

Original article

Научная статья

УДК 631.11

doi: https://doi.org/10.55186/25880209_2026_10_5_46

edn: JXLDAK

**THE ECONOMICS OF LAND FRAGMENTATION: ASSESSING THE
NEED FOR LAND CONSOLIDATION AMONG SMALLHOLDER
FARMERS IN AZERBAIJAN**

**ЭКОНОМИЧЕСКИЕ АСПЕКТЫ ФРАГМЕНТАЦИИ ЗЕМЕЛЬ:
ОЦЕНКА НЕОБХОДИМОСТИ КОНСОЛИДАЦИИ ЗЕМЕЛЬНЫХ
УЧАСТКОВ МЕЛКИХ ФЕРМЕРОВ В АЗЕРБАЙДЖАНЕ**



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Abstract. Background The land privatizations of the late 1990s in Azerbaijan successfully established private property rights but inadvertently led to severe land fragmentation and sub-optimal parcel sizes. Today, this structural inefficiency serves as a primary bottleneck for agrarian modernization and rural development.
Objective This study evaluates the economic consequences of land fragmentation

across various economic regions of Azerbaijan and assesses the institutional necessity for systemic land consolidation. **Methodology** A comprehensive, mixed-methods approach was deployed, integrating three core components: (1) statistical and economic analysis of national agrarian datasets, (2) comparative institutional valuation of farm expenditures, and (3) empirical field surveys among smallholder farmers across diverse natural-economic zones of the republic. **Results** The findings demonstrate that excessive fragmentation exponentially inflates operational costs, disrupts automated machinery deployment, and severely restricts the adoption of modern irrigation frameworks. Economic modeling indicates a clear threshold for baseline financial sustainability: to achieve optimal economies of scale and maintain long-term production profitability, the minimum viable operational area for individual smallholder farms must not fall below 5 hectares. **Conclusion** The study concludes that voluntary, state-supported land consolidation is economically imperative for Azerbaijan. These insights provide actionable benchmarks for policy-makers implementing newly proposed land code amendments and formulating national sustainable rural strategies.

Аннотация. Введение. Земельная приватизация конца 1990-х годов в Азербайджане успешно обеспечила права частной собственности, но непреднамеренно привела к острой фрагментации земель и неоптимальным размерам участков. Сегодня эта структурная неэффективность служит основным сдерживающим фактором для модернизации аграрного сектора и развития сельских территорий. **Цель.** В данном исследовании оцениваются экономические последствия фрагментации земель в различных экономических районах Азербайджана и обосновывается институциональная необходимость системной консолидации земель. **Методология.** Был применен комплексный комбинированный подход, включающий три ключевых компонента: (1) статистико-экономический анализ национальных баз данных аграрного сектора, (2) сравнительную институциональную оценку фермерских расходов и (3) эмпирические полевые опросы мелких фермеров в различных естественно-экономических зонах республики. **Результаты.**

Полученные результаты демонстрируют, что чрезмерная фрагментация экспоненциально увеличивает эксплуатационные расходы, препятствует внедрению средств автоматизации и механизации, а также серьезно ограничивает переход на современные системы орошения. Экономическое моделирование указывает на четкий порог базовой финансовой устойчивости: для достижения оптимального эффекта масштаба и поддержания долгосрочной рентабельности производства минимальная жизнеспособная эксплуатационная площадь отдельных мелких фермерских хозяйств должна составлять не менее 5 гектаров.

Заключение. В исследовании сделан вывод о том, что добровольная, поддерживаемая государством консолидация земель является экономически необходимой для Азербайджана. Полученные результаты дают обоснованные ориентиры для директивных органов, реализующих предлагаемые поправки к Земельному кодексу и разрабатывающих национальные стратегии устойчивого развития сельских территорий.

Keywords: land fragmentation, land consolidation, smallholder farmers, economic efficiency, minimum farm size, Azerbaijan, transition economies

Ключевые слова: фрагментация земель, консолидация земель, мелкие фермеры, экономическая эффективность, минимальный размер фермерского хозяйства, Азербайджан, страны с переходной экономикой

SECTION 1: INTRODUCTION

1.1 Global and Theoretical Context

"Land fragmentation remains a critical structural impediment to agricultural efficiency, supply chain integration, and rural sustainability globally. While operating small parcels can occasionally serve as a risk-diversification strategy against localized climate shocks, excessive fragmentation exponentially inflates production costs. It restricts the deployment of heavy machinery, increases boundary-related land loss, and generates severe transaction costs in water and infrastructure management (King & Burton, 1982) [1].

