

Article

Beyond Forest Expansion: State Forest Land Acquisitions as an Instrument of Sustainable Land Governance

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Abstract

Land-use conflicts in non-urbanized areas are fundamentally governance problems rather than purely environmental ones: sustainability outcomes increasingly depend on integrated, cross-sectoral decision-making reconciling forestry, agriculture, tourism, infrastructure, and urbanization within a finite land resource. This study examines whether statutory land acquisitions by a public forest administration can be understood as such a governance instrument rather than simply forest-area expansion, using an original transaction-level database of 911 land purchases by the Polish State Forests (Lasy Państwowe) through statutory pre-emption rights between 2022 and mid-2026. The database covers 2806.1 hectares and, for the 903 transactions with a determinable price, approximately 114.2 million PLN. Using descriptive statistics, concentration indices (Gini, Herfindahl–Hirschman), an exploratory hedonic-style log–log regression of unit price on parcel area with location and year fixed effects, and a spatial-autocorrelation analysis (Moran’s I), the study examines spatial concentration, price differentiation, and parcel-size effects. Results show pronounced sub-regional concentration (county-level Gini = 0.615, more than double the voivodeship-level value of 0.284), a systematic price premium for parcels below 0.5 ha, and a dominant role of location over parcel size in explaining price variation (R-squared rising from 0.042 to 0.198 with location fixed effects); these are descriptive associations rather than causal estimates, given the absence of parcel-level quality covariates and a fully specified spatial–econometric model. The findings support interpreting statutory pre-emption purchases as a market-based institutional mechanism contributing to boundary rationalization, ownership consolidation, and mediation of competing land-use pressures, with implications for county-level monitoring and cross-sectoral coordination with spatial planning.

Keywords: sustainable land governance; State Forests; land fragmentation; pre-emption right; hedonic pricing; spatial concentration; Poland



Academic Editor: Maria Rosa Trovato

Received: 5 July 2026

Revised: 24 July 2026

Accepted: 28 July 2026

Published: 7 August 2026

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1. Introduction

Non-urbanized land is increasingly subject to competing pressures from forestry, agriculture, housing, tourism, infrastructure, renewable energy, and biodiversity conservation, all contesting a spatially fixed and non-reproducible resource [1,2]. Sustainable land governance requires not only planning regulations and zoning instruments, but also institutional mechanisms through which public bodies can shape ownership patterns, reduce spatial fragmentation, and mediate between these competing claims over time [3–5]. Public bodies that hold statutory rights to acquire land—either through direct purchase or through pre-emption mechanisms—occupy a distinctive position in this governance landscape, since

their acquisition decisions are simultaneously market transactions and instruments of land policy [6,7].

Contemporary land management in Poland reflects a wider European transition from sectoral land allocation towards integrated and multifunctional land governance. The principal challenge is managing competing pressures from urbanization, agricultural production, renewable energy development, biodiversity restoration, and climate adaptation within finite land resources; this makes strategic spatial planning, institutional coordination, and ecosystem-based approaches central determinants of long-term sustainability [1,8]. Land-use conflicts of this kind are, at the root, governance problems rather than purely technical or environmental ones, since they concern who holds the authority and the instruments to reconcile competing claims on the same finite resource.

In Poland, the State Forests (*Lasy Państwowe*), a state holding that manages roughly a quarter of the country's territory and the large majority of its forest resource, hold a statutory pre-emption right over forest land offered for sale by private owners, and a related right of first refusal over agricultural land bordering State Forests holdings, under Article 37a of the Act on Forests of 28 September 1991 [9]. Each exercise of this right is a market transaction: a specific parcel, in a specific municipality, is purchased at a specific price. Over time, these transactions cumulatively reshape the ownership structure of non-urbanized land at the local and regional scale. Yet, despite the importance of the State Forests as a land-market actor, little systematic empirical attention has been paid to where, at what price, and at what scale these acquisitions take place, still less to whether they can be understood as a coherent instrument of land governance. Existing research on Polish forestry has focused chiefly on governance paradigms, ownership ideology, and the post-socialist institutional legacy of state forest management [10,11], rather than on the transaction-level geography and economics of land acquisition.

This paper addresses that gap using an original, transaction-level database of 911 land purchases carried out by the State Forests between 2022 and mid-2026, compiled from official notices published under Article 37a of the Act on Forests. The paper's guiding proposition is that land acquisition by the State Forests should not be read solely as an act of forest-resource expansion, but as an instrument of sustainable land governance—consolidating ownership, rationalizing boundaries, supporting ecological continuity, and mediating between forestry and competing land uses. Building on this framework, the paper addresses four research questions:

- RQ1. How spatially and economically differentiated are State Forests' land acquisitions in Poland?
- RQ2. Do small parcels command a systematic price premium, indicating a boundary-rationalization function?
- RQ3. Is the spatial concentration of acquisitions regional or local/county-based?
- RQ4. Can statutory pre-emption purchases be interpreted as an institutional mechanism of sustainable land governance?

Correspondingly, three hypotheses are tested:

H1. *Smaller parcels are acquired at higher unit prices, reflecting boundary-rationalization and fragmentation-reduction functions.*

H2. *The spatial concentration of acquisitions is stronger at the county level than at the voivodeship level.*

H3. *Location explains more variation in unit price than parcel area, indicating that acquisition patterns are embedded in local land-use pressure.*

The empirical analysis pursues six specific objectives underlying these questions: (1) to quantify the number, area, and value of transactions on an annual basis; (2) to identify the voivodeships (Poland's sixteen principal first-tier administrative regions, broadly equivalent to provinces), counties (powiaty, second-tier administrative units, of which there are approximately 300), and forest districts (nadlesnictwa, the local operational units of the State Forests) with the highest purchasing activity; (3) to characterize the differentiation of unit prices (PLN per hectare); (4) to assess whether transaction size is associated with unit price; (5) to evaluate the regional concentration and spatial autocorrelation of purchasing activity; and (6) to interpret these patterns through the lens of sustainable land governance rather than forestry economics alone.

This study makes four core contributions. First, it compiles and analyses the first transaction-level micro-database of State Forests pre-emption purchases (911 records, 2022–mid-2026), a level of empirical granularity not previously available for this policy instrument. Second, it reframes statutory pre-emption purchases explicitly as an instrument of sustainable land governance, rather than as a sectoral forestry activity, through the conceptual framework developed in Section 2.1. Third, it shows that regional (voivodeship-level) reporting substantially understates the true spatial concentration of purchasing activity relative to county-level analysis, a methodological point with direct implications for how this and comparable land-acquisition programmes should be monitored. Fourth, it develops an inductive, five-category typology of acquisition functions (Section 4.7) linking individual transactions to broader governance objectives—boundary rationalization, ownership consolidation, ecological continuity, and mediation of competing land uses.

The remainder of the paper is organized as follows. Section 2 situates the study within the literature on sustainable land governance, land as a spatial–economic resource, public agencies as land-market actors, and the determinants of forest and rural land prices. Section 3 describes the institutional context of the State Forests' pre-emption right, the data source, and the analytical methods, including a hedonic price regression and an exploratory spatial-autocorrelation analysis. Section 4 presents the results. Section 5 discusses the findings in relation to the literature and to sustainable land governance. Section 6 concludes with policy implications and directions for future research.

2. Theoretical Background and Literature Review

2.1. Sustainable Land Governance and Non-Urbanized Land

Sustainable land governance denotes the set of institutions, rights, and decision-making mechanisms through which societies allocate, regulate, and monitor the use and ownership of land in pursuit of long-term ecological, economic, and social objectives [4]. Unlike land-use planning, which operates primarily through zoning and permitting, land governance also encompasses the ownership-structuring mechanisms—including public acquisition, pre-emption rights, and land banking—through which a public body can shape who holds land and on what terms, independently of, but in coordination with, formal planning instruments [5]. The 2030 Agenda for Sustainable Development explicitly recognizes land as a governance object in its own right, calling for the integration of ecosystem and biodiversity values into national and local planning and development processes [12] (SDG target 15.9) and for the sustainable management of natural resources more broadly.

Three dimensions organize how public land acquisition can be read as an instrument of sustainable land governance. The ecological dimension concerns the spatial continuity of forest cover and habitat: eliminating private enclaves, straightening boundaries, and reducing fragmentation supports ecological connectivity and lowers the long-run cost of managing dispersed, discontinuous holdings [13]. The economic dimension concerns

the transaction-cost rationale for consolidation: fragmented ownership raises the cost of coordinated management, and a statutory pre-emption right lowers the cost of correcting this fragmentation incrementally, parcel by parcel [14,15]. The institutional and social dimension concerns the capacity of a public body to mediate between competing claims on non-urbanized land—forestry, agriculture, tourism, residential development, and infrastructure—through market-based intervention rather than compulsory acquisition or blanket zoning restriction [6,7]. Read together, these dimensions reframe the State Forests’ pre-emption purchases as more than a sectoral, forestry-specific activity: they are an instance of land governance in the broader sense used in the sustainability literature, in which ownership change is itself a policy instrument bearing on spatial resilience and long-term land-use coordination [5]. Figure 1 summarizes this framework, linking the statutory pre-emption right to four governance functions performed at the transaction level and, cumulatively, to the sustainable governance of non-urbanized land.

