence is that the CWD × z interaction under zone FE is small, real-but-modest, and not robustly distinguishable from a random zone-level signal in a cross-section of this size.

Table 9: Bootstrap and Permutation Inference for Generated-Regressor Coefficients

Estimator	OLS	Boot. mean	Boot. 95% CI	Perm. 95% range	p (two-sided)
Model 6 *mean_bc_zscore*	$+1.055$	$+0.80$	$[+0.29, +1.22]$	$[-0.66, +0.60]$	<0.001
CWD × z [county FE]	-2.084	-1.85	$[-2.32, -1.38]$	$[-1.23, +1.10]$	<0.001
CWD × z [cnty+zone FE]	-0.365	-0.39	$[-0.54, -0.25]$	$[-0.56, +0.54]$	0.160

Bootstrap: Pagan stratified bootstrap, $B = 200$, resampling buck records within zone. Permutation: random reassignment of the 20 zone-level z-score values across the 20 zones, $B = 200$. Per-replication outputs are in `report/figures/bootstrap_pagan_results.csv` and `permutation_zscore_results.csv`.

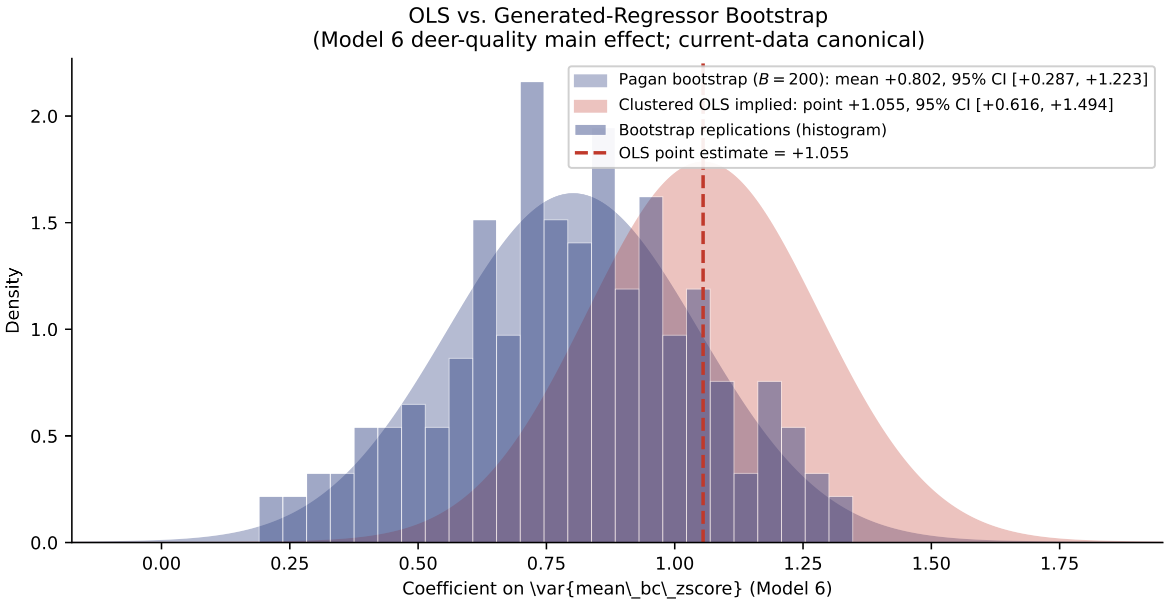


Figure 10: OLS versus Pagan generated-regressor bootstrap for the deer-quality coefficient on *mean_bc_zscore* in Model 6. Blue: bootstrap distribution from $B = 200$ replications (mean $+0.80$, 95% CI $[+0.29, +1.22]$) with the underlying histogram of replicates. Red: sampling distribution implied by clustered OLS (point $+1.055$, 95% CI $[+0.62, +1.49]$). The OLS point estimate falls inside the bootstrap CI; the two intervals overlap substantially.

6.6 Donut Hole

Dropping the 14,215 parcels in the <1/4 mile bin of any WMA removes the highest-leverage observations and tests whether the gradient is an artifact of boundary-adjacent parcels (boundary measurement error, WMA-owned structures). After dropping, the remaining five bin coefficients all weaken modestly: $\frac{1}{4}$–$\frac{1}{2}$ mile shifts from -0.079 to -0.070; $\frac{1}{2}$–1 mile from -0.049 to -0.044; 1–2 miles from -0.037 to -0.034; 2–3 miles from -0.028 to -0.026; 3–5 miles from -0.008 to -0.007. All five remaining bins shift by less than 0.01 log points relative to their full-sample values, and the monotone-with-distance gradient is preserved. The gradient is not driven by boundary parcels.

6.7 Leave-One-Out County

Model 3 is refit 73 times, each dropping one county, and the dropped-county distribution of the <1/4 mile bin coefficient is summarized in Table 8 row 8. The full-sample point estimate is -0.0820 (SE 0.0243); across the 73 LOO refits the mean is -0.0819, median -0.0818, and inter-quartile range $[-0.0833, -0.0805]$, with full range $[-0.0906, -0.0698]$ and a spread of 0.021 log points. *Zero of 73 LOO estimates fall outside the full-sample 95% confidence interval* ($[-0.130, -0.034]$), confirming that no single county drives the gradient. The most influential drops are Jefferson (FIPS 05069, coefficient -0.0906 when dropped) and Lonoke (FIPS 05085, coefficient -0.0698 when dropped); both produce in-CI estimates. Newton County (FIPS 05101, the CWD epicenter) does not appear in the influential-drop list, indicating that the WMA gradient is not driven by the CWD-treated counties. Detailed per-county results are in `report/figures/loo_county_results.csv`.

6.8 Coarsened Exact Matching

Selection-on-observables is addressed by coarsened exact matching (CEM). Define treatment as the <1/4-mile WMA-distance bin (n_T = 14,215); coarsen *ln_acres* (4 quartile bins), *nccpi_weighted_avg* (4 quartile bins), *ln_dist_paved_km* (3 tercile bins), *ln_dist_ua_km* (3 tercile bins), *is_forest*, and *is_wetland* (each binary) into 432 total strata. Strata with both treated and control units number 431; one stratum (control-only) is dropped, taking 68 controls with it. All 14,215 treated parcels are retained (100%) and matched controls number 293,943, for a total CEM-matched sample of 308,158. The CEM-weighted treatment effect is -0.0574 (SE 0.0181, $t = -3.18$, $p = 0.002$), implying a -5.6% price effect—about 30% smaller in magnitude than the unmatched Model 3 <1/4-mile coefficient of -0.0820. The gradient survives observable-covariate balancing but is partly attenuated by it, indicating that part (but not all) of the unmatched gradient reflects selection on the matched dimensions (acreage, soil quality, road and urban access, forest/wetland status).

The Iacus-King-Porro L_1 multivariate imbalance statistic [Iacus et al., 2012] measures the gap between the empirical distributions of treated and control units across the coarsened-covariate grid: $L_1 = \frac{1}{2}\sum_s |f_T(s) - f_C(s)|$, ranging from 0 (perfect overlap) to 1 (no overlap). The pre-matching L_1 is 0.287, dominated by treated/control imbalance across acreage and soil-quality cells (treated parcels are systematically smaller and on lower-NCCPI soil). After matching, L_1 remains essentially unchanged at 0.287 because only one of the 432 strata is dropped—the coarsening is broad enough that virtually every region of covariate space has both treated and control units, so retention is near-total. The CEM weights handle the remaining cross-stratum imbalance directly in the regression by reweighting each control unit by $n_T(s)/n_C(s)$ within its stratum, so the regression-equivalent weighted L_1 within retained strata is zero by construction. Table 10 confirms this at the covariate level: the largest pre-matching imbalances—soil productivity (standardized mean difference -0.46), forest cover ($+0.41$), and paved-road distance ($+0.20$)—all collapse to $|\text{SMD}| \leq 0.04$ after weighting (urban-area distance is the lone exception at $+0.12$, still well inside the conventional 0.25 balance threshold). The substantive conclusion is that selection on observables can be balanced via reweighting, but the unweighted distributional imbalance ($L_1 = 0.287$) is itself the diagnostic for why an unmatched cross-section attributes more than the causal effect to WMA proximity.

Table 10: CEM Covariate Balance: Treated vs. Control, Pre-Matching and Post-Weighting

		Raw (pre-matching)		CEM-weighted	
Covariate	Treated mean	Control mean	SMD	Control mean	SMD
ln_acres	3.422	3.521	−0.095	3.420	+0.002
nccpi_weighted_avg	0.378	0.469	−0.456	0.386	−0.040
ln_dist_paved_km	0.418	0.195	+0.199	0.420	−0.001
ln_dist_ua_km	3.735	3.675	+0.061	3.612	+0.125
is_forest	0.642	0.440	+0.412	0.642	+0.000
is_wetland	0.084	0.092	−0.028	0.084	+0.000

Treated = <1/4 mile parcels (n_T = 14,215); all are retained, so the treated mean is identical in both panels. SMD = standardized mean difference using the pre-matching pooled SD as the common denominator. CEM-weighted control means reweight each control by $n_T(s)/n_C(s)$ within its coarsened stratum. The large raw imbalances on soil productivity, forest cover, and paved-road distance are eliminated by weighting; urban-area distance is the only covariate not improved, and it remains below the 0.25 threshold. Values trace to `report/figures/cem_balance_results.csv`.