1.2 The Post-Soviet Transition and Azerbaijan

In the South Caucasus and wider transition economies, land fragmentation is primarily an institutional legacy of rapid de-collectivization. Following the collapse of the Soviet Union, Azerbaijan's Law on Land Reform of 1996 successfully established private property rights and dissolved state-owned farms (*kolkhozes* and *sovkhozes*). While socially equitable, distributing land parcels based on family size resulted in a highly fragmented agrarian structure. Today, over 800,000 smallholder farms operate on non-contiguous plots, with average total holdings often falling below 1.5–2 hectares. This structural bottleneck severely hinders the modernization aims of Azerbaijan's socio-economic development strategies (Nizamzade & Ramazanova, 2015).

1.3 Research Gap and Objective

While the socio-economic impacts of land reforms in Eastern Europe are well-documented, empirical assessments pinpointing the precise financial sustainability thresholds for individual smallholders in the South Caucasus remain scarce. This study addresses this gap by assessing the economic consequences of fragmentation across diverse natural-economic zones of Azerbaijan. Specifically, we model farm expenditures to determine the minimum viable operational area required to achieve economies of scale under modern market conditions.

SECTION 2: LITERATURE REVIEW

2.1 Drivers and Metrics of Fragmentation

Scholars distinguish between different dimensions of land fragmentation: holding size, the number of parcels per farm, parcel geometric shapes, and spatial distribution (King & Burton, 1982; Van Dijk, 2003). In Southern Europe and transition economies, high fragmentation significantly reduces labor productivity due to time wasted traveling between distant plots. To quantify this structural efficiency, contemporary literature heavily relies on integrated mathematical metrics, such as the Simpson and Januszewski indices (Van Dijk, 2003; Deininger et al., 2012).

2.2 Land Consolidation as a Policy Tool

According to guidelines established by the Food and Agriculture Organization (FAO, 2003; 2020), modern land consolidation has evolved from a purely technical approach focused on reshaping parcels into a comprehensive rural development instrument. Successful voluntary, state-supported consolidation frameworks in countries like Poland, Romania, and Turkey demonstrate that clustering land plots reduces operational overheads by 20% to 35% and accelerates the adoption of drip and pivot irrigation systems (FAO, 2003; Hartvigsen, 2014).

SECTION 3: METHODOLOGY

To assess the economic and institutional impacts of land fragmentation, a micro-level empirical study was conducted across three distinct agro-ecological and economic regions of Azerbaijan: Guba-Khachmaz (characterized by intensive horticulture and fruit production), Kur-Araz (dominated by cotton, grain, and large-scale irrigation challenges), and Lankaran-Astara (specializing in sub-tropical crops, tea, and high population density).

Primary data was collected through structured field surveys and face-to-face interviews with 178 smallholder farmers ($n = 178$). A stratified random sampling approach was used to ensure representation across different parcel sizes and crop types. The survey instrument evaluated operational costs, irrigation access, logistical constraints, credit availability, and land tenure security. Statistical and economic modeling was then applied to analyze the correlation between total operational farm size and financial sustainability thresholds.

SECTION 4: RESULTS AND DISCUSSION

4.1 Economic Efficiency and Operational Bottlenecks

The empirical data reveals that excessive land fragmentation severely undermines the financial viability of smallholder farms. The 178 surveyed farmers identified several interconnected operational bottlenecks:

- High Input and Fuel Costs: The spatial dispersion of multiple small plots belonging to a single household drastically inflates petroleum, oil, and lubricant (POL) expenses due to frequent machinery transit between distant fields.

- Irrigation Inefficiencies: Fragmented layouts create critical water distribution barriers. Smallholders report acute water shortages and logistical complexities in access to irrigation infrastructure, as non-contiguous plots complicate canal routing and modern drip system deployment.
- Disruption of Agrotechnical Cycles: Due to sub-optimal parcel sizes, farmers cannot implement standard crop rotation, effective pest control, or automated field operations. This inability to maintain modern agrotechnical standards directly leads to low crop yields and depressed farm incomes (Nizamzade, 2019).
- Credit Constraints: Low profitability, combined with unviable operational scales, alienates commercial banks. Smallholders face near-total exclusion from agricultural credit markets, preventing capital investment.

The comprehensive breakdown of these interconnected operational and economic constraints reported across the three surveyed regions is aggregated in the statistical matrix below (see Table 1).