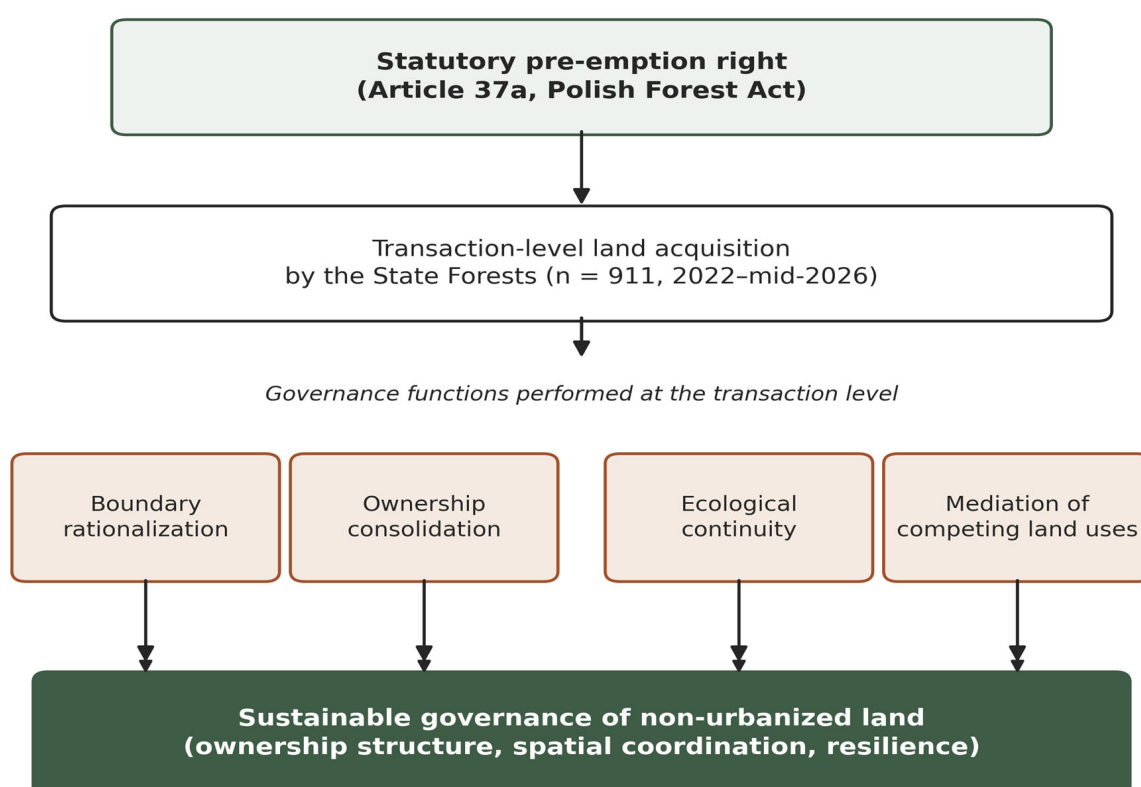


Figure 1. Conceptual framework: State Forests’ land acquisitions as an instrument of sustainable land governance.

2.2. Land as a Scarce and Multifunctional Resource in Spatial Economics

Land-use policy scholarship has long treated non-urbanized land as a scarce, non-reproducible resource whose allocation among competing functions—agricultural, forestry, ecological, residential, infrastructural, and recreational—is a central concern of spatial governance [2]. The classical foundations of this view reach back to von Thünen’s [16] model of land rent as a function of distance to a central market, and to Alonso’s [17] generalization of location-dependent land rent to a wider set of competing uses; both establish the basic proposition, still central to hedonic and spatial-economic analysis today, that the value and use of a parcel of land are inseparable from its position within a wider spatial and functional structure, not merely from its physical attributes. Because land cannot be relocated, decisions about its ownership and use have persistent, path-dependent consequences for the spatial structure of a territory. Changes in ownership

are therefore not neutral economic events: they can alter the functional trajectory of a parcel, its accessibility, its integration into larger management units, and its resilience against fragmentation [13]. Land fragmentation in particular has been shown to reduce the efficiency of land management and to complicate the maintenance of ecological and infrastructural continuity, which is one of the principal justifications, in both agricultural and forestry contexts, for policy instruments aimed at consolidation [13].

Within this framework, a purchase of land by a public body is not merely a private transaction replicated at scale; it is a mechanism through which the state can influence the trajectory of non-urbanized space without resorting to compulsory acquisition or spatial planning restrictions alone. This makes the analysis of such purchases—their location, scale, and price—directly relevant to land-use policy, even where the acquiring institution is nominally a sectoral (forestry) rather than a spatial-planning body.

It should be acknowledged that the von Thunen–Alonso tradition, and the broader bid–rent framework it inspired, was developed within a predominantly market-oriented conception of land allocation, in which land use and value are determined by competing willingness to pay. Contemporary land-use conflicts increasingly involve non-market values—biodiversity conservation, climate change mitigation, ecosystem services, and social equity—that cannot be adequately captured through bid–rent competition alone [18]. A sustainability-oriented account of public land acquisition must therefore integrate considerations of public goods and ecological governance alongside classical location theory, consistent with the sustainable-land-governance framework introduced in Section 2.1: the State Forests’ pre-emption purchases are read here not only as responses to locational land rent, but as an institutional mechanism for internalizing non-market ecological and social values that private land markets do not price on their own.

2.3. Property Rights, Transaction Costs, and the Economics of Pre-Emption

The economic rationale for treating ownership changes as policy-relevant events, rather than as neutral private exchanges, rests on the broader theory of property rights and transaction costs. Coase’s [14] foundational analysis showed that the allocation of resources is independent of the initial assignment of property rights only when transaction costs are negligible; where they are not, as is generically the case in real estate markets characterized by search costs, asymmetric information, and administrative procedure, the specific legal design of ownership and transfer rights has first-order allocative consequences. Ostrom’s [15] study of common-pool resource governance further showed that neither pure market allocation nor centralized state control is uniquely efficient, and that intermediate institutional arrangements—of which a statutory pre-emption right vested in a public body is one example—can be understood as a designed response to the transaction-cost and coordination problems inherent in managing a spatially dispersed, multi-owner resource such as a national forest estate. A pre-emption right of the kind analyzed in this paper can accordingly be read as an institutional device that lowers the transaction costs of consolidating a fragmented ownership structure, at the cost of constraining the private land market in which it operates.

2.4. Public Forest Agencies as Actors in Non-Urbanized Land Markets

Public forestry agencies are frequently treated in the literature primarily as resource managers rather than as market participants. Yet where such agencies hold statutory purchase or pre-emption rights, they function as institutional actors within local land markets, with the capacity to affect price formation, competition among bidders, and the pool of land available to other buyers [7]. Rights of first refusal and pre-emption rights held by tenants, neighbouring owners, or public bodies have received comparatively

limited attention in the economic literature, despite their wide diffusion across European land-tenure systems [6]. Evidence from farmland auctions shows that such rights can measurably reduce the number of competing bidders and depress sale prices relative to open, unencumbered auctions [7], while evaluations of neighbour pre-emption rights in Italian agriculture underline the need to assess these instruments empirically rather than assume their distributive effects [6].

The Polish case is distinctive in one respect relevant to this literature: unlike several other post-socialist countries in the region, Poland did not reconstitute forest land to former owners after 1989, so the State Forests retained an exceptionally large, spatially continuous public forest estate under a centralized management model [10]. This institutional continuity, combined with a strong ideological commitment within Polish forestry to state ownership as a guarantor of sustainable management [10], provides the backdrop against which the State Forests' pre-emption purchases should be interpreted: they are not a residual administrative function but an active, ongoing mechanism of land-market intervention operating within an already state-dominated ownership structure. Comparable, though institutionally distinct, models of large-scale public forest ownership exist elsewhere in Europe: the Swedish state forest company Sveaskog, for instance, combines commercial timber management with a dedicated network of "ecoparks" in which conservation objectives take precedence over production [19], illustrating that public forest holdings across Europe increasingly serve multiple, and at times competing, land-use policy objectives rather than a purely productive forestry mandate.

Poland's non-restitution path is only one of several institutional trajectories followed by former socialist countries after 1989, and situating it within this wider comparative literature clarifies what is, and is not, distinctive about the Polish case. In the Czech Republic, Slovakia, and Serbia, forest restitution redistributed substantial areas of state forest to private and communal owners, but the relative power of state agencies, restituted owners, and other actors in shaping the process varied considerably across the three countries, with state administrations retaining greater practical control in some settings than the formal restitution law implied [20]. In Romania, restitution proceeded through a more fragmented and contested governance process, analyzed through a Drivers–Pressures–State–Impact–Response (DPSIR) framework, in which weak monitoring and enforcement capacity undermined the sustainability objectives the restitution process was nominally designed to serve [21]. A recent synthesis of three decades of forest policy research across the former socialist countries of Europe confirms that restitution, privatization, and the resulting ownership fragmentation remain the dominant themes of the regional literature, while transaction-level analysis of how public forest administrations subsequently intervene in land markets—through purchase, pre-emption, or repurchase—remains comparatively underexplored [22]. Read against this literature, Poland's centralized, non-restituted forest estate represents something close to the opposite institutional endpoint from the fragmented-then-partially-reconsolidated ownership structures documented in the Czech, Slovak, Serbian, and Romanian cases; the pre-emption mechanism analyzed in this paper is best understood as a continuous, incremental land-market intervention rather than as a one-off restitution or reprivatization event, making it a distinct but complementary object of study within the broader Central and Eastern European forest-governance literature.

2.5. Forest Transitions and the Changing Ownership Structure of European Forests

A complementary body of the literature examines how forest area and forest ownership evolve over time at the national scale. Forest transition theory holds that forest cover in a given territory typically follows a U-shaped trajectory—an initial phase of clearing driven by agricultural expansion, followed by a turning point and subsequent recovery once non-

farm employment, forest-product scarcity, or explicit afforestation policy take hold [23,24]. Meyfroidt and Lambin [25] show that such transitions are frequently accompanied not merely by area recovery but by institutional consolidation of forest management, of which growth in the extent and continuity of a public forest estate is one manifestation. Parallel to this literature on forest area, a distinct strand of research documents ownership-level change: private forest ownership across Europe has become markedly more fragmented over recent decades, with an estimated 0.8 million owners holding some 3.9 million distinct parcels in the countries reviewed by Weiss et al. [26], with typologies of private forest owners increasingly dominated by non-traditional, non-agricultural, and part-time owners whose management priorities diverge from those of professional foresters [27], and with comparable fragmentation dynamics documented outside forestry, for instance in the partible-inheritance-driven splitting of Central European farmland holdings [28]. This macro-level European fragmentation trend forms the backdrop against which the parcel-level rationalization mechanism examined in Section 2.6 should be read; the two operate at different scales and are treated separately below to avoid conflating a continent-wide ownership trend with the transaction-level mechanism this paper tests.