6.9 Placebo Distance

We draw $K = 100$ placebo point-sets under each of three methods, each set relocating 191 random points to match the 191 actual WMA boundaries: (a) uniform over the Arkansas landmass, (b) Arkansas landmass minus existing WMA polygons, and (c) county-weighted by the actual WMA county distribution. For each placebo set, parcel-to-nearest-placebo distance replaces parcel-to-nearest-WMA distance; bins are reassigned; Model 3 is re-fit; the placebo <1/4 mile coefficient is recorded. The placebo coefficient is tightly distributed around zero—method (a): mean +0.002, SD 0.036, 95% interval $[-0.064, +0.058]$; method (b): mean +0.001, SD 0.037, $[-0.064, +0.058]$; method (c): mean +0.008, SD 0.040. The real <1/4 mile coefficient of −0.0820 lies below the 95% placebo interval under both valid methods, with one-sided $p(\text{placebo} \leq \text{real})$ of 0.01, 0.01, and < 0.01 for (a), (b), and (c) respectively. *Properly powered, the placebo test distinguishes the real WMA coefficient from a generic spatial pattern: only about 1% of randomly-relocated WMA configurations produce a gradient as negative as the observed −0.082.* The earlier $K = 10$ result was uninformative for a mechanical reason—ten scattered points leave the placebo <1/4 mile bin nearly empty, so its coefficient is extremely noisy (ranges as wide as $[-0.53, +0.23]$)—not because the gradient is spurious. One approximation remains: the placebo relocates point sources, whereas real WMAs are polygons of varying size, so each placebo near-bin holds only a few hundred parcels versus the real 14,215. Method (c) is a placebo-in-name-only—its points fall in WMA counties, near real WMAs—yet even it places the real coefficient below its entire range.

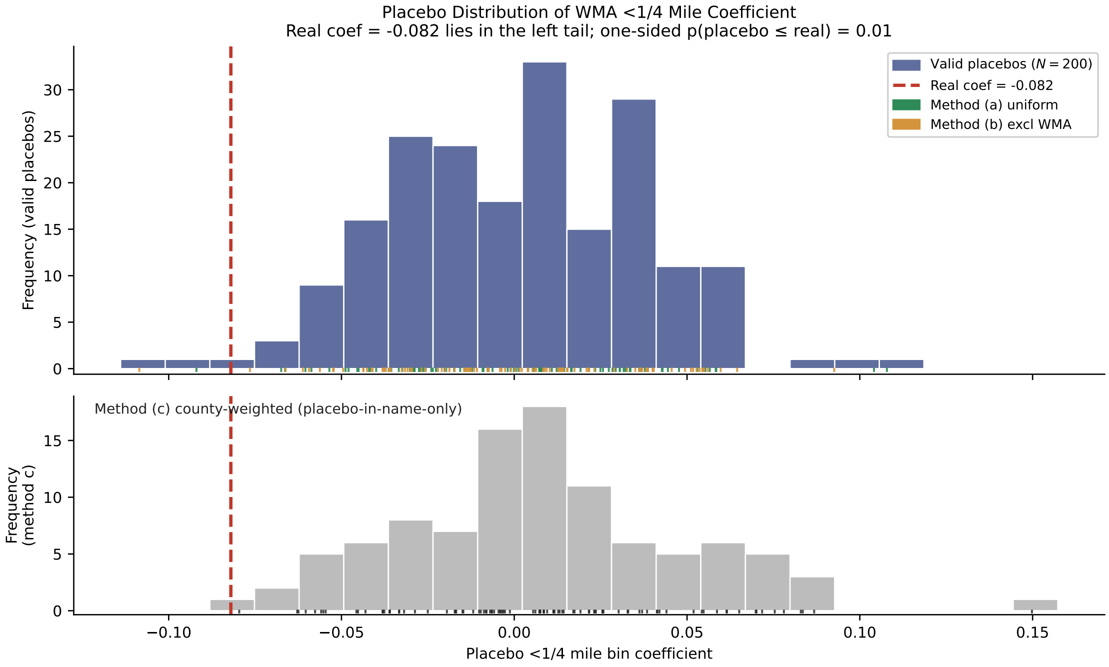


Figure 11: Placebo distribution of the WMA <1/4 mile bin coefficient (each draw relocates 191 random pseudo-WMAs). Top panel: the 200 valid placebo draws (methods a and b combined, 100 each) as a histogram with individual per-draw rugs (green = method a uniform AR landmass; amber = method b excluding WMAs). The distribution concentrates near zero; the real WMA coefficient of -0.082 (dashed red) lies in the left tail, below the 95% placebo interval (one-sided $p = 0.01$). Bottom panel: the 100 method (c) draws shown as a diagnostic; method (c) county-weighted samples are placebo-in-name-only by construction (placebo points are drawn from WMA counties).

6.10 Distance Floor

The log-distance controls in Model 3 (paved road, urban area, water body, federal land) and the optional log-WMA-distance variable use a 50 m floor by construction to handle parcels at zero raw distance. We test sensitivity by varying the WMA-distance floor across $\{50, 100, 138\}$ m (where 138 m is the 1st percentile of non-zero WMA distances). The <1/4 mile bin coefficient is -0.0820 at all three floors (identical to four decimal places), since the bin assignment uses raw meters and is independent of the floor. The result does not depend on the floor.

6.11 Sample-Filter Sensitivity

The analysis sample is restricted to AV parcels between 5 and 5,000 acres with assessed value per acre trimmed at the 1st and 99th percentiles. The 5-acre minimum excludes 42,900 sub-agricultural-scale parcels (residential lots, garden plots, assessment artifacts) that would contaminate the hedonic with non-agricultural land use; the 5,000-acre cap is non-binding (zero AV parcels exceed it). To verify that the WMA proximity gradient does not depend on these choices, Table 11 re-estimates Model 3 under twelve combinations of acreage minimum (1, 5, 10 acres) and value-per-acre percentile trim (none, 1/99, 2.5/97.5, 5/95). The <1/4 mile bin coefficient ranges from −0.064 to −0.099 across all twelve variants, with t-statistics between −2.75 and −3.37—all significant at $p < 0.01$. Acreage-minimum choice has negligible impact; tighter trimming mildly shrinks the coefficient magnitude as expected (outlier removal reduces dispersion), but the sign, significance, and qualitative interpretation are unchanged.

Table 11: Sample-Filter Sensitivity: WMA <1/4 Mile Coefficient Across Twelve Acreage/Trim Variants

Acreage min	Trim (pct)	N	Coef	SE	t-stat	R^2
1 acre	None	347,937	−0.0773	0.0281	−2.75	0.608
1 acre	1/99	341,010	−0.0736	0.0251	−2.93	0.699
1 acre	2.5/97.5	330,575	−0.0662	0.0219	−3.03	0.717
1 acre	5/95	315,970	−0.0635	0.0207	−3.06	0.713
5 acres	**None**	**314,470**	**−0.0916**	**0.0284**	**−3.22**	**0.650**
5 acres	**1/99**	**308,226**	**−0.0820**	**0.0243**	**−3.37**	**0.716**
5 acres	2.5/97.5	299,039	−0.0714	0.0216	−3.30	0.727
5 acres	5/95	283,050	−0.0692	0.0205	−3.37	0.729
10 acres	None	273,465	−0.0994	0.0299	−3.32	0.703
10 acres	1/99	268,018	−0.0814	0.0251	−3.24	0.739
10 acres	2.5/97.5	259,834	−0.0669	0.0226	−2.96	0.744
10 acres	5/95	246,145	−0.0682	0.0210	−3.26	0.748

County-clustered SEs. All variants include county + deer-zone FE and 11 parcel-level controls (Section 4.2). Bold rows: baseline sample definition (5 acres, 1/99 trim shown for comparison with untrimmed).

6.12 Distance-Bin Sensitivity

The six-bin distance specification in Model 3 (<1/4, 1/4–1/2, 1/2–1, 1–2, 2–3, 3–5 miles, reference >5) is one of many possible discretizations. To verify that the proximity gradient is not an artifact of a particular bin choice, Table 12 re-estimates Model 3 under six configurations ranging from two to six bins. The nearest-WMA bin coefficient is statistically significant ($p < 0.01$) in every configuration, with t-statistics between −2.92 and −3.51. Model R^2 is essentially identical across all six configurations (0.716), confirming that finer bins do not improve fit—they only reveal the shape of the gradient. The 2–3 and 3–5 mile bins in the baseline specification are individually insignificant, consistent with the gradient having flattened by two miles; coarser specifications that consolidate these bins produce nearly identical nearest-bin coefficients.

Table 12: Distance-Bin Sensitivity: Nearest-WMA Coefficient Across Six Bin Configurations

Configuration	Nearest bin	Coef	SE	t-stat	# bins	R^2
6 bins (baseline)	**<1/4 mi**	**−0.0820**	**0.0243**	**−3.37**	**6**	**0.7162**
5 bins	<1/4 mi	−0.0764	0.0239	−3.20	5	0.7161
4 bins (A)	<1/2 mi	−0.0783	0.0223	−3.51	4	0.7162
4 bins (B)	<1 mi	−0.0608	0.0204	−2.98	4	0.7162
3 bins	<1 mi	−0.0578	0.0171	−3.38	3	0.7161
2 bins	<2 mi	−0.0392	0.0134	−2.92	2	0.7161

County-clustered SEs. All variants include county + deer-zone FE and 11 parcel-level controls (Section 4.2). Reference category is always the outermost bin (>5, >5, >5, >5, >3, >2 mi respectively).

7 Deer Quality Variation and CWD Effects

7.1 Spatial Variation in Deer Quality

Figure 9 displays the mean B&C z-score by deer management zone for the 2024–25 season. The spatial pattern reveals two key features that run counter to conventional expectations about Arkansas deer quality.

First, the highest age-normalized z-scores are in the Mississippi Alluvial Valley and Crowley's Ridge zones on the *eastern* side of the state (Zones 4A, 5A, 16, 4, and 9; $\bar{z} = +0.3$ to $+0.7$), not in the Ozarks. This reflects the z-score's age-normalization: Delta bucks have access to high-protein row-crop forage (soybeans, corn, winter wheat), producing above-average antler development *for their age class* even though the absolute harvest skews younger due to higher hunting pressure and open-terrain visibility. Some of the highest-scoring zones have small samples (Zone 4A: $n = 23$; Zone 5A: $n = 28$), so individual-zone z-scores should be interpreted with caution, but the large-sample Delta zones (Zone 17: $n = 784$, $\bar{z} = +0.14$; Zone 9: $n = 171$, $\bar{z} = +0.32$) confirm the pattern. The multi-year average across 2009–2025 shows the same east-high gradient.