Table 1. Institutional and Operational Barriers Affecting Smallholder Farmers in Azerbaijan.

Identified Bottleneck / Constraints	Guba-Khachmaz (n=58)	Kur-Araz (n=65)	Lankaran-Astara (n=55)	Total Average (n=178)
Economic & Operational Barriers				
1. High operational and fuel (POL) costs due to plot distance	45%	15%	39%	32.2%
2. Irrigation water scarcity and infrastructure complexities	68%	21%	37%	41.3%
3. Inability to maintain standard agrotechnical measures	81%	41%	93%	70.1%
4. Low production profitability and depressed farm income	97%	89%	98%	94.4%
5. Near-total exclusion from formal agricultural credit	94%	76%	91%	86.5%
Institutional & Tenure Issues				
6. Systemic cadastral coordinate errors and boundary shifts	89%	41%	78%	68.1%
7. Active land tenure disputes and conflicts with neighbors	83%	33%	72%	61.3%
8. Outdated, missing, or inaccurate property documentation	91%	47%	89%	74.3%

A comprehensive analysis of the generated empirical data indicates that low production profitability combined with depressed farm income constitutes the most pervasive economic constraint, impacting an overwhelming majority of smallholders across all surveyed regions (with a total weighted average of 94.4%). This systemic financial vulnerability is critically exacerbated by the near-total exclusion of small-scale producers from formal agricultural credit channels (86.5%), which effectively deprives farms of the working capital required for operational modernization.

Within the institutional and tenure dimension, the deficient status of property documentation emerges as a primary bottleneck, reported by 74.3% of the total sample. This widespread lack of accurate title deeds and historical land acts serves as a root cause for systemic cadastral coordinate errors and boundary shifts (68.1%), which directly triggers high tenure insecurity and escalating land disputes with neighboring plots (61.3%). These interrelated institutional defects create severe friction in the local land market, blocking any attempts at voluntary land consolidation.

The empirical results also reveal distinct regional variations in how these barriers manifest. In the Guba-Khachmaz economic region, infrastructural risks are prominently highlighted, with 68% of respondents suffering from acute irrigation water scarcity and complex canal degradation. Conversely, the Lankaran-Astara zone, characterized by extreme physical land fragmentation, exhibits severe technological challenges: 93% of farmers state an absolute inability to maintain standard agrotechnical measures, a crisis driven by the unsustainable operational and transport costs associated with excessive plot distance (39%).

Consequently, these mathematical and statistical findings provide strong empirical justification for immediate policy interventions. Overcoming these barriers requires a coordinated approach that links national land management modernization, systematic cadastral corrections, and targeted financial inclusion frameworks tailored specifically for smallholder farms in Azerbaijan.

This structural interdependence of high fuel inputs, water losses, and credit exclusion underscores the complexity of the current agrarian bottleneck (see Figure 1).

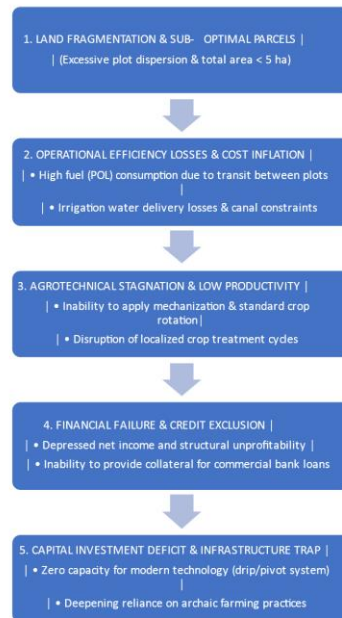


Figure 1. Structural model of operational and economic bottlenecks hindering smallholder farm efficiency.

4.2 Institutional and Tenure Insecurity

Beyond direct economic losses, the study highlights severe institutional gaps in the post-privatization land administration framework:

- Cadastral and Coordinate Discrepancies: A widespread systemic issue is the mismatch between physical field boundaries and the digital/paper coordinates stated in state ownership titles (*çixarış*) (Nizamzade, 2025).
- Land Disputes and Conflicts: These geometric and boundary errors spark intensive, ongoing legal and social conflicts between neighboring landowners, paralyzing collective action and hindering voluntary land leasing or pooling.
- Documentation Legacy Issues: Complex, bureaucratic, and expensive procedures for correcting title deeds discourage smallholders from updating their land documentation, locking them into an informal or legally ambiguous operational status.