2.6. Land Acquisition as an Instrument of Rationalizing Spatial Structure

Building on the fragmentation-efficiency logic introduced in Section 2.2, a specific and directly testable mechanism deserves separate attention here: small, oddly shaped, enclaved, or boundary-adjacent parcels can carry disproportionate management significance for a forest administration independent of their area, because acquiring them reduces the incidence of private enclaves, straightens awkward boundary lines, and improves continuity for silvicultural management and ecological connectivity [13]. If this boundary-rationalization logic operates empirically, one would expect small parcels to be acquired at a price premium relative to their productive or market value alone—a pattern this paper tests directly in Section 4.4. This logic parallels the rationale of land consolidation programmes long used in Polish rural land policy, where deliberately organized consolidation of fragmented agricultural plots has been shown to raise the socio-economic development trajectory of affected municipalities; incremental pre-emption purchases and formal consolidation schemes can thus be read as two variants of the same underlying policy lever, operating respectively through market transactions and administrative reallocation.

2.7. Public Land Acquisition in Comparative and International Perspective

Placing State Forests' purchases in a still wider comparative frame, two distinct international studies are relevant, even though neither maps directly onto the Polish case. First, the literature on large-scale land-acquisitions ("land grabbing"), which expanded rapidly after the 2007–2008 food and financial crises, analyses how domestic and foreign investors acquire extensive tracts of agricultural and forest land, often in the Global South, for commodity production, conservation, or speculative purposes [29–31]. Although the State Forests' acquisitions differ fundamentally from the literature's typical subject—they are small-parcel, domestic, statutorily constrained purchases by a long-established public institution rather than large, often contested transnational deals—the land-grabbing literature offers a useful methodological lesson: scale, concentration, and distributional effects of land acquisition programmes cannot be inferred from aggregate totals alone and must be examined at a disaggregated, transaction level, which is precisely the approach adopted here. Second, the North American literature on public land banking [32] describes how municipal or state bodies acquire, hold, and later reallocate land parcels—typically vacant or tax-delinquent urban property—as an instrument of spatial and community-development policy rather than of any single sector. Although the State Forests operate in a

rural, forestry-specific legal context rather than an urban land-banking one, the underlying policy logic is structurally similar: a public body uses acquisition powers to accumulate a land inventory whose eventual configuration is more a matter of spatial and institutional strategy than of the sum of individual transactions. Comparative land-use law scholarship further shows that pre-emption and compensation regimes for land-related public interventions vary widely even among broadly similar European legal systems, including Poland's own general takings framework [33], underscoring the value of treating the specific legal design of the State Forests' pre-emption right as an empirical, and not merely doctrinal, object of study.

2.8. Price Determinants of Forest and Rural Land

The dominant analytical framework for explaining variation in land prices is Rosen's hedonic price model, which treats an observed transaction price as an implicit sum of prices attached to a bundle of parcel and location characteristics [34]. Applications to forest land consistently find that unit price is shaped by parcel size, shape and fragmentation, access, proximity to water bodies or population centres, site productivity, and financing terms. In the Swedish forest-estate market, land value per hectare has been shown to be negatively related to fragmentation and parcel size and positively related to a capital-density index that captures amenity and locational value [35]. In northern Minnesota, road access, proximity to population centres, and waterfront presence were found to be the strongest positive determinants of per-hectare price in a hedonic model explaining roughly half of observed price variation [36]. A consistent finding across these studies—a negative size–price relationship—supports the hypothesis that smaller parcels command a per-hectare premium, plausibly reflecting locational, amenity, or boundary-completion value that does not scale with area. Within Poland specifically, hedonic analysis of the agricultural land market shows that unit prices are shaped by proximity to settlements, soil quality, the degree of ownership fragmentation, forest cover in the surrounding municipality, and eligibility for EU area-based support [37], findings that closely parallel the location- and fragmentation-sensitive pricing patterns this paper documents for State Forests' purchases.

Beyond parcel-level hedonic determinants, land prices exhibit well-documented spatial structure: nearby locations tend to show more similar prices than distant ones, a regularity long summarized as the first law of geography [38] and formally testable through global measures of spatial autocorrelation such as Moran's I [39] and, at a finer resolution, through local indicators of spatial association [40] and distance-based statistics for detecting spatial clusters [41]. A more general spatial–econometric framework for modelling such dependence directly within a regression model, rather than only testing for its presence in residuals, is provided by LeSage and Pace [42]; adopting such a framework—for instance a spatial-lag or spatial-error hedonic specification—is a natural extension of the exploratory Moran's I analysis conducted here, once parcel-level geographic coordinates become available (see Limitations). Whether spatial dependence in prices holds at a coarse (regional) or fine (local) scale is itself informative about the underlying market process: strong regional autocorrelation would suggest that macro-level factors (regional development, tourism pressure, urbanization gradients) dominate price formation, whereas its absence, combined with strong local concentration, would point to idiosyncratic, site-specific drivers operating below the regional scale. This paper applies both a hedonic regression and an exploratory spatial-autocorrelation analysis to adjudicate between these possibilities in the Polish case, while also situating the analysis within the broader literature on land ownership concentration, for which the Gini coefficient [43] and the Herfindahl–Hirschman Index [44,45] remain the standard summary measures.

3. Materials and Methods

3.1. Institutional Framework of Pre-Emption Rights

Under Article 37a of the Act on Forests of 28 September 1991 (Dz.U. 1991 No. 101, item 444, as amended), the State Forests National Forest Holding (Panstwowe Gospodarstwo Lesne Lasy Panstwowe) [46] hold a statutory pre-emption right over forest land, and forest-adjacent agricultural land in defined circumstances, that is offered for sale by non-state owners. When a qualifying sale agreement is concluded, the relevant local forest district may exercise the pre-emption right and step into the position of buyer at the agreed price, or in specified cases determine the price through a judicial procedure. Each exercised transaction is subsequently disclosed through a public notice, published on the government information portal (gov.pl), under the recurring title “Informacja o wykonaniu przez Lasy Panstwowe prawa pierwokupu lub uprawnienia” (“Notice on the exercise by the State Forests of the pre-emption right or entitlement”). These notices constitute the primary administrative record of the State Forests’ land-acquisition activity and are the source of the database analyzed in this paper.

3.2. Data Source and Transaction Database

All notices published on the gov.pl portal under the Directorate-General of the State Forests for the years 2022 through 2026 (through the data-collection cutoff of early July 2026) were identified and their attached PDF documents processed to extract structured transaction records. Each notice follows a standardized legal template specifying the acquiring forest district, the date of the notice, the voivodeship, county, municipality, cadastral precinct, parcel number(s), area, price, and land and mortgage register number. Where the source PDF was an unreadable scanned image with no machine-extractable text, the corresponding notice could not be converted into a structured record and was excluded from the database; such exclusions accounted for approximately 3% of all identified notices in the period (see Limitations). After removing duplicate publications, exclusions of this kind, and a small number of unrelated administrative notices (e.g., lost official stamps or identification badges) that share the same publication category, the final database comprises 911 individual land-purchase transactions. At approximately 3% of all identified notices, this exclusion rate is small relative to the final database size, which limits the potential scale of any resulting bias even were it non-random. Because scanned-image publication is a function of which local forest district or administrative office generated the original notice and of the office scanning equipment and workflow used at the time, rather than of any transaction attribute (price, parcel size, or region), there is no a priori mechanism linking exclusion to the price- or size-related outcomes analyzed in this paper; nonetheless, a formal test of this assumption was not possible without a record of the excluded notices themselves, and the possibility of non-random exclusion is acknowledged as a limitation below.

3.3. Variables and Data Preparation

Voivodeship names, which appeared in the source notices with inconsistent capitalization, were normalized to the sixteen official voivodeships of Poland. Area (hectares) and price (PLN) were parsed as numeric fields. Eight transactions (0.9% of the database) had a price pending judicial determination at the time of publication (marked in the source as “cena do ustalenia przez sąd” or equivalent) or a recorded price of zero; these were retained in the database for transaction-count and area statistics but excluded from all price-based statistics, leaving 903 transactions for price analysis. For every valid transaction, a unit price variable was computed as unit price (PLN/ha) = transaction price (PLN)/parcel area (ha). A parcel-size classification (six classes, from below 0.5 ha to above 10 ha) was constructed to test the relationship between transaction size and unit price. The two smallest classes

(below 0.5 ha and 0.5–1 ha) are additionally aggregated into a national fragmentation profile (Section 4.4), summarizing their combined share of transactions, area, and value relative to the priced-subset total. Two records had a missing voivodeship field due to a damaged source document and were excluded from region-level aggregation only.

3.4. Analytical Strategy

The analysis proceeds in five stages. First, descriptive statistics (count, area, value, median and area-weighted mean unit price) are computed for each year and for each voivodeship, county, and forest district to establish the scale and regional distribution of purchasing activity. Second, land purchases are classified into six parcel-size classes to test whether smaller transactions command higher unit prices, consistent with the boundary-rationalization hypothesis developed in Section 2.6. Third, regional concentration of purchase value and transaction counts is summarized using the Gini coefficient [43] and the Herfindahl–Hirschman Index (HHI; [44,45]), computed at both the voivodeship level (16 units) and the county level (approximately 300 units).