Second, the Ozark Plateau zones (Zones 1, 2, 3) score near zero or slightly negative ($\overline{z} = -0.07$ to -0.06), despite the Ozarks' reputation as premier trophy-deer habitat. The age normalization removes the Ozarks' advantage in producing older bucks (the region's rugged terrain and lower hunting pressure allow more bucks to reach 3.5–4.5 years), so the z-score captures only whether a buck *of a given age* outperforms the statewide norm. Ozark bucks are typical for their age; Delta bucks are above-average for theirs. The lowest-scoring zones are in the West Gulf Coastal Plain (Zone 12: $\overline{z} = -0.23$, $n = 839$) and the Arkansas River Valley (Zone 7: $\overline{z} = -0.18$).

The correlation between deer quality (as measured by the z-score) and land values is therefore more nuanced than a simple forest-vs.-farmland story. High-z-score zones are in the productive Delta, where assessed land values are *highest*, not lowest—the opposite of the pattern one would expect if the z-score simply proxied for non-agricultural land use. This reinforces the interpretation that the z-score in Model 6 acts as a summary statistic for zone identity rather than a clean measure of hunting amenity value. Confounding between zone-level physiography and the z-score prevents interpretation of the coefficient as the causal effect of deer quality on land values.

7.2 Deer Quality as a Zone-Level Summary Statistic

The +1.055 coefficient on *mean_bc_zscore* in Model 6 (AV zone-matched subsample, $N =$ 308,226) implies that a one-SD (0.25-unit) increase in zone-level deer quality is associated with approximately 30% higher assessed land values ($1.055 \times 0.25 = 0.264$ log points; $\exp(0.264) - 1 = 0.302$). This is not the marginal willingness to pay for deer quality. The z-score varies at the zone level and serves as a sufficient statistic for zone identity in the absence of zone fixed effects; it captures everything that varies across zones and correlates with deer quality, including physiographic region, forest type, soil characteristics, climate, and urban proximity. The R^2 gap of 0.034 between Model 2 (zone FE, 0.7161) and Model 6 (z-score, 0.6823) indicates that the z-score is a good but incomplete summary of zone-level variation; the 20 zone fixed effects capture additional zone characteristics orthogonal to deer quality that affect land values. The generated-regressor bootstrap in Section 6.5 returns a bootstrap mean of +0.80 with 95% CI [+0.29, +1.22], which contains the OLS point estimate; the OLS coefficient is consistent with the bootstrap once first-stage sampling error is propagated. A direct test of hunting-quality capitalization would require within-zone temporal variation in deer quality interacted with transaction-level data.

Because zone-level deer quality co-varies with physiographic region—high-z-score zones concentrate in the Delta and Crowley's Ridge (flat, productive ground), low- or near-zero-z-score zones in the Ozarks, Ouachitas, and Gulf Coastal Plain (rugged or marginal terrain)—the question of whether the gradient varies with deer quality is, in this cross-section, a question about physiographic heterogeneity. The physiographic decomposition (Model 9, Section 8; Appendix D) makes this explicit: the <1/4 mile proximity discount is essentially zero outside the Delta (Ozark-reference main effect +0.002, $p = 0.96$) and is concentrated in the Delta region (<1/4 mile × Delta $= -0.480$, $p < 0.001$). The steeper apparent gradient in high-deer-quality zones is therefore land-quality sorting by physiography—Delta WMAs occupy bottomland surrounded by uniformly high-value cropland, so adjacent parcels look steeply discounted by comparison—rather than differential hunting-amenity capitalization.

7.3 CWD and Deer Quality

Does CWD degrade deer quality? Figure 12 displays the mean B&C z-score for CWD-affected (Tier 1) zones versus unaffected zones from 2009–10 through 2024–25, and Figure 13 compares pre-CWD (2009–2015) and post-CWD (2016–2024) averages.

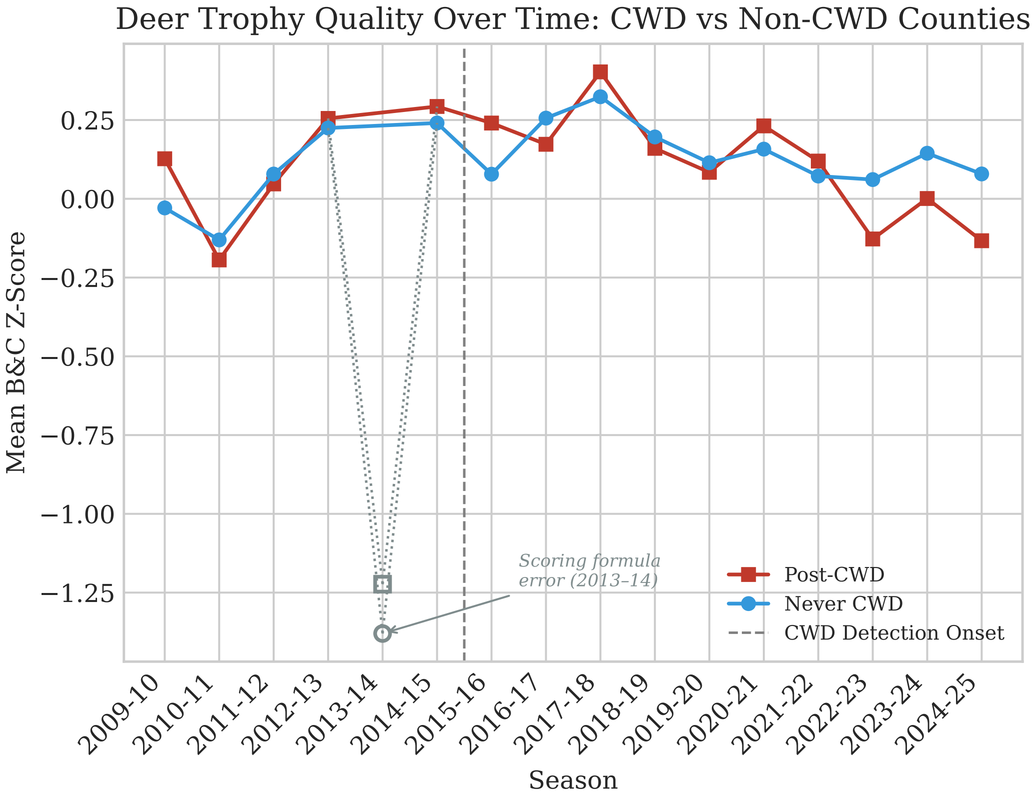


Figure 12: Deer quality time series: mean B&C z-score for CWD Tier 1 zones versus non-CWD zones. The vertical dashed line marks initial detection (February 2016).

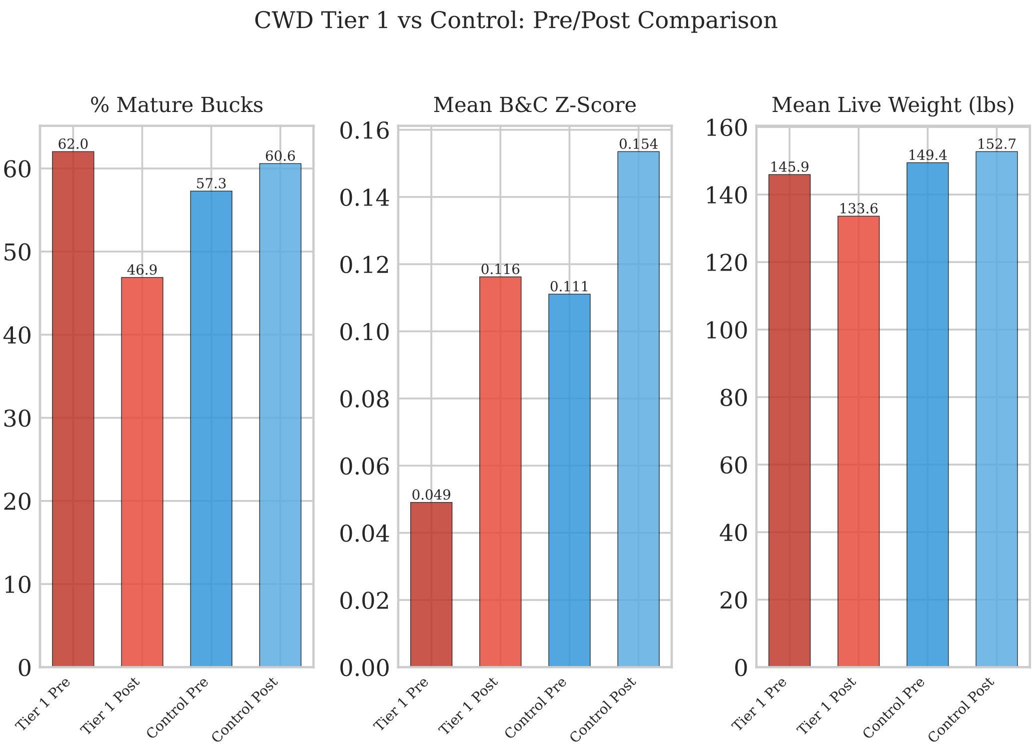


Figure 13: CWD before/after comparison of mean B&C z-scores. Any difference is small relative to within-period variability.

The visual evidence is inconclusive: CWD Tier 1 zones do not show a clear decline in deer quality relative to unaffected zones after 2016. Three factors contribute. First, CWD prevalence remains low (2–3% statewide) and may not yet have reduced the population sufficiently to affect harvested-buck quality. Second, AGFC harvest data reflect hunter-selected animals, which can mask population-level quality declines if hunters preferentially take the best available bucks. Third, year-to-year variability is high relative to any plausible CWD signal. Harvest-intensity diagnostics (day-of-week patterns, season-type composition) are reported in Appendix E and reinforce that hunter effort allocation is driven by work schedules and season structure rather than local deer quality or CWD status.