Fourth, an exploratory hedonic-style regression, inspired by Rosen [34] but without the full complement of parcel-quality covariates a strict hedonic specification would require (see below and Limitations), is estimated by ordinary least squares, with the natural logarithm of unit price (PLN/ha) as the dependent variable and the natural logarithm of parcel area as the key explanatory variable of interest, controlling for voivodeship and year fixed effects:

$$\ln(\text{unit_price_ha}) = \text{beta0} + \text{beta1} \cdot \ln(\text{area_ha}) + \text{Sum}(\text{voivodeship fixed effects}) + \text{Sum}(\text{year fixed effects}) + \text{epsilon}$$

Heteroscedasticity-robust (HC3) standard errors are used throughout. A restricted model without voivodeship fixed effects is also estimated for comparison to gauge how much of the explained price variation is attributable to location as opposed to parcel size and year alone. Because the model omits parcel-level quality attributes (e.g., timber stock, site productivity, road access) not disclosed in the source notices and does not incorporate a fully specified spatial–econometric structure (e.g., a spatial-lag or spatial-error term; [42]), the estimated coefficients are potentially affected by omitted-variable bias and unmodelled spatial dependence (cf. [47]). They are therefore interpreted throughout this paper as descriptive statistical associations between parcel characteristics, location, and price, rather than as causal determinants of forestry land value.

Fifth, an exploratory spatial-autocorrelation analysis is carried out at the voivodeship level using global Moran’s I [39], computed on voivodeship median unit prices and on voivodeship transaction counts, using a row-standardized queen-contiguity spatial weights matrix constructed from the official administrative adjacency of Poland’s sixteen voivodeships. Statistical significance is assessed through a conditional permutation test (9999 permutations). Because a full polygon-based geographic information system (GIS) treatment (e.g., shapefile-based choropleth mapping, county-level hot-spot analysis) was beyond the scope of the data infrastructure available for this study, the spatial analysis presented here uses administrative contiguity and schematic centroid-based mapping rather than precise cartographic boundaries; this is an explicit simplification discussed under Limitations. All computations were carried out in Python 3 (pandas, NumPy, SciPy, statsmodels).

A descriptive typology of acquisitions (Section 4.7) is developed inductively from the results of these five stages, rather than through a separate statistical procedure. Formal extensions incorporating county-level Location Quotients (normalizing purchase intensity by each county’s share of State Forests-managed forest area) and local indicators of spatial

association (LISA; [40]), which require additional geospatial reference data not available for this study, are discussed under Limitations.

4. Results

4.1. Scale and Temporal Dynamics of Land Purchases, 2022–Mid-2026

Between 2022 and the data-collection cutoff in mid-2026, the State Forests completed 911 land-purchase transactions through the exercise of the pre-emption right, covering a cumulative area of 2806.1 hectares and, for the 903 transactions with a determinable price, a cumulative value of approximately 114.2 million PLN. Table 1 summarizes the database, and Table 2 presents the annual breakdown.

Table 1. Characteristics of the transaction database.

Item	Value
Time span	2022–2026 (2026 partial, through early July)
Total transactions (N)	911
Transactions with determinable price	903 (99.1%)
Transactions excluded from price analysis	8 (judicially pending price/zero price)
Total area	2806.1 ha
Total transaction value (valid subset)	114,193,589 PLN
Median unit price	39,623 PLN/ha
Mean unit price	44,446 PLN/ha
Voivodeships represented	16 of 16
Counties represented	~300

Table 2. Scale of land purchases by year.

Year	N Transactions	Area (ha)	Value (PLN)	Median PLN/ha	Area-Weighted Mean PLN/ha
2022	200	654.5	23,473,051	34,344	36,362
2023	215	603.5	31,295,422	44,248	51,855
2024	208	538.3	23,033,126	40,816	42,836
2025	156	565.9	17,131,643	37,409	34,876
2026 (partial)	132	444.0	19,260,345	43,750	46,802

Note: 2026 covers transactions published through the data-collection cutoff and is not a complete calendar year; annual comparisons involving 2026 should be interpreted with this in mind.

The number of transactions and the purchased area do not move together: 2023 recorded the highest transaction count (215) but 2022 the highest cumulative area (654.5 ha), while transaction value peaked in 2023 at 31.3 million PLN. This indicates that the scale of the State Forests' purchasing activity cannot be adequately captured by transaction counts alone; area, value, and unit price must be considered jointly. No simple monotonic trend is apparent across 2022–2025; year-to-year variation more plausibly reflects the availability of qualifying parcels and a small number of large transactions than a deliberate programmatic expansion or contraction. Nominal unit prices show an overall upward drift over the period (confirmed in the regression in Section 4.4), which should be interpreted net of general price-level inflation over 2022–2026, a control not available within the scope of this database.

4.2. Regional Differentiation of Purchasing Activity

Table 3, Figures 2 and 3 ranks voivodeships by transaction count, alongside area, value, and value share. Mazowieckie (124 transactions), Slaskie (110), and Podlaskie (92) recorded the highest transaction counts, but this ranking does not correspond to the ranking by cumulative value: Dolnoslaskie, Wielkopolskie, Podlaskie, and Podkarpackie together with Mazowieckie account for the five highest-value voivodeships, jointly representing 48.9% of total transaction value (Table 4). Slaskie is a particularly informative case: it ranks second by transaction count but only eighth by cumulative area (126.2 ha) and value share (6.3%), reflecting a market of numerous, comparatively small, high-unit-price parcels rather than large-area acquisitions (see Section 4.3).

Table 3. Land purchases by voivodeship, ranked by transaction count.

Voivodeship	N	Area (ha)	Value (PLN)	Value Share (%)	Median PLN/ha
Mazowieckie	124	325.3	9,623,862	8.4	31,674
Slaskie	110	126.2	7,156,145	6.3	59,739
Podlaskie	92	289.7	10,445,497	9.1	35,066
Wielkopolskie	70	261.3	12,583,110	11.0	48,709
Dolnoslaskie	64	356.0	12,639,914	11.1	44,914
Malopolskie	63	94.9	7,854,750	6.9	47,698
Lubelskie	62	102.0	2,785,124	2.4	28,662
Lodzkie	61	151.8	6,964,397	6.1	43,137
Kujawsko-pomorskie	50	176.0	6,894,325	6.0	38,351
Podkarpackie	45	184.5	10,366,100	9.1	48,942
Pomorskie	43	221.6	8,938,687	7.8	36,784
Warminsko-mazurskie	36	195.9	5,517,006	4.8	39,759
Zachodniopomorskie	29	186.4	6,926,791	6.1	35,896
Opolskie	28	62.1	2,768,013	2.4	41,234
Swietokrzyskie	20	43.9	1,468,067	1.3	28,037
Lubuskie	12	19.2	838,500	0.7	48,212

Table 4. Top 10 counties by cumulative transaction value.

Powiat	Voivodeship	N	Area (ha)	Value (PLN)	Median PLN/ha
Tatrzański	Malopolskie	1	10.2	4,200,000	413,618
Zawierciański	Slaskie	43	55.4	3,633,805	66,246
Przeworski	Podkarpackie	7	35.5	3,590,000	89,928
Człuchowski	Pomorskie	8	90.0	3,421,305	35,157
Strzełiński	Dolnoslaskie	6	41.7	3,068,858	32,149
Białostocki	Podlaskie	11	65.6	2,909,814	39,535
Sremski	Wielkopolskie	4	60.7	2,906,286	52,065
Drawski	Zachodniopomorskie	1	78.2	2,600,000	33,268
Kłodzki	Dolnoslaskie	8	57.4	2,211,300	47,919
Przemyski	Podkarpackie	6	33.3	2,210,000	63,000

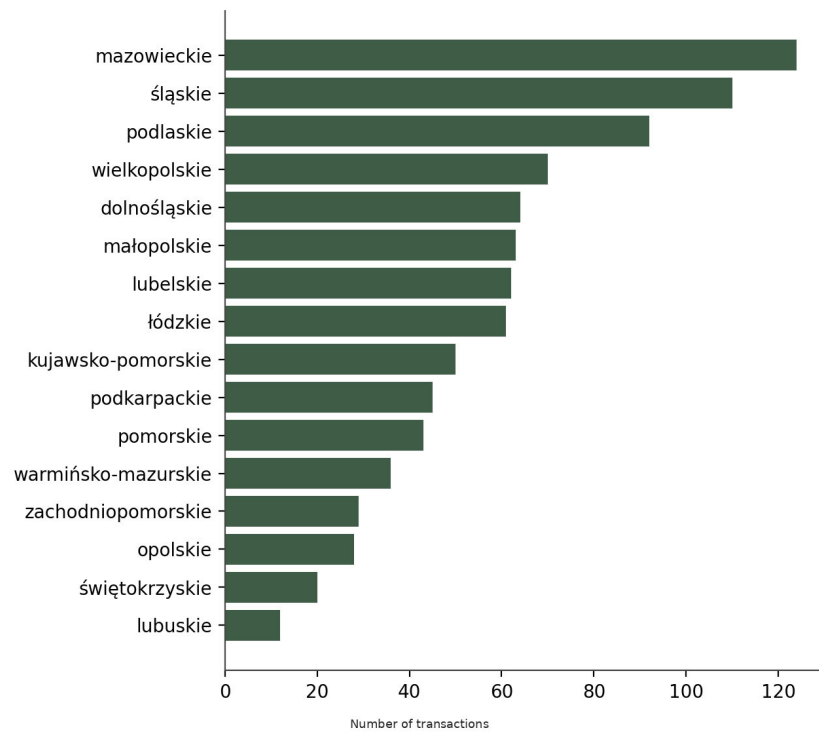


Figure 2. Number of transactions by voivodeship.