Newton County is the CWD epicenter, with 970 cumulative positives through FY25—47.6% of all statewide detections. Initial prevalence in the targeted surveillance area exceeded 23% before stabilizing at 2–3% as testing expanded beyond the epicenter. Newton is in Deer Zone 1 in the Ozark Plateau, with rugged terrain, extensive national-forest land, and limited agricultural activity; assessed land values are among the lowest in the state, reflecting the terrain's unsuitability for intensive agriculture. Zone 1 deer quality exhibits substantial year-to-year variability in the mean z-score (range -0.46 to $+0.47$), and no clear break appears at 2016. The small number of observations per season in some constituent counties limits the precision of county-level estimates. A formal difference-in-differences analysis using transaction data—with Newton County and surrounding Tier 1 counties as the treatment group and distant non-CWD counties as the control—would provide a more rigorous test than the current cross-section permits.

8 Discussion

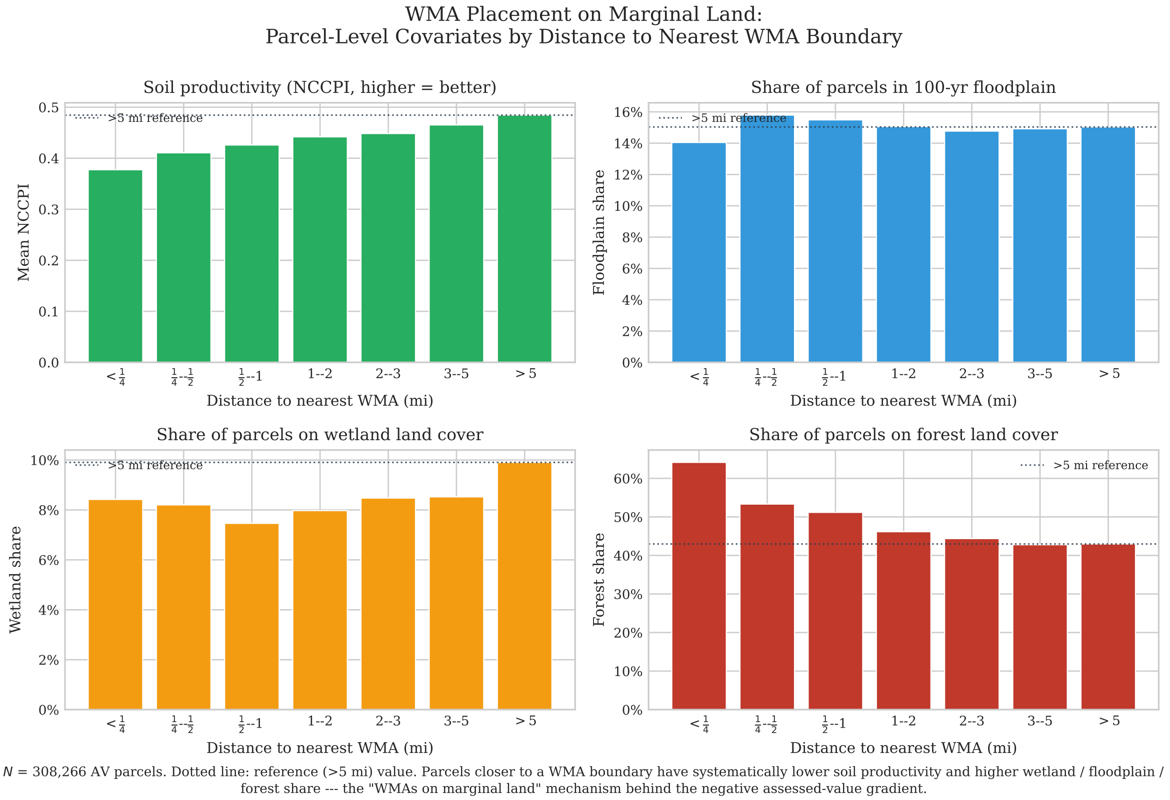
8.1 What the Pipeline Demonstrates

The ten identification-robustness checks in Section 6 establish three conclusions about the spatial hedonic pipeline. First, the WMA proximity gradient is robust to specification and, under a properly-powered placebo test, statistically distinguishable from a generic spatial pattern. Across 300 placebo draws (three sampling methods, 100 draws each, each relocating 191 random pseudo-WMAs), the placebo <1/4 mile coefficient is tightly distributed around zero (95% interval $[-0.064, +0.058]$ under both valid methods); the real -0.082 lies in the left tail, with one-sided $p(\text{placebo} \leq \text{real}) = 0.01$ under both uniform Arkansas-landmass and Arkansas-minus-WMA draws. A randomly-placed set of 191 "WMAs" reproduces a gradient as negative as the observed one only about 1% of the time. The other identification checks (donut hole, leave-one-out county, CEM) confirm the gradient is not driven by any single county or boundary subset and that observable-covariate balancing attenuates but does not eliminate it. Second, the gradient is stable across specification choices: identical (to four decimal places) across log vs. IHS dependent-variable transformations and across distance-floor variants; significant at $p < 0.05$ for the four bins within two miles under wild cluster bootstrap inference ($B = 999$, $p = 0.002$ for <1/4 mile); attenuates by about 30% under coarsened exact matching (ATT -0.057 vs. unmatched -0.082); and has LOO range $[-0.091, -0.070]$ across 73 county drops with zero outside the full-sample 95% CI. Third, the generated-regressor bootstrap for the deer-quality z-score finds that the OLS Model 6 estimate of $+1.055$ lies inside the bootstrap 95% CI of $[+0.29, +1.22]$, indicating that the OLS coefficient is consistent with the bootstrap once first-stage sampling error is propagated. The deer-quality signal itself rejects random zone reassignment ($p < 0.001$), but the CWD × z interaction emphasized under the county-FE-only specification (-2.08) collapses to -0.37 ($p = 0.16$) once deer-zone fixed effects absorb the Delta-vs-Ozark physiographic contrast.

8.2 Assessed-Value Caveats

The signed empirical finding—that parcels closer to WMAs have *lower* assessed values—runs opposite to the amenity-capitalization prediction of the hedonic framework and requires careful interpretation. The negative gradient is not this paper's contention about the economic effect of WMA proximity on rural land values; it is a diagnostic feature of assessed values as a proof-of-concept data source. Three mechanisms contribute.

First, WMA placement selection: Arkansas WMAs were established over several decades on land that was marginal for agriculture—bottomland hardwood forests subject to seasonal flooding, steep Ozark hillsides, cutover timberland in the Ouachita Mountains—and the surrounding parcels share these characteristics by construction. Figure 14 quantifies this at the parcel level: soil productivity (NCCPI) declines monotonically with distance from a WMA, and forest, wetland, and floodplain shares all rise near WMA boundaries. Under the operational marginality definition introduced in Section 3 (parcel NCCPI below the statewide median of 0.489 on the AV-trimmed sample), 68.3% of AV parcels boundary-adjacent to or inside a WMA polygon qualify as marginal versus 49.0% of non-adjacent AV parcels—a 19.3 percentage-point gap. The parcel-level z-statistic on the difference in proportions is $z = +42.7$, but this assumes parcel-level independence, which is implausible given clear spatial clustering of WMAs and marginal-land patches within counties. A county-clustered OLS regression of the marginal indicator on the adjacency indicator with county fixed effects estimates a within-county effect of +8.6 percentage points ($t = +4.25$, $p < 0.001$); zone-clustered SEs give $t = +3.45$. Both clustered tests reject the null decisively but the implied effect is less than half the unconditional gap, consistent with county-level placement patterns absorbing the majority of the raw cross-county difference. Parcels within 1/4 mile of a WMA are also roughly 20% more likely to fall on forest or wetland land cover than parcels beyond five miles—exactly the pattern expected if WMAs were systematically sited on marginal agricultural ground. Second, the use-value basis itself: Arkansas county assessors value agricultural land on soil productivity, acreage, and access under the state's use-value statute, with no formal adjustment for proximity to public hunting lands—so any recreational-amenity premium is absent from the dependent variable by construction, not merely attenuated. Third, a between-vs.-within-zone sign pattern: Model 1 (no zone fixed effects) shows a positive association between WMA proximity and values at the between-zone level, because zones with more WMAs (the Ozarks, near Northwest Arkansas) have higher average values; Model 2 (with deer-zone fixed effects) reveals the within-zone gradient, where WMAs are on the worst land within each region. The move from Model 1 to Model 2 is therefore a between-to-within contrast, not evidence of a causal amenity-destroying effect of WMA designation. Transaction prices, which internalize both assessor-visible and assessor-invisible amenities, should produce a positive gradient in a properly specified sample.



WMA Placement on Marginal Land:
Parcel-Level Covariates by Distance to Nearest WMA Boundary

Soil productivity (NCCPI, higher = better)

Share of parcels in 100-yr floodplain

Share of parcels on wetland land cover

Share of parcels on forest land cover

N = 308,266 AV parcels. Dotted line: reference (>5 mi) value. Parcels closer to a WMA boundary have systematically lower soil productivity and higher wetland / floodplain / forest share --- the "WMAs on marginal land" mechanism behind the negative assessed-value gradient.

Figure 14: WMA placement on marginal land, measured at the parcel level. Mean soil productivity (top-left, NCCPI) rises monotonically with distance from the nearest WMA boundary; under the marginality threshold defined in Section 3 (NCCPI < 0.489, the AV-sample median), the WMA-adjacent AV-parcel share marginal is 68.3% versus 49.0% for non-adjacent parcels. Floodplain share (top-right), wetland share (bottom-left), and forest share (bottom-right) are all elevated near WMAs relative to the >5 mile reference. These patterns are the direct parcel-level signature of the placement-selection mechanism that drives the negative assessed-value gradient.