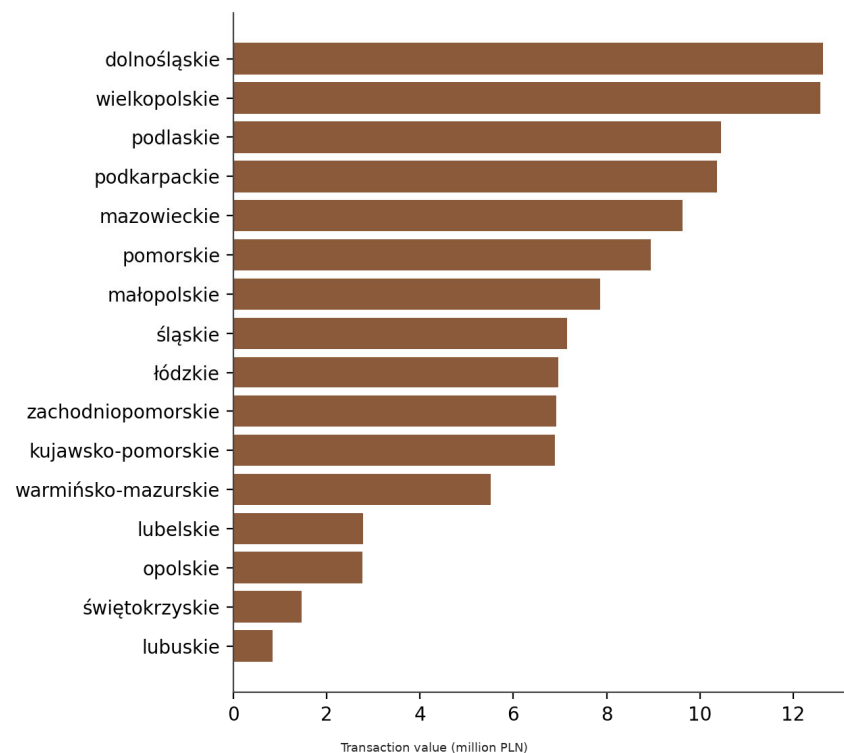


Figure 3. Transaction value by voivodeship.

Table 4 lists the leading counties (powiaty) and forest districts (nadlesnictwa) by cumulative transaction value. A striking feature of this ranking is its heterogeneity of composition: some leading counties owe their rank to a single very large transaction (e.g., Tatrzański county, discussed as an outlier in Section 4.6, and Drawski county with a single 78.2-ha, 2.6-million-PLN purchase), while others (notably Zawierciański county, within Śląskie voivodeship) owe it to a high volume of small transactions—43 purchases totalling only 55.4 ha but 3.63 million PLN. This contrast reinforces the point made for

Slaskie voivodeship as a whole and motivates the county-level concentration analysis in Section 4.5.

4.3. Unit Price Differentiation

For the 903 transactions with a determinable price, unit price (PLN/ha) has a median of 39,623 PLN, a mean of 44,446 PLN, and a standard deviation of 26,949 PLN, with the interquartile range spanning 27,908–56,058 PLN/ha. This wide dispersion (coefficient of variation ~ 0.61) confirms that unit price is highly heterogeneous and location-sensitive rather than approximating a single national market rate. Ranking voivodeships with at least ten valid transactions by median unit price (Table 5), Slaskie stands out with a median of 59,739 PLN/ha, roughly 50% above the next-highest voivodeships (Podkarpackie, 48,942; Wielkopolskie, 48,709) and 90% above Lubelskie, the lowest-priced voivodeship among those with sufficient sample size (28,662 PLN/ha).

Table 5. Voivodeships ranked by median unit price (min. 10 transactions).

Voivodeship	Median PLN/ha	N
Slaskie	59,739	110
Podkarpackie	48,942	45
Wielkopolskie	48,709	70
Lubuskie	48,212	12
Malopolskie	47,698	63
Dolnoslaskie	44,914	64
Lodzkie	43,137	61
Opolskie	41,234	28

The comparatively high price level in Slaskie voivodeship is one of the more informative findings of this study: it is not explained by cumulative area or by transaction value share, both of which are unremarkable for this region, but reflects a market of frequent, small, comparatively expensive parcel purchases. A plausible interpretation, developed further in Section 5, is that this pattern reflects the historically dense and fragmented land ownership structure of parts of Slaskie, together with locational, infrastructural, and urbanization pressure that raises the opportunity cost of land regardless of its forestry function.

4.4. Parcel-Size Premium and Boundary-Rationalization Function

Table 6 and Figure 4 present the size-class breakdown of unit price. Parcels below 0.5 ha show the highest median (49,695 PLN/ha) and area-weighted mean (54,872 PLN/ha) unit price of any size class, while unit price declines, non-monotonically but consistently at the extremes, toward the 5–10 ha class (median 35,589 PLN/ha) before rising slightly for parcels above 10 ha (38,462 PLN/ha), the latter likely reflecting the amenity or productivity value of a small number of large, high-quality holdings rather than a reversal of the general size–price relationship.

As present Figure 5 the bivariate relationship between (log) area and (log) unit price is weakly negative (Pearson $r = -0.090$), and this is corroborated by the multivariate hedonic-style regression reported in Table 7. In the full specification, which includes voivodeship and year fixed effects ($N = 901$, $R\text{-squared} = 0.198$, adjusted $R\text{-squared} = 0.180$), the coefficient on $\log(\text{area})$ is -0.045 (HC3-robust $p = 0.019$): each 1% increase in parcel area is associated, on average and holding location and year constant, with a 0.045% decrease in unit price. Although the elasticity is modest in magnitude, its statistical significance across a specification that already controls for sixteen voivodeship fixed effects and five annual

periods supports the boundary-rationalization interpretation set out in Section 2.6—small parcels are acquired at a systematic, if not large, premium.

Table 6. Unit price by parcel-size class.

Size Class	N	Area (ha)	Value (PLN)	Median PLN/ha	Area-Weighted Mean PLN/ha
<0.5 ha	128	36.3	1,993,538	49,695	54,872
0.5–1 ha	194	143.6	6,449,885	43,174	44,917
1–2 ha	217	311.6	13,108,927	38,462	42,074
2–5 ha	232	724.9	30,444,709	38,302	42,001
5–10 ha	81	549.7	20,066,975	35,589	36,503
>10 ha	51	923.4	42,129,554	38,462	45,622

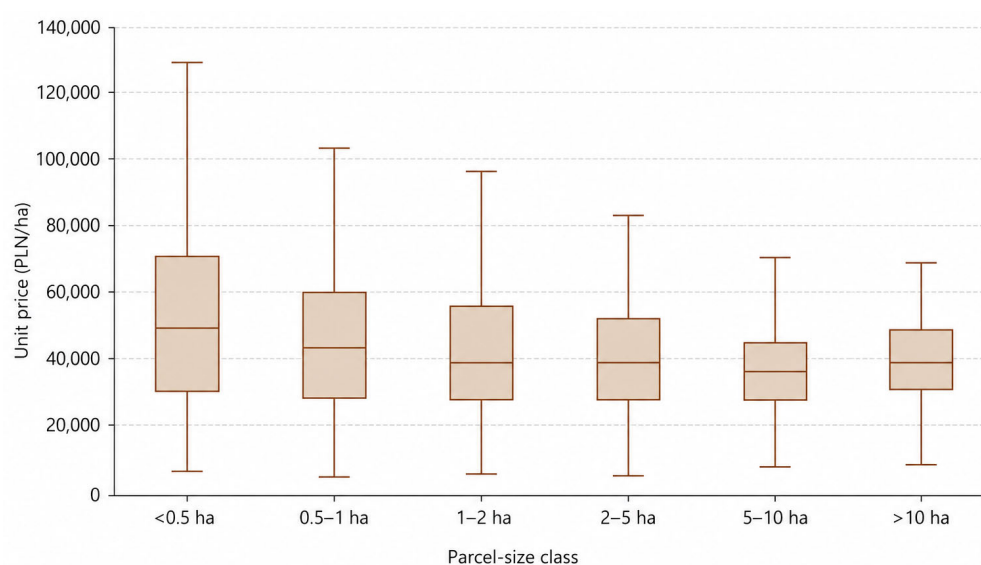


Figure 4. Unit price (PLN/ha) by parcel-size class (box plots, outliers excluded for readability).

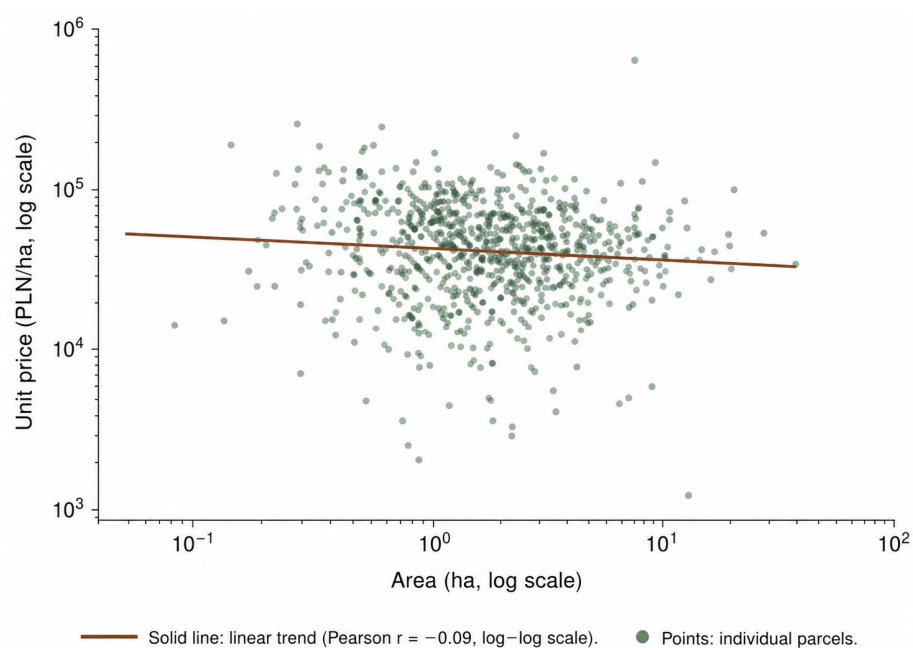


Figure 5. Parcel area against unit price, log–log scale, with fitted regression line.

Table 7. Hedonic regression of log unit price (PLN/ha) for selected coefficients (HC3-robust SE).

Variable	Coefficient	Robust SE	p-Value
Intercept	10.515	0.064	<0.001
ln (area, ha)	−0.045	0.019	0.019
Voivodeship: Slaskie	+0.228	0.071	0.001
Voivodeship: Mazowieckie	−0.381	0.078	<0.001
Voivodeship: Lubelskie	−0.603	0.095	<0.001
Voivodeship: Swietokrzyskie	−0.663	0.177	<0.001
Voivodeship: Podlaskie	−0.294	0.072	<0.001
Voivodeship: Warminsko-mazurskie	−0.157	0.079	0.048
Year 2023	+0.260	0.054	<0.001
Year 2024	+0.223	0.053	<0.001
Year 2025	+0.109	0.066	0.096
Year 2026	+0.342	0.060	<0.001

Note: Full model: Non-significant voivodeship coefficients (Kujawsko-pomorskie, Lubuskie, Malopolskie, Opolskie, Podkarpackie, Pomorskie, Wielkopolskie, Lodzkie) omitted from the table for brevity; full output available on request.

The voivodeship fixed effects are jointly informative and consistent with the descriptive ranking in Table 5: Slaskie shows a significant positive coefficient (+0.228, $p = 0.001$) relative to the Dolnoslaskie baseline, while Lubelskie (−0.603), Swietokrzyskie (−0.663), Mazowieckie (−0.381), and Podlaskie (−0.294) show significant negative coefficients, mirroring their comparatively low median unit prices in the descriptive analysis. Year fixed effects indicate a general upward nominal price drift, most pronounced in 2026 (+0.342 relative to 2022), which, as noted, should be read as the net of overall price-level inflation rather than as a forestry-specific appreciation. A restricted model without voivodeship fixed effects yields a materially lower fit (R -squared = 0.042) while retaining a similar, significant area elasticity (−0.048, $p = 0.009$). The nearly five-fold increase in explained variance when voivodeship fixed effects are added (from 4.2% to 19.8%) indicates that location, not parcel size, is the dominant systematic source of unit-price variation in this market—a result that anchors the spatial-concentration analysis that follows.

These parcel-level patterns can be summarized in a national fragmentation profile. Parcels below 1 ha account for 35.7% of all priced transactions (322 of 903) but only 6.7% of cumulative area (179.9 of 2689.5 ha) and 7.4% of cumulative value (8.44 of 114.19 million PLN) (Table 8). This asymmetry—a large share of transactions concentrated in a small share of area and value—is consistent with a boundary-rationalization function operating alongside, and largely independently of, the area-expansion function performed by larger acquisitions.

Table 8. National fragmentation profile of acquisitions by parcel-size threshold.

Parcel-Size Group	N	Share of N (%)	Area (ha)	Share of Area (%)	Value (PLN)	Share of Value (%)
<1 ha	322	35.7	179.9	6.7	8,443,423	7.4
≥1 ha	581	64.3	2509.6	93.3	105,750,165	92.6
Total (priced subset)	903	100.0	2689.5	100.0	114,193,588	100.0

Note: figures cover the 903 transactions with a determinable price (Section 3.3); the eight excluded transactions contribute negligibly to area and value.

4.5. Localized Concentration of Public Land Intervention

As shown in Figure 6, the distribution of unit prices varies substantially across voivodeships, both in terms of median values and within-voivodeship dispersion. Śląskie, Podkarpackie and Wielkopolskie exhibit the highest median unit prices, whereas Lubelskie and Świętokrzyskie show the lowest median values.

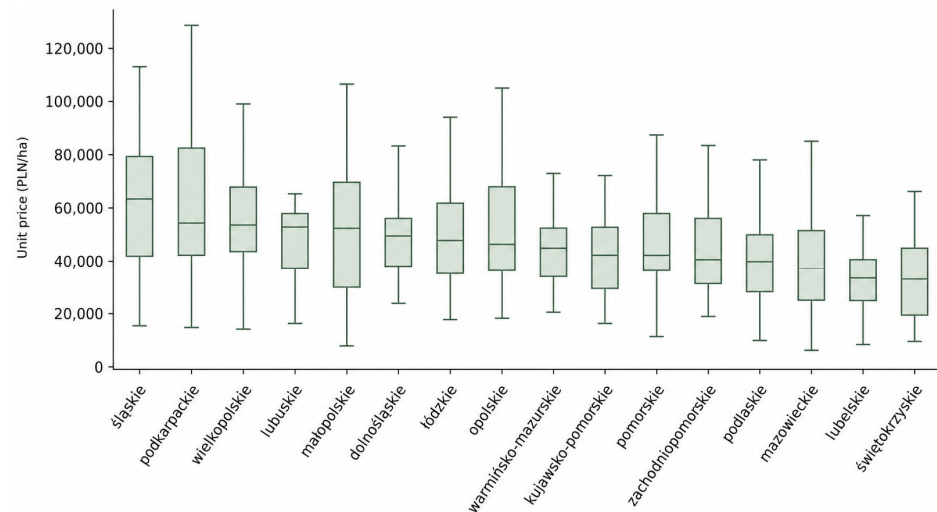


Figure 6. Distribution of unit prices (PLN/ha) by voivodeship, ranked by median (outliers excluded for readability). Note: illustrative representation based on approximate voivodeship centroids, not a precise cartographic base; see Limitations.

As shown in Figure 7, the concentration of transaction value across the sixteen voivodeships is moderate: the Gini coefficient is 0.284 and the Herfindahl–Hirschman Index is 782.5 (on a 0–10,000 scale), both indicating a fairly dispersed regional distribution—for reference, an HHI below 1500 is conventionally classified as an unconcentrated market. Transaction counts show a similar pattern (Gini = 0.294; HHI = 802.5). This picture changes sharply at the county level: the Gini coefficient of transaction value across the roughly 300 counties represented in the database rises to 0.615, more than double the voivodeship-level figure, indicating that purchasing activity, while fairly evenly spread across regions, is considerably more concentrated within specific counties—consistent with the county-level examples discussed in Section 4.2 (Zawierciański, Tatrzański, Przeworski). National or regional statistics may therefore hide localized land-governance pressures; sustainable monitoring of public land acquisition should operate at the county or forest-district scale, a point developed further in Section 5.

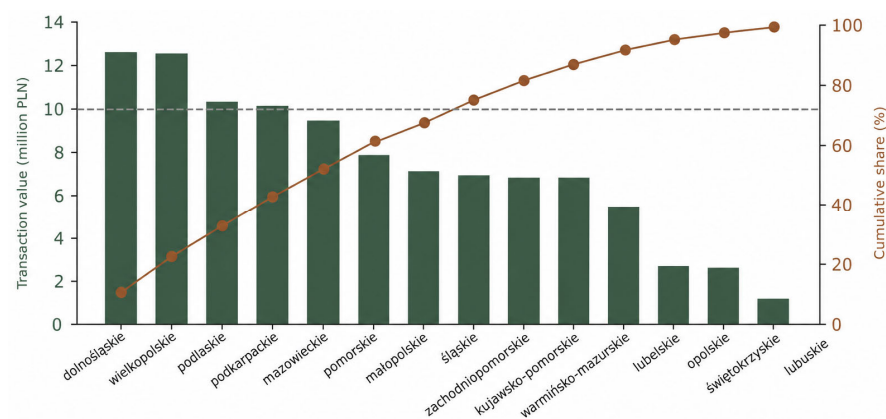
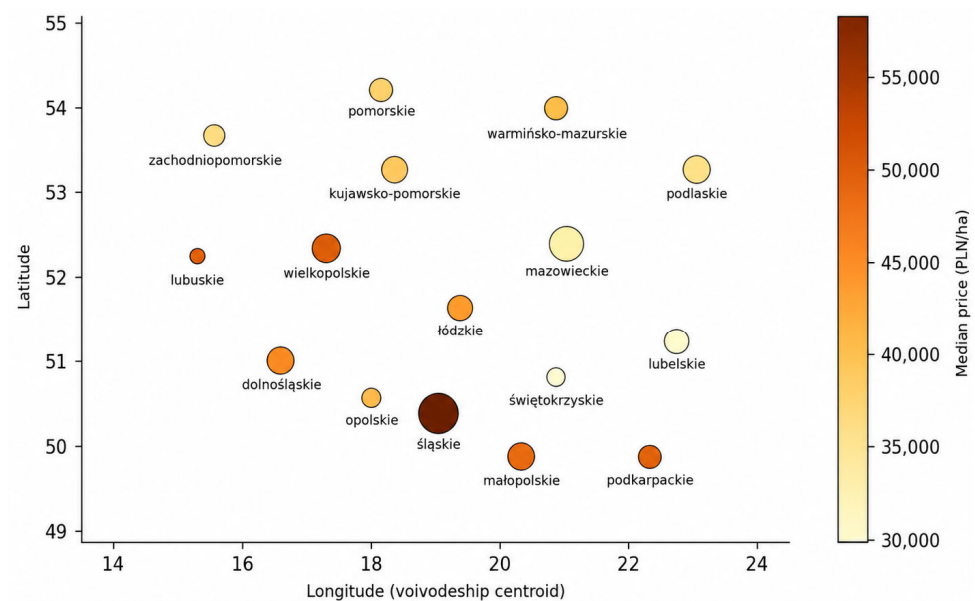


Figure 7. Pareto chart of cumulative transaction value share by voivodeship.

An exploratory global Moran's I analysis of voivodeship median unit prices, based on a row-standardized queen-contiguity matrix of the sixteen voivodeships (Figure 8), yields $I = 0.111$ (expected value under spatial randomness $E[I] = -0.067$; permutation-based $p = 0.114$), indicating a weak positive spatial autocorrelation that does not reach conventional significance thresholds. Transaction counts show, if anything, weak negative autocorrelation ($I = -0.163$, $p = 0.257$) that is also non-significant. Taken together with the concentration results, this suggests that price formation in this market is not primarily a macro-regional phenomenon—adjoining voivodeships do not systematically share similar price levels—but is instead driven by more localized, county- or district-scale factors, a conclusion consistent with the sharp difference between voivodeship- and county-level Gini coefficients reported above.