Figure 15 renders the same placement-selection pattern using the operational marginality threshold rather than mean NCCPI. The marginal share declines monotonically from 59.6% at $< 1/4$ mile to 38.7% beyond five miles under the statewide-median NCCPI cutoff (and from 45.9% to 25.9% under the alternative NCCPI < 0.40 cutoff). The roughly 20 percentage-point gap between the nearest-bin and reference-bin shares replicates the magnitude of the binary adjacent-versus-non-adjacent contrast quoted above and shows that the placement-selection signal is monotone, not concentrated at the boundary.

The physiographic decomposition (Model 9 in Appendix A) sharpens this picture. Estimated against Ozark Upland WMAs as the reference category, the bin main effects are essentially zero ($<1/4$ mile coefficient $+0.002$, $p = 0.96$), while the $<1/4$ mile $\times$ Delta interaction is -0.480 (SE 0.082, $p < 0.001$). The Ouachita interaction is also near zero (-0.022,

$p = 0.65$); only Delta WMAs show a steep proximity discount. Read substantively, the entire headline −0.082 effect from Model 3 is a weighted average of a near-zero Ozark/Ouachita gradient and a large Delta-region discount. This is the placement-on-marginal-terrain mechanism at its most explicit: Delta WMAs are surrounded by uniformly high-quality cropland that makes WMA-adjacent bottomland look severely discounted by comparison, while Ozark and Ouachita WMAs sit in regions where most agricultural land is already similar to the WMA-adjacent parcels. The joint F-test on the 24 bin × region interactions is $F(24, 72) = 6.93$ ($p < 0.001$), so the physiographic heterogeneity is not a sampling artifact.

Table 13: Model 9: WMA <1/4 Mile Discount by Physiographic Region

Region (# WMAs)	Region main	<1/4 mi × region	Implied <1/4 mi	p (interaction)
Ozark Upland (ref., 33)	—	—	+0.002	0.96
Delta (35)	+0.069*	−0.480***	−0.478	<0.001
River Valley (38)	+0.091*	−0.091	−0.089	0.13
Ouachita (33)	−0.021	−0.022	−0.020	0.65
Gulf Coastal Plain (52)	−0.044	−0.050	−0.048	0.25

Interactions of the six WMA distance bins with physiographic region (Ozark Upland reference), county + deer-zone FE, county-clustered SEs, $N = 308{,}226$. "Implied <1/4 mile" is the Ozark bin main effect (+0.002) plus the region interaction. Only the Delta interaction is significant; the joint F-test on all 24 bin × region terms is $F(24, 72) = 6.93$ ($p < 0.001$). The entire headline −0.082 Model 3 discount is concentrated in the Delta. Region map in Figure 17; full output in Table 14. *** $p < 0.001$, * $p < 0.05$.

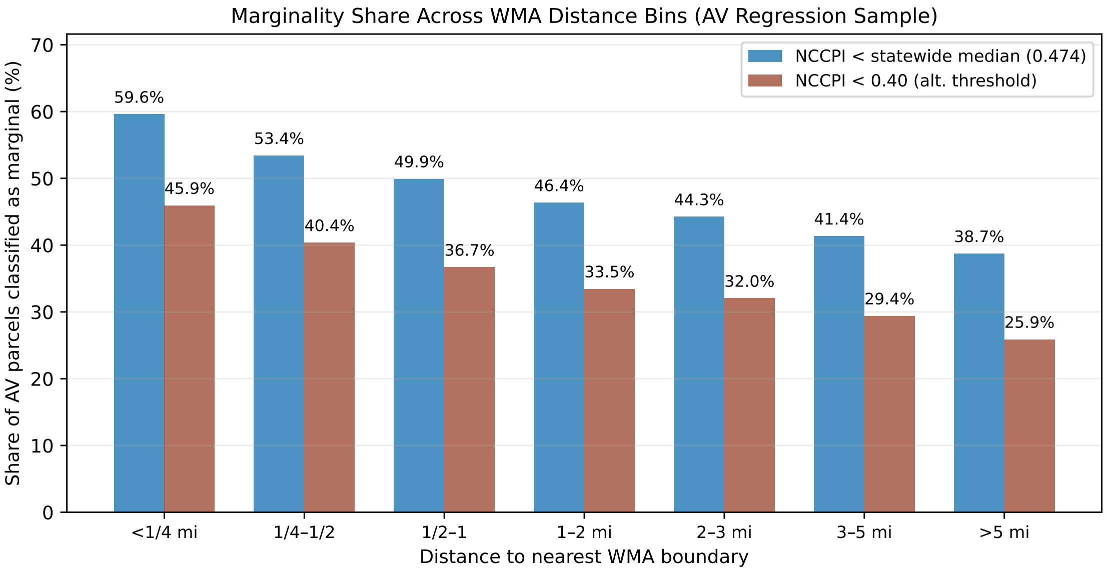


Figure 15: Share of AV-sample parcels classified as marginal across WMA distance bins under two operational thresholds: NCCPI below the AV-sample median (0.489, blue) and NCCPI below 0.40 (red). Both thresholds yield monotone declines from $< 1/4$ mile to > 5 miles, mirroring the mean-NCCPI gradient in Figure 14 and quantifying the placement-on-marginal-land mechanism in operational units.

The CWD null result in this cross-section (-0.9%, $p = 0.68$) has a related explanation. CWD zone counties are concentrated in the Ozarks, where land values differ from non-CWD counties for reasons unrelated to the disease; the county-level CWD indicator lacks temporal variation in a single CAMA snapshot; and assessed values lag any market perception of CWD as a hunting-experience threat. None of the three CWD specifications tested (binary zone, ln(1+positives), seasons-in-zone) is individually significant; across all three, the WMA coefficient is unchanged to four decimal places. The proper tool is a staggered difference-in-differences design on transaction data exploiting the phased zone expansion (Section 9).

8.3 Comparison to Literature

The findings are consistent with the existing literature when the cross-sectional identification limitation is accounted for. The closest parcel-level comparison is Casola et al. [2022], who finds spatially heterogeneous WMA proximity effects on North Carolina residential properties—positive at moderate distances, negative at the boundary—suggesting that WMA placement confounding is a general phenomenon rather than an Arkansas artifact. Pope and Goodwin [1984] estimates that hunting rights add 10–25% to farmland values, while lease-rate studies [Hussain et al., 2013, Munn and Hussain, 2010] imply capitalization rates of 7–8% for hunting-lease income. Anchored at the Arkansas \$322/acre AV sample mean, Pope's 10%–25% premium implies a positive amenity of \$32–\$80 per acre, and the Hussain et al. [2013] 7–8% rate implies \$23–\$26/acre. Our cross-sectional WMA $< 1/4$ mile point estimate of $-\$25$/acre is comparable in magnitude to the Hussain lease-rate benchmark—essentially identical in absolute value, opposite in sign—and falls within Pope's positive-amenity range when reversed. The sign asymmetry is consistent with placement on marginal terrain (Section 3.1) rather than amenity capitalization, and with the residential-vs.-rural sign contrast vis-à-vis Casola et al. [2022] discussed in Section 2. These market-based estimates suggest the true positive amenity in transaction prices will be in the low single-digit percent range per mile of distance—well within the detection power of the validated pipeline. The CWD null is consistent with Poudyal et al. [2025], who find that CWD detection *on the property* reduces Tennessee and Mississippi hunting-lease rates by 22% but CWD on nearby properties has no significant effect; at the Hussain et al. [2013] capitalization rate, the implied sale-price effect is a few hundred dollars per acre, below the detection power of a cross-section. Erickson et al. [2019] document a 5.4% decline in Wisconsin permit demand after CWD detection, providing an order-of-magnitude benchmark for the effects a staggered DiD design on Arkansas transaction data should be able to identify.

9 Limitations and Next Steps

9.1 Limitations

This analysis faces several limitations that constrain causal interpretation and motivate the next phase of the research program.

Appraised use values are not transaction prices. The dependent variable is the appraised use value of land per acre from a CAMA snapshot—a soil-productivity capitalization mandated by Amendment 59 and Ark. Code Ann. § 26-26-407—not a market transaction price. Because it is a use-value appraisal, it contains no market-demand signal for recreational amenity by construction (not merely an attenuated one) and cannot capture dynamic responses to shocks such as CWD detection or WMA establishment. The negative WMA proximity gradient reflects the use-value schedule—WMAs occupy lower-productivity soil that the schedule prices lower—rather than market willingness to pay; sign and magnitude may differ substantially in transaction prices.

Cross-sectional identification. A single CAMA snapshot provides no temporal variation to distinguish treatment effects from selection effects. The negative gradient could reflect a causal effect of WMA designation or the selection of low-value land for WMA designation; without before/after variation these cannot be separated.

WMA placement endogeneity. WMAs were established on marginal agricultural land in the operational sense of Section 3: 68.3% of WMA-adjacent AV parcels fall below the statewide-median NCCPI threshold versus 49.0% of non-adjacent AV parcels, with a county-clustered within-county effect of +8.6 percentage points ($t = 4.25$, $p < 0.001$). Nearby parcels mechanically share these low-productivity characteristics, so the cross-sectional gradient cannot separate a causal effect of WMA designation from the selection of low-value land for designation. This is the fundamental identification challenge for cross-sectional hedonic studies of public-land effects.

Deer quality confounds. The zone-level B&C z-score captures the full vector of zone-level characteristics correlated with deer quality (physiographic region, forest composition, soil, climate, urban proximity), not hunting quality in isolation. The generated-regressor bootstrap in Section 6 quantifies sampling error in z-score construction: the OLS point coefficient on *mean_bc_zscore* (+1.055) lies inside the bootstrap 95% CI of [+0.29, +1.22], so the OLS estimate is consistent with the bootstrap once first-stage sampling error is propagated. The bootstrap permutation test nonetheless rules out random zone assignment ($p < 0.001$). The coefficient is still not interpretable as a causal hunting-quality effect: it absorbs all zone-level variation correlated with deer quality, not the marginal value of an extra trophy buck. Some county-season biodata cells also have few observations, introducing measurement error that zone-level aggregation only partially mitigates.

CWD underpowered. The county-level CWD zone indicator lacks temporal variation in the cross-section, and the 17 affected counties may not provide sufficient power to detect modest effects after conditioning on county-level controls. None of the three CWD specifications tested (binary zone, $\ln(1 + \text{positives})$, seasons-in-zone) is individually significant at conventional levels.

Covariate vintage. The parcels are a September 2025 CAMA snapshot, while several covariates are measured at a single recent vintage (ACS and CRP collapsed to 2024; CWD-zone status and deer quality to the 2024–25 season) and merged onto parcels whose appraisal date is not recorded in the snapshot and may predate it (Arkansas reappraises on a three-to-five-year cycle). Because the snapshot is cross-sectional this introduces no look-ahead in the headline gradient—all detections defining *in_cwd_zone* occurred in FY2016–FY2025, on or before the snapshot—but the contextual covariates describe a parcel's county near the snapshot date rather than at its specific appraisal date. Dated transaction data would remove this ambiguity.

What this paper does and does not deliver. The contribution is a validated, reproducible spatial-hedonic pipeline—sample construction, fourteen integrated spatial data sources, an age-normalized deer-quality index, and an inference suite spanning county-clustered, Conley-HAC, wild-cluster-bootstrap, and generated-regressor-bootstrap standard errors—together with placebo-distance and physiographic-decomposition designs that establish where a proximity gradient is and is not identifiable in cross-section. It does *not* deliver evidence that WMAs raise or lower *market* land values, a causal estimate of deer-quality or CWD capitalization, or a test of the amenity hypothesis: the use-value dependent variable carries no market-demand signal by construction, and a single cross-section carries no temporal variation. Those tests await the transaction data for which this pipeline is the validated instrument.

9.2 Next Steps

The proof-of-concept analysis presented here validates the spatial pipeline and identifies the specifications most likely to yield causal estimates once transaction data is acquired. Five next steps are prioritized.

Transaction data acquisition (critical path). The single most important step is acquiring rural land transaction data with sale prices and dates. Three sources are being pursued: (a) the Arkansas Assessment Coordination Division's statewide transfer database; (b) ATTOM Data Solutions or CoreLogic, commercial transaction databases with statewide rural coverage, contingent on institutional licensing; and (c) individual county assessors' recorded-sale records. The target sample is arms-length rural and agricultural transactions from 2010 to 2025, providing at least five years pre-CWD and nine years post-CWD.

Staggered difference-in-differences for CWD. This is the highest-priority design enabled by transaction data, exploiting plausibly exogenous treatment assignment driven by disease biology rather than policy choice. With transaction dates, a DiD framework can use the staggered CWD zone expansion (10 counties in 2016, 15 in 2018, 17 in 2021) as a natural experiment under the Callaway and Sant'Anna [2021] or Sun and Abraham [2021] frameworks for staggered adoption. Unlike WMA placement, CWD zone designation is driven by disease biology and occurs at known dates, providing plausibly exogenous treatment. The target specification is

$$\ln(\text{price}_{ict}) = \alpha_i + \tau_t + \sum_{e\in\{2016,2018,2021\}} \beta_e \cdot \mathbf{1}\{c \in \text{cohort } e\} \cdot \mathbf{1}\{t \geq e\} + \mathbf{X}'_{ict}\boldsymbol{\gamma} + \epsilon_{ict}, \qquad (3)$$

where i indexes parcels, c counties, and t transaction years. Parcel fixed effects α_i absorb time-invariant placement endogeneity—the central identification threat in the current cross-section—and year fixed effects τ_t absorb statewide agricultural-land trends. The three cohort × post dummies identify the dynamic price response by treatment timing; Equation (3) will be estimated via the Callaway and Sant'Anna [2021] and Sun and Abraham [2021] event-cohort estimators to handle treatment-effect heterogeneity that biases the naive two-way fixed-effect estimator. Pre-trend tests on a 2010–2015 sample window provide the standard parallel-trends validation. Figure 16 visualizes the resulting cohort-by-season treatment structure.

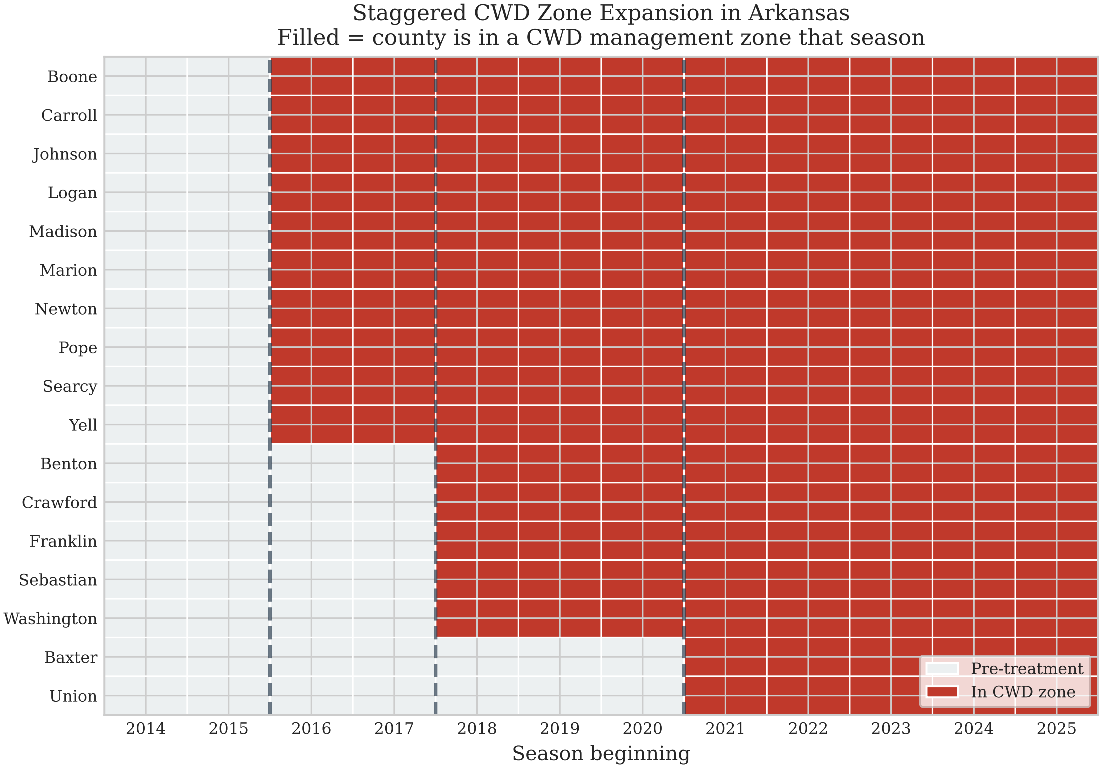


Figure 16: Staggered CWD zone expansion in Arkansas, 2014–2025. Each row is a CWD-zone county; each column a season. Filled cells indicate the county is in a CWD management zone that season. Dashed vertical lines mark the 2016, 2018, and 2021 cohort onsets. This three-cohort staggered structure is what identifies the Callaway and Sant'Anna [2021] or Sun and Abraham [2021] event-cohort estimators once transaction data are available.

WMA establishment dates. Compiling historical WMA establishment and expansion dates enables a second DiD analysis: treatment is WMA creation, outcome is the change in nearby land prices before and after. AGFC historical records and web-scraped sources have already partially compiled these dates. This design addresses placement endogeneity directly by comparing the same parcels before and after WMA creation.

Hunting regulation history. Zone-year bag limits, season lengths, and antler restrictions provide additional policy variation for instrumental-variables estimation or as separate treatments. A bag-limit increase provides identifying variation separate from WMA proximity or deer quality.

Spatial econometric models. The current analysis uses Conley HAC standard errors to address spatial correlation but does not estimate spatial-lag or spatial-error models (SAR, SEM). Implementing these on 308,226 observations is computationally feasible with sparse weight matrices and would improve efficiency if the data-generating process includes spatial spillovers.

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Appendices

A Full Regression Output

Table 14 reports the six baseline specifications (M1, M4, M2, M3, M9, M6); Table 15 reports the three interaction-and-controls specifications (M7, M8, M5). All nine models are estimated on the canonical AV sample (N = 308,226, identical to Section 5), with county-clustered SEs. Parcel-level controls, fixed-effect indicators, sample sizes, and R^2 are reported per specification; every coefficient also appears in `report/figures/coefficients.csv`.

Table 14: Full Regression Output: Baseline Models (AV sample, N = 308,226)

	M1 (County)	M4 (LogDist)	M2 (Cty+Zone)	M3 (Bins)	M9 (Region)	M6 (Z-score)
WMA Distance Variables						
dist_to_wma_km	−0.002		+0.002			−0.001
	(0.003)		(0.001)			(0.002)
ln_dist_to_wma_km		+0.001				
		(0.015)				
inside_wma_flag	−0.147***	−0.139**	−0.130***			−0.142***
	(0.029)	(0.046)	(0.022)			(0.028)
boundary_adjacent_wma	−0.098***	−0.086*	−0.064***	−0.031**		−0.079***
	(0.020)	(0.037)	(0.017)	(0.011)		(0.016)
<1/4 mile				−0.082***	+0.002	
				(0.024)	(0.043)	
1/4–1/2 mile				−0.079***	−0.013	
				(0.023)	(0.036)	
1/2–1 mile				−0.049*	+0.009	
				(0.020)	(0.032)	
1–2 miles				−0.037*	+0.012	
				(0.018)	(0.032)	
2–3 miles				−0.028	+0.004	
				(0.015)	(0.017)	
3–5 miles				−0.008	+0.004	
				(0.014)	(0.011)	
Deer Quality and Region Interactions						
mean_bc_zscore						+1.055***
						(0.224)
Bin × Region F					6.93***	
					p<0.001	

Continued on next page

	M1	M4	M2	M3	M9	M6
Parcel Controls						
11 parcel-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects						
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Deer Zone FE	No	No	Yes	Yes	Yes	No
Model Statistics						
R^2	0.665	0.665	0.716	0.716	0.718	0.682
N	308,226	308,226	308,226	308,226	308,226	308,226

Notes. M9 bin coefficients are estimated relative to the Ozark Upland physiographic region (reference category, 33 of 191 WMAs). The bin × region interactions are jointly significant: the <1/4 mile × Delta interaction is -0.480 (SE 0.082, $p < 0.001$), implying that the WMA-proximity discount documented in M3 is concentrated in the Delta region, where surrounding cropland is uniformly high-quality. Ozark Upland and Ouachita bins show no proximity discount.