Note: Schematic representation based on voivodeship centroids, not a precise cartographic map.

Figure 8. Schematic centroid-based representation of transaction count (marker size) and median unit price (colour) by voivodeship.

4.6. Outlying Transactions

Thirteen transactions (1.4% of the priced subset) show a standardized log unit price beyond three standard deviations of the sample mean. The most extreme is a 10.15 ha parcel purchased in Zakopane municipality (Tatrzański county, Małopolskie voivodeship, Nowy Targ forest district) for 4.2 million PLN, equivalent to 413,618 PLN/ha—more than seven times the sample median. Given the intense tourism-driven land pressure characteristic of the Tatra/Zakopane area, this transaction plausibly reflects a location premium entirely disconnected from forestry or agricultural land values, illustrating how, in specific localities, land acquired by the State Forests competes directly with high-value non-forestry uses. At the opposite end, several transactions in Lubelskie and Mazowieckie voivodeships show unit prices below 5000 PLN/ha, generally corresponding to larger parcels of comparatively low agricultural or forestry productivity in peripheral rural municipalities. Consistent with standard practice, these observations were retained in the main analysis (given their documented, plausible provenance) but are flagged here for transparency; a robustness check using median-based and quartile-based statistics throughout Section 4, rather than only means, mitigates their influence on the reported results.

4.7. A Typology of Land Acquisitions as Sustainable-Land-Governance Functions

Building on the preceding results, this paper proposes an exploratory, five-category typology of State Forests land acquisitions, intended as a conceptual contribution for future, more granular research rather than a statistically derived classification. Each category maps onto one of the four governance functions introduced in the conceptual framework (Figure 1):

- Complementary (boundary-rationalizing) transactions [boundary rationalization]: predominantly parcels below 1 ha, commanding a systematic unit-price premium (Table 6; Figure 9), plausibly acquired to eliminate private enclaves, straighten boundaries, or secure access rather than to expand area per se.
- Area-expansion transactions [ecological continuity]: larger parcels (generally above 5–10 ha) whose primary contribution is to the aggregate forest area and its ecological continuity rather than to boundary or access improvements.
- Location-sensitive transactions [mediation of competing land uses]: parcels situated in voivodeships or municipalities under strong tourism, urbanization, or investment pressure (e.g., the Zakopane outlier in Section 4.6), where unit price substantially exceeds regional norms.
- Ownership-stabilizing transactions [ownership consolidation]: purchases concentrated within a small number of counties or forest districts (e.g., Zawierciański county/Siewierz forest district, with 43–44 transactions), suggesting a sustained, localized programme of reducing ownership fragmentation rather than isolated opportunistic purchases.
- Strategic transactions [ecological continuity/supra-local coordination]: high-value or large-area purchases (e.g., the leading transactions in Wielkopolskie and Dolnośląskie voivodeships) that may carry supra-local significance for forest connectivity or environmental objectives.

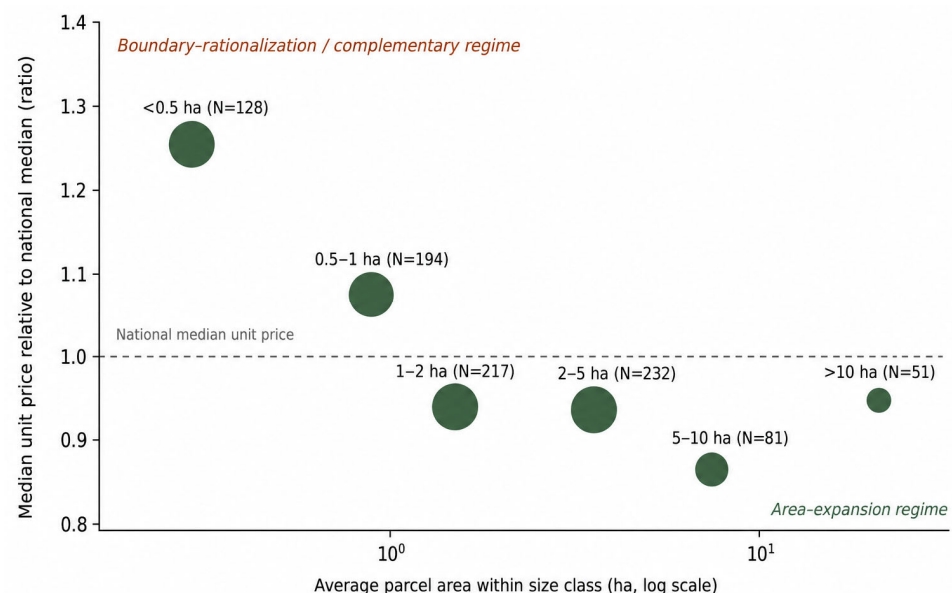


Figure 9. Illustrative positioning of parcel-size classes across the boundary-rationalization and area-expansion regimes. Note: The figure provides an illustrative positioning of the six parcel-size classes summarized in Table 6; marker size is proportional to the number of transactions (N). The Zakopane/Tatrzański outlier (ratio ≈ 10.4 ; Section 4.6) and the Zawierciański county cluster (ownership-stabilization regime; Section 4.2) are location-specific cases discussed in the text and are omitted for clarity.

Figure 9 positions the six parcel-size classes from Table 6 on axes of average parcel area and unit price relative to the national median, illustrating how the boundary-rationalization and area-expansion regimes correspond to opposite ends of the size–price relationship documented in Section 4.4.

This typology is offered as a heuristic bridge between the transaction-level data analyzed here and the qualitative, case-based literature on Polish forest governance [10,11]; testing it formally would require linking individual transactions to cadastral boundary data and forest-management-plan information, which lies beyond the scope of the present database.

5. Discussion

5.1. Land Acquisitions as Sustainable Land Governance

The results support the paper’s central proposition: land acquisition by the State Forests is not adequately described as a uniform, forestry-driven process of area expansion, but is better understood as an instrument of sustainable land governance in the sense set out in Section 2.1. This reading is reinforced by the institutional literature on Polish forest governance, which emphasizes the State Forests’ strong ideological and legal commitment to public forest ownership as a policy goal in itself [10]. The present analysis complements that literature by showing that this commitment is operationalized, at the transaction level, through a spatially uneven and functionally differentiated pattern of land purchases—some oriented toward boundary rationalization, some toward area expansion, and some responsive to acute local land-value pressure. The relevance of pre-emption and first-refusal rights as land-market instruments, documented in agricultural contexts elsewhere in Europe [6,7], extends, on this evidence, to the forestry sector in Poland and merits comparative attention in future sustainable-land-governance research.

Viewed through the lens of property-rights theory, the pre-emption right can be interpreted as an institutional response to the transaction costs that would otherwise impede consolidation of a spatially fragmented forest estate: rather than relying on the state forest administration to negotiate with, and potentially be outbid by, every prospective private buyer of every relevant parcel [14], the pre-emption mechanism gives the State Forests a low-transaction-cost route to intervene selectively in the market, consistent with Ostrom’s [15] broader observation that intermediate institutional designs, rather than pure market or pure state allocation, are frequently the most effective response to the governance problems posed by dispersed, multi-owner natural resources. This institutional interpretation is compatible with, but adds a market-transaction dimension to, the ideological account of State Forests governance offered by Konczal [10].

This reading is also consistent with, though distinct from, the international land-banking literature: unlike the often opaque, large-parcel, foreign-investor transactions at the centre of the land-grabbing literature [29–31], State Forests’ purchases are small-parcel, domestic, statutorily bounded, and fully disclosed through public notice, illustrating that a public land-acquisition programme can achieve a comparable cumulative scale of land-ownership change (2806.1 ha over the study period) through a fundamentally more transparent and incremental transactional mode, closer in spirit to municipal land banking [32] than to transnational land acquisition. Read together with RQ4, the evidence assembled here—systematic parcel-size pricing effects, sharply localized concentration, and a dominant role for location over size—supports treating statutory pre-emption purchases as a genuine, if modest-scale, institutional mechanism of sustainable land governance rather than a residual administrative by-product of forestry management.

5.2. Fragmentation Reduction and Ecological–Spatial Continuity

Three findings, in particular, speak directly to the ecological and economic dimensions of the sustainable-land-governance framework set out in Section 2.1. First, the systematic unit-price premium attached to small parcels (Table 6; Table 8; regression coefficient on log-area, Section 4.4) is consistent with a boundary-rationalization or enclave-elimination motive rather than a pure area-maximization motive, echoing the broader land-use policy literature on the management costs of fragmented ownership [13] and the parcel-size effects documented in international hedonic studies of forest land [35,36]. Because the elasticity, while significant, is modest (-0.045), this should be read as a systematic tendency rather than a dominant price driver; it operates alongside, not instead of, locational effects. Second, the national fragmentation profile (Table 8; Figure 9) shows that parcels below 1 ha account for over a third of all transactions but only around 7% of area and value—a pattern of frequent, small, boundary-oriented interventions that is largely invisible in area- or value-weighted summary statistics, and that supports H1 directly.

These findings also speak to the broader European literature on forest ownership dynamics. Where private forest ownership across Europe is becoming more fragmented, with millions of increasingly small, often non-professionally managed parcels [26,27], the State Forests' pre-emption purchases documented here operate, at the margin, in the opposite direction—incrementally re-consolidating ownership through parcel-by-parcel acquisition. This is a modest but structurally distinctive contribution to the forest-transition literature [23–25], which has focused primarily on aggregate forest-area recovery and pays comparatively little attention to the ownership-structure channel through which such recovery, or in this case consolidation, is achieved. To the extent that boundary rationalization and enclave elimination also reduce the incidence of small, disconnected non-forest inclusions within larger forest complexes, these transactions plausibly contribute to ecological–spatial continuity, though verifying this connection formally would require linking transactions to forest-management-plan and habitat-connectivity data not available in the present database (see Limitations).