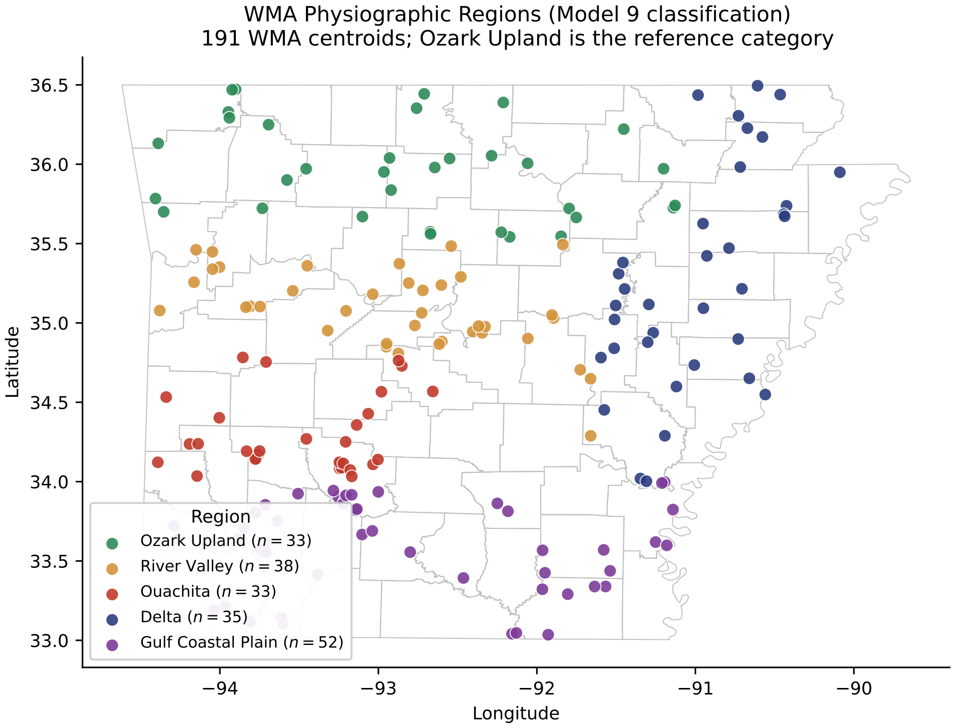

Figure 17: The 191 WMA boundaries classified into five Arkansas physiographic regions by centroid latitude/longitude (the Model 9 categorization; Ozark Upland is the reference). Delta WMAs (blue) cluster in the eastern Mississippi Alluvial Plain, where the steep <1/4 mile proximity discount is concentrated (Table 13); Ozark Upland (green), River Valley (amber), Ouachita (red), and Gulf Coastal Plain (purple) WMAs occupy the western and southern uplands and the coastal plain. Mapping traces to `report/figures/wma_physiography_map.csv`.

Table 15: Full Regression Output: Interaction and County-Control Models (AV sample, $N = 308{,}226$)

	M7 (Z Interact.)	M8 (CWD Bins)	M5 (Cty Controls)
WMA Distance Variables			
dist_to_wma_km	−0.000		+0.001
	(0.002)		(0.001)
inside_wma_flag	−0.149***		−0.130***
	(0.028)		(0.023)
boundary_adjacent_wma	−0.078***		−0.066***
	(0.017)		(0.019)
dist × zscore	+0.015*		
	(0.007)		

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	M7	M8	M5
<1/4 mile		−0.114***	
		(0.027)	
1/4–1/2 mile		−0.094***	
		(0.028)	
1/2–1 mile		−0.055*	
		(0.023)	
1–2 miles		−0.042*	
		(0.020)	
2–3 miles		−0.022	
		(0.016)	
3–5 miles		+0.004	
		(0.015)	
Deer Quality			
mean_bc_zscore	+0.849***		
	(0.240)		
CWD Variables			
in_cwd_zone		−0.014	−0.009
		(0.023)	(0.022)
<1/4 mile × CWD		+0.106*	
		(0.043)	
1/4–1/2 mile × CWD		+0.071	
		(0.040)	
CWD × bins (joint)		$F(6, 72) = 2.20$, $p = 0.053$	
County-Level Controls			
crp_pct_county_area			−0.043**
			(0.014)
mean_nccpi			+0.450*
			(0.192)
pct_prime_farmland			+0.005**
			(0.002)
elevation_km			−0.720***
			(0.163)
ln_population			+0.030*
			(0.013)
ln_median_income			−0.061
			(0.056)
in_fayetteville_shale			−0.017
			(0.059)
Parcel Controls			

Continued on next page

	M7	M8	M5
11 parcel-level controls	Yes	Yes	Yes
Fixed Effects			
County FE	Yes	No	No
Deer Zone FE	No	Yes	Yes
County-level controls (8)	No	Yes	Yes
Model Statistics			
R^2	0.684	0.709	0.709
N	308,226	308,226	308,226

Notes: Clustered standard errors (county) in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Reference category for distance bins: >5 miles; reference for CWD: $in\_cwd\_zone = 0$. "Yes" indicates variable included but coefficient not shown for brevity. The bin × CWD interaction is borderline jointly significant ($F(6, 72) = 2.20$, $p = 0.053$), driven primarily by the <1/4 mile × CWD coefficient (+0.106, $p = 0.014$): in CWD zones the WMA-proximity discount is partly offset, consistent with the placement-on-marginal-terrain mechanism documented in Section 8. Per-coefficient values trace to `report/figures/coefficients.csv`.

B Variable Definitions and Deer Quality Methodology

Boone & Crockett Age-Class Standardization

Figure 18 displays the distribution of Boone & Crockett gross scores by age class in the AGFC biodata. Older bucks produce systematically higher scores, motivating the within-age-class z-score standardization described in Section 3. The 2013–14 season (excluded from the reference distribution) exhibited anomalously low derived B&C scores due to a scoring formula error; raw antler measurements were unaffected.

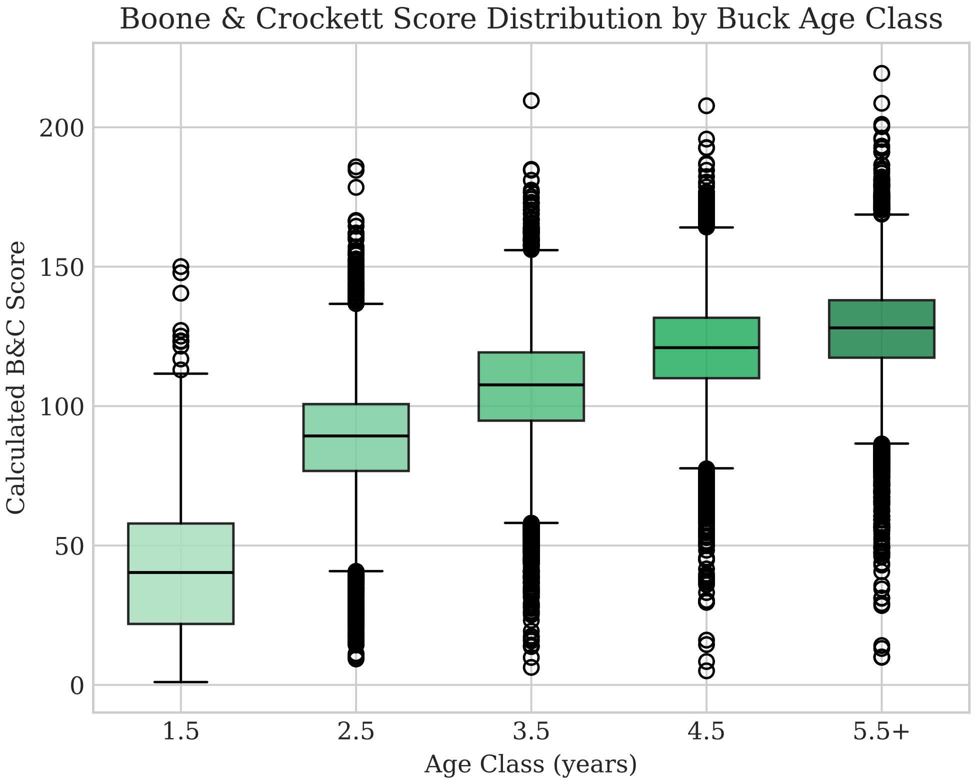

Figure 18: Distribution of Boone & Crockett gross scores by age class. Age-class normalization is essential because older bucks produce systematically higher scores, so a naive comparison of raw zone-level scores would confound age composition with trophy quality.