5.3. Local Land-Use Pressure and Differentiated Sustainability Regimes

The case of Slaskie voivodeship—high transaction frequency, modest cumulative area, and the highest median unit price in the country—illustrates that in regions with a historically dense, fragmented, and industrially influenced land ownership structure, State Forests acquisitions increasingly resemble a market for numerous small, comparatively costly parcels rather than for extensive tracts. This is consistent with the broader observation, in the international hedonic literature, that land prices reflect locational and amenity value as much as productive capacity [34,35], and suggests that in such regions the State Forests' purchasing activity functions predominantly as an ownership-consolidation instrument rather than an area-expansion instrument. The comparatively low prices and larger average parcel sizes observed in Lubelskie and Mazowieckie voivodeships point to a different regime, in which acquisitions more directly expand the manageable forest area at comparatively low unit cost.

The sharp contrast between moderate voivodeship-level concentration (Gini = 0.284) and much higher county-level concentration (Gini = 0.615), together with the non-significant Moran's I at the voivodeship scale, indicates that the geography of State Forests land acquisition is best understood as a patchwork of localized markets rather than a small number of macro-regional "hot" zones, directly supporting H2. The Zakopane/Tatrzański outlier (Section 4.6) sharpens this picture further: it shows that in specific localities under intense tourism or urbanization pressure, State Forests acquisitions compete directly with non-forestry land-value drivers entirely disconnected from forestry or agricultural produc-

tivity. Taken together, these results imply that Poland's non-urbanized land is governed under differentiated sustainability regimes rather than a single national one: some counties and forest districts face predominantly agricultural or forestry-driven land markets, while others—Slaskie, the Tatra/Zakopane area, and comparable tourism- or investment-pressure zones—face acquisition conditions shaped by competing, non-forestry land uses.

5.4. Implications for Spatial Planning and Public Policy

This has a direct methodological implication for future research and monitoring: regional (voivodeship) reporting, of the kind typically used in national forestry statistics, is likely to understate the true spatial concentration of purchasing activity, and county- or forest-district-level reporting is necessary to detect it, directly supporting RQ3 and H2. Sustainable-land-governance frameworks that rely on regional aggregates risk overlooking exactly the local concentrations—such as Zawiercianski county or the Tatra/Zakopane area—that carry the greatest coordination and policy relevance.

In regions under strong non-forestry land-value pressure—exemplified here by the Tatra/Zakopane outlier and by the elevated price levels in Slaskie voivodeship—pre-emption purchases by a public forestry body interact directly with land-use policy objectives (tourism development, urbanization, biodiversity protection) that lie outside forestry's traditional remit and would benefit from more explicit coordination with spatial planning authorities. Because small, boundary-adjacent parcels appear to carry disproportionate acquisition value relative to their area (Section 4.4; Table 8), policy and budgetary frameworks governing pre-emption purchases could explicitly recognize boundary-rationalization and enclave-elimination as objectives distinct from, and not reducible to, area expansion. These implications are developed into concrete recommendations in Section 6.

5.5. Limitations and Future Research

- Database completeness: notices published as scanned images without machine-readable text could not be converted into structured records and were excluded; the database should therefore be regarded as a large, representative, but not fully exhaustive sample of all pre-emption transactions in the period.
- Nominal prices: transaction prices are reported in nominal PLN; no deflator was applied, so year-on-year price comparisons (Sections 4.1 and 4.4) reflect both real price change and general inflation over 2022–2026.
- Partial final year: 2026 figures cover only transactions published through the data-collection cutoff and are not directly comparable to complete calendar years.
- Simplified spatial analysis: the spatial-autocorrelation and mapping components rely on administrative contiguity and approximate voivodeship centroids rather than a full polygon-based GIS treatment (e.g., shapefile-based choropleth mapping, county-level Getis-Ord G_i^* hot-spot analysis [41], or a spatial-lag/spatial-error hedonic model of the kind described by LeSage and Pace [42]); a natural extension of this work would repeat the spatial analysis using official cadastral or administrative boundary datasets and parcel-level coordinates in a dedicated GIS environment, applying local indicators of spatial association (LISA; [40]) and a county-level Location Quotient normalizing purchase intensity by each county's share of State Forests-managed forest area, at the county rather than voivodeship level, where the concentration results reported here suggest clustering is more likely to be detected.
- Omitted hedonic covariates: the hedonic regression controls for area, voivodeship, and year but does not include parcel-level covariates available in richer forest-land hedonic studies (e.g., road access, timber stock, site productivity, distance to water bodies or urban centres; cf. [35,36]), because these were not disclosed in the source notices;

incorporating such covariates, where obtainable from cadastral or forest-management-plan sources, would likely raise the model's explanatory power.

- Typology validation: the five-category typology proposed in Section 4.7 is conceptual and illustrative; formal validation would require linking transactions to forest-management-plan and cadastral-boundary data to verify acquisition motives.
- Heterogeneity and robustness: the regression reported in Section 4.4 is estimated on the full priced subset and does not report region-by-parcel-size heterogeneous specifications or formal robustness checks beyond the median/quartile-based descriptive statistics used throughout Section 4 and the outlier discussion in Section 4.6; given the regional heterogeneity in price levels documented in Section 4.2, interaction models splitting the area coefficient by voivodeship or parcel-size class, together with winsorized or quantile-regression robustness checks on the extreme-value transactions identified in Section 4.6, are identified as priorities for future work once the underlying microdata can be made available for full replication.

6. Conclusions and Policy Implications

This paper has presented the first transaction-level empirical analysis of land purchases carried out by the Polish State Forests through the exercise of statutory pre-emption rights between 2022 and mid-2026. Based on an original database of 911 transactions, the analysis shows: (1) a scale and spatial-economic differentiation of activity—2806.1 ha and approximately 114.2 million PLN over the period, regionally uneven but not extremely concentrated at the voivodeship level (Gini = 0.284) while considerably more concentrated at the county level (Gini = 0.615)—directly addressing RQ1; (2) a systematic, statistically significant unit-price premium for smaller parcels, consistent with a boundary-rationalization function of many acquisitions and confirming H1 (RQ2); (3) a dominant role for location, rather than parcel size, in explaining unit-price variation (R-squared rising from 4% to 20% once voivodeship fixed effects are included), confirming H3; and (4) the absence of strong macro-regional spatial autocorrelation in prices, pointing to localized rather than broadly regional price formation and confirming H2 (RQ3). Together, these findings support an affirmative answer to RQ4: statutory pre-emption purchases by the State Forests can be interpreted as an institutional mechanism of sustainable land governance, operating through boundary rationalization, ownership consolidation, ecological continuity, and the mediation of competing land uses (Figure 1).

From a sustainable-land-governance perspective, these findings support four normative conclusions.

- Public pre-emption rights can support sustainable land governance when they are used not only to expand forest area, but explicitly to rationalize boundaries and reduce ownership fragmentation. Policy and budgetary frameworks governing pre-emption purchases should recognize boundary-rationalization and enclave-elimination as objectives in their own right, distinct from, and not reducible to, area expansion.
- Monitoring and evaluation of public land-acquisition programmes of this kind should be conducted at the county or forest-district level, not only at the regional (voivodeship) level, since regional aggregates can substantially understate the true spatial concentration of purchasing activity (Sections 4.5 and 5.4).
- Small, boundary-adjacent parcels should be treated as strategically significant acquisitions despite their limited area, because they carry disproportionate functional value for boundary rationalization and ownership consolidation (Section 4.4; Table 8).
- State Forests acquisitions in regions under strong non-forestry land-value pressure—exemplified here by the Tatra/Zakopane outlier and by the elevated price levels in Slaskie voivodeship—should be more explicitly coordinated with spatial planning

authorities, given their interaction with tourism development, urbanization, and biodiversity-protection objectives that lie outside forestry's traditional remit.

- These general orientations translate into differentiated, county-type-specific regulatory schemes: in tourism-pressure counties such as Tatrzański (Section 4.6), pre-emption purchases above a defined per-hectare price threshold should trigger mandatory pre-approval review by, or consultation with, the relevant spatial and tourism planning authority before completion; in counties with an industrially influenced, historically dense ownership structure such as Śląskie (Sections 4.2 and 4.3), budget allocation should explicitly recognize the higher per-hectare cost of boundary-rationalization purchases rather than penalizing forest districts for a lower area-per-currency-unit acquisition rate; and in predominantly agricultural counties with larger, lower-priced parcels (e.g., Lubelskie, Mazowieckie), acquisition criteria can continue to prioritize area expansion and enclave elimination under the existing, less differentiated approach. Operationalizing this typology of county regimes—rather than applying a single national acquisition criterion—is the concrete institutional step that follows from the county-level concentration and price-differentiation results reported in Sections 4.2–4.5.

Although grounded in the Polish case, these findings plausibly generalize to other European, and particularly post-socialist, jurisdictions in which public forest or land administrations hold statutory acquisition or pre-emption rights. Where such institutional mechanisms exist, similar dynamics of boundary rationalization, locally rather than regionally concentrated governance pressure, and interaction with non-forestry land-use pressures are plausible, though the specific legal design, scale, and transparency of pre-emption regimes vary considerably across countries [1,33]. Comparative, cross-national research applying the transaction-level approach developed here would help establish how general these patterns are beyond the Polish context.

Author Contributions: Conceptualization, H.K. and K.K.; methodology, H.K.; software, H.K.; validation, H.K. and K.K.; formal analysis, H.K.; investigation, H.K.; data curation, H.K.; writing—original draft preparation, H.K.; writing—review and editing, H.K. and K.K.; visualization, H.K.; supervision, K.K.; project administration, K.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The transaction database compiled for this study was derived from publicly available notices published by the Directorate-General of the State Forests on the Polish government information portal (gov.pl), under the recurring title “Informacja o wykonaniu przez Lasy Państwowe prawa pierwokupu lub uprawnienia” (<https://www.gov.pl/web/dglp/wystapienia-komunikaty-i-ogloszenia>) (accessed on 26 May 2026). The aggregated dataset and analysis code are available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

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