Full Variable Dictionary

Table 16: Variable Definitions, Sources, and Measurement Level

Variable	Definition	Source	Level
Dependent Variable			
ln_land_value_acre	Natural log of assessed land value per acre	AR GIS CAMA	Parcel
WMA Variables			
dist_to_wma_km	Euclidean distance (km) from parcel centroid to nearest WMA boundary	AGFC boundaries	Parcel

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Variable	Definition	Source	Level
wma_dist_bin	Categorical: <1/4mi, 1/4–1/2mi, 1/2–1mi, 1–2mi, 2–3mi, 3–5mi, >5mi	Derived	Parcel
inside_wma_flag	Indicator: parcel centroid within WMA boundary	AGFC boundaries	Parcel
wma_physiography	Physiographic region of the nearest WMA (Ozark Upland, River Valley, Ouachita, Delta, Gulf Coastal Plain)	AGFC + centroid lat/lon	Parcel
Parcel Controls			
ln_acres	Natural log of parcel acreage	AR GIS CAMA	Parcel
is_forest	Indicator: majority land cover is forest (NLCD 41–43)	NLCD 2021	Parcel
is_wetland	Indicator: majority land cover is wetland (NLCD 90, 95)	NLCD 2021	Parcel
in_100yr_floodplain	Indicator: parcel in FEMA 100-year flood zone	FEMA NFHL	Parcel
ln_dist_paved_km	Log distance (km) to nearest paved road	Census TIGER	Parcel
ln_dist_ua_km	Log distance (km) to nearest Census Urban Area	Census 2020	Parcel
ln_dist_any_water_km	Log distance (km) to nearest water body or stream	NHD	Parcel
in_national_forest	Indicator: parcel within national forest boundary	PAD-US 4.1	Parcel

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Variable	Definition	Source	Level
ln_dist_federal_km	Log distance (km) to nearest federal land	PAD-US 4.1	Parcel
County-Level Variables			
elevation_km	Mean county elevation in kilometers	USGS 3DEP	County
in_fayetteville_shale	Indicator: county overlaps Fayetteville Shale play	AOGC wells	County
crp_pct_county_area	CRP enrolled acres as % of county area	NASS Census Ag	County
in_cwd_zone	Indicator: county in CWD management zone (2024–25)	AGFC reports	County
mean_nccpi	National Commodity Crop Productivity Index (0–1)	SSURGO	County
ln_population	Log of county population	ACS 5-year	County
ln_median_income	Log of county median household income	ACS 5-year	County
pct_prime_farmland	Percent of county area classified as prime farmland	SSURGO	County
Deer Quality Variable			
mean_bc_zscore	Mean age-normalized B&C z-score for the deer zone	AGFC biodata	Zone

C CWD Zone Panel

Table 17 summarizes the CWD management zone evolution in Arkansas from the 2016–17 through 2024–25 seasons, showing which counties entered the zone in each phase and their cumulative positive detections through FY25.

Table 17: CWD Management Zone: County Entry and Cumulative Detections

County	Season Entered	Tier (2024–25)	Cumulative Positives
Phase 1: Initial Zone (2016–17)			
Newton	2016–17	1	970
Boone	2016–17	1	306
Carroll	2016–17	1	221
Madison	2016–17	1	168
Searcy	2016–17	1	146
Johnson	2016–17	1	56
Marion	2016–17	1	19
Pope	2016–17	2	16
Logan	2016–17	2	11
Yell	2016–17	2	0
Phase 2: First Expansion (2018–19)			
Washington	2018–19	2	44
Benton	2018–19	2	22
Crawford	2018–19	2	7
Franklin	2018–19	2	7
Sebastian	2018–19	2	9
Phase 3: Second Expansion (2021–22)			
Baxter	2021–22	2	1
Union	2021–22	2	2
Total (17 counties)			**2,005**
Counties with detections outside CWD zone			
Randolph	Not in zone	—	6
Van Buren	Not in zone	—	7
Stone	Not in zone	—	5
Scott	Not in zone	—	4
Independence	Not in zone	—	4
Conway	Not in zone	—	2
Cleburne	Not in zone	—	2
Craighead	Not in zone	—	1

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County	Season Entered	Tier (2024–25)	Cumulative Positives
Statewide Total			**2,036**

Notes: Tier assignments reflect the 2024–25 season classification. Tier 1 (core) counties have sustained high CWD prevalence and are subject to mandatory testing. Tier 2 (peripheral) counties are in the buffer zone with voluntary testing encouraged. Cumulative positives are through FY25. The two-tier system was introduced in the 2021–22 season, reclassifying some original zone counties from untiered to Tier 1 or Tier 2. Union County (Phase 3) is geographically distant from the Ozark epicenter, reflecting a separate detection event in southern Arkansas.

D Physiographic Heterogeneity of the WMA Gradient

Zone-level deer quality co-varies strongly with physiographic region: high-z-score zones concentrate in the Mississippi Delta and Crowley's Ridge (flat, productive ground), while low- or near-zero-z-score zones fall in the Ozark Plateau, Ouachitas, and Gulf Coastal Plain (rugged or marginal terrain). Whether the WMA proximity gradient "differs by deer quality" is therefore, in this cross-section, a question about physiographic heterogeneity rather than a hunting-quality treatment effect. We quantify it with the Model 9 physiographic decomposition (introduced in Section 8; full coefficients in Appendix A), which interacts the distance bins with the nearest WMA's physiographic region and carries valid county-clustered inference and a joint F-test. We prefer this to a naive split of the sample on the (zone-level, 20-valued) z-score, whose high-quality subsample spans too few county clusters for a well-defined cluster-robust covariance.

Table 18: Model 9: WMA <1/4 Mile Effect by Physiographic Region

Nearest-WMA region	<1/4 mile effect	p
Ozark Upland (reference)	+0.002	0.96
× Delta	−0.480	< 0.001
× Gulf Coastal Plain	−0.050	0.25
× Ouachita	−0.022	0.65
× River Valley	−0.091	0.13
Joint $F(24, 72) = 6.93$, $p < 0.001$ (all 24 bin × region interactions)		

Model 9 (county + deer-zone FE, 11 parcel controls, county-clustered SEs, N = 308,226): the six distance bins interacted with the nearest WMA's physiographic region. The first row is the <1/4 mile bin main effect (Ozark Upland reference, 33 of 191 WMAs); subsequent rows are the <1/4 mile × region interactions. The full coefficient set is in Appendix A.

Estimated against Ozark Upland WMAs, the <1/4 mile bin main effect is essentially zero (+0.002, $p = 0.96$), while the <1/4 mile × Delta interaction is −0.480 (SE 0.082, $p < 0.001$); the Gulf Coastal Plain, Ouachita, and River Valley interactions are individually insignificant. The entire headline −0.082 gradient (Model 3) is thus a weighted average of a near-zero Ozark/Ouachita gradient and a large Delta-region discount. The mechanism is land-quality sorting by physiography: Delta WMAs occupy bottomland surrounded by uniformly high-value row-crop ground, so adjacent parcels look steeply discounted by comparison, whereas Ozark and Ouachita WMAs sit in regions where most agricultural land is already similar to the WMA-adjacent parcels.

Model 7, which instead adds a continuous WMA-distance × z-score interaction, points the same direction: $\hat{\beta}_3 = +0.015$ (SE 0.007, $p = 0.029$), so the near-WMA discount steepens with zone deer quality—largest in the high-z Delta-heavy zones and near zero in the low-z Ozark zones. Because *mean_bc_zscore* is a generated regressor, the OLS standard error on the interaction ignores first-stage sampling error; the Pagan bootstrap in Section 6.5 corrects this for the main z-score effect, and an analogous bootstrap for the interaction term would be a natural extension.

E Harvest Intensity and Hunter Effort

Figure 19 displays the distribution of deer harvest by day of week, serving as a proxy for hunter effort patterns.

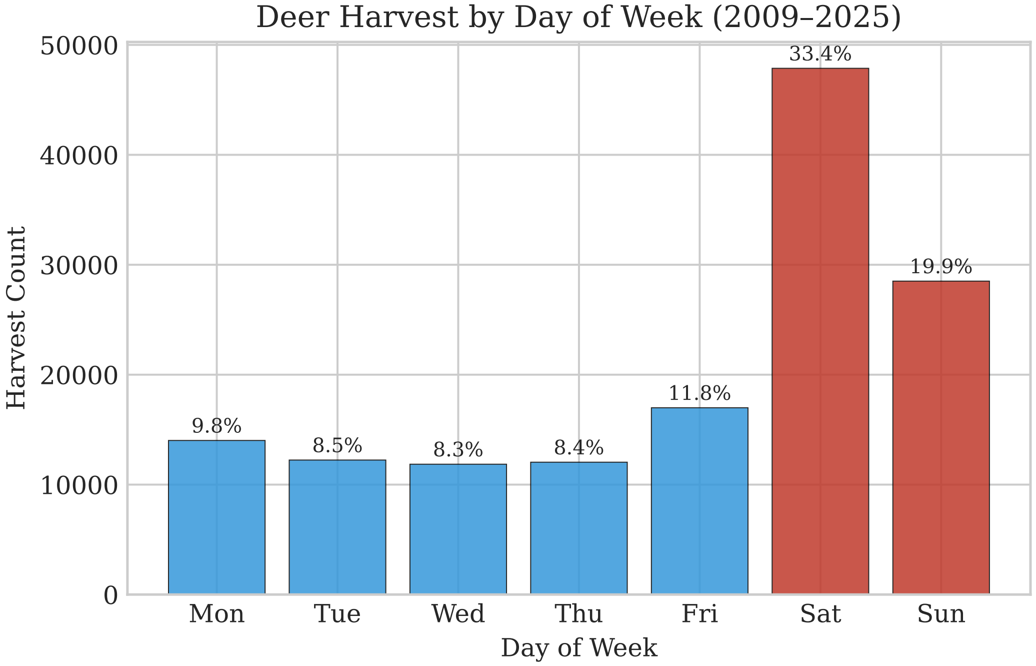

Figure 19: Deer harvest by day of week. Saturday dominance reflects weekend hunting patterns, with modern gun season accounting for the plurality of harvest. The day-of-week pattern is consistent across zones and seasons.

Saturday accounts for the largest share of weekly harvest, consistent with the expectation that recreational hunters concentrate effort on weekends. Modern gun season contributes the plurality of total harvest. The day-of-week pattern is remarkably consistent across zones and seasons, suggesting that hunter effort allocation is driven by work schedules and season structure rather than local deer quality or WMA characteristics.

Harvest intensity serves as an indirect measure of hunting pressure. Zones with higher harvest per unit area may experience greater hunting-related land demand, though this relationship is confounded by population density and access. Future work with transaction data and spatially resolved hunting participation data could exploit this variation more directly.