To visually demonstrate the structural escalation of these institutional failures, the specific systemic pathways leading from primary mapping errors to chronic boundary disputes are systematically mapped below (see Figure 2).

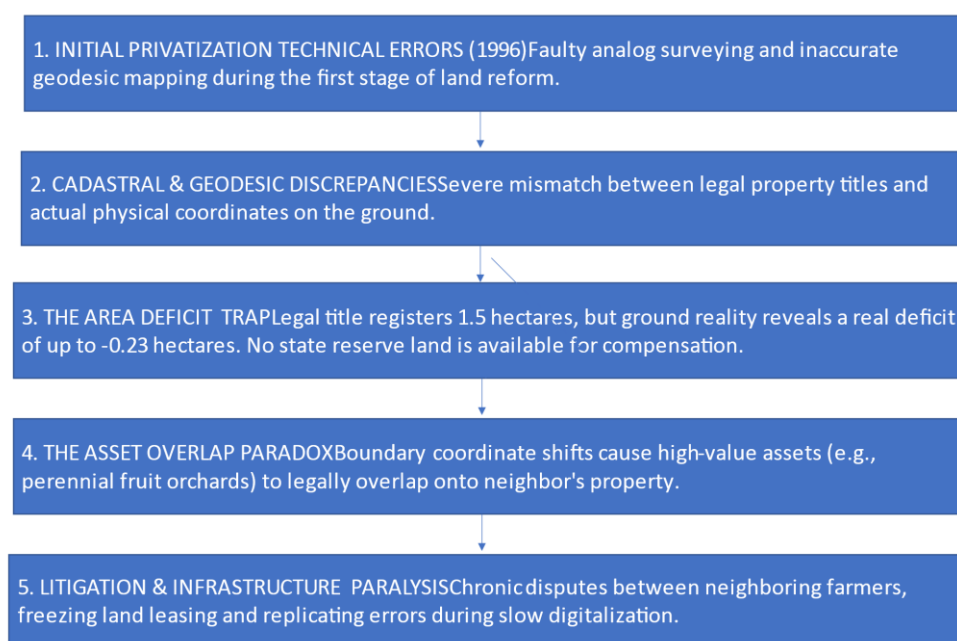


Figure 2. Vertical process mapping of post-privatization cadastral discrepancies and land tenure conflicts in Azerbaijan.

4.3 Economic Modeling of the Viability Threshold: Break-Even and Scale Analyses

To transition from qualitative structural constraints to quantitative benchmarks, this study establishes the mathematical threshold for smallholder financial sustainability under modern Azerbaijani market conditions. This threshold is evaluated through break-even parameters and the indivisibility of production inputs.

4.3.1 Break-Even Operational Area Analysis

For smallholders cultivating strategic crops (such as wheat, barley, or alfalfa), operating below a specific land area result in structural deficit due to the inability to dilute fixed costs. We model the minimum viable operational area ($A_{\min}$) using the following break-even formulation:

$$A_{\min} = \frac{FC}{P \times Y - VC}$$

where:

- FC (*Fixed Costs*) represents annual fixed farm overheads, including property taxes, basic depreciation of machinery, and structural irrigation maintenance fees.
- Y (*Yield*) is the average crop yield per hectare localized to the respective economic region.
- P (*Price*) is the current farm-gate market price per ton of output.
- VC (*Variable Costs*) represents variable operational inputs per hectare, encompassing seeds, fertilizers, petroleum-oil-lubricants (POL), and seasonal hired labor.

Empirical application of this model across the surveyed cohort reveals that when total holdings fall below the 5-hectare threshold, $A_{\min}$ systematically shifts into the unprofitability zone. Smallholder revenue streams fail to generate a positive contribution margin ($P \times Y - VC$) sufficient to cover the fixed costs (FC).

4.3.2 Scale Economies and Input Indivisibility

The financial penalty of sub-optimal land scale is further exacerbated by the physical indivisibility of modern agricultural inputs:

- **Operational Land Loss:** On highly fragmented parcels (1–2 ha), modern tractors and combine harvesters operate at sub-optimal efficiency due to extreme boundary densities and frequent turnaround maneuvers. Field observations indicate that up to 10–15% of the total arable parcel area is entirely wasted on boundaries, access tracks, and turning headlands.
- **Capital Cost Asymmetry:** Purchasing standard machinery for a holding under 5 ha is economically irrational, as the amortization period far outlasts the technical lifespan of the assets. Consequently, smallholders fall into a vulnerable dependency on expensive third-party machinery rentals during narrow, volatile peak harvesting windows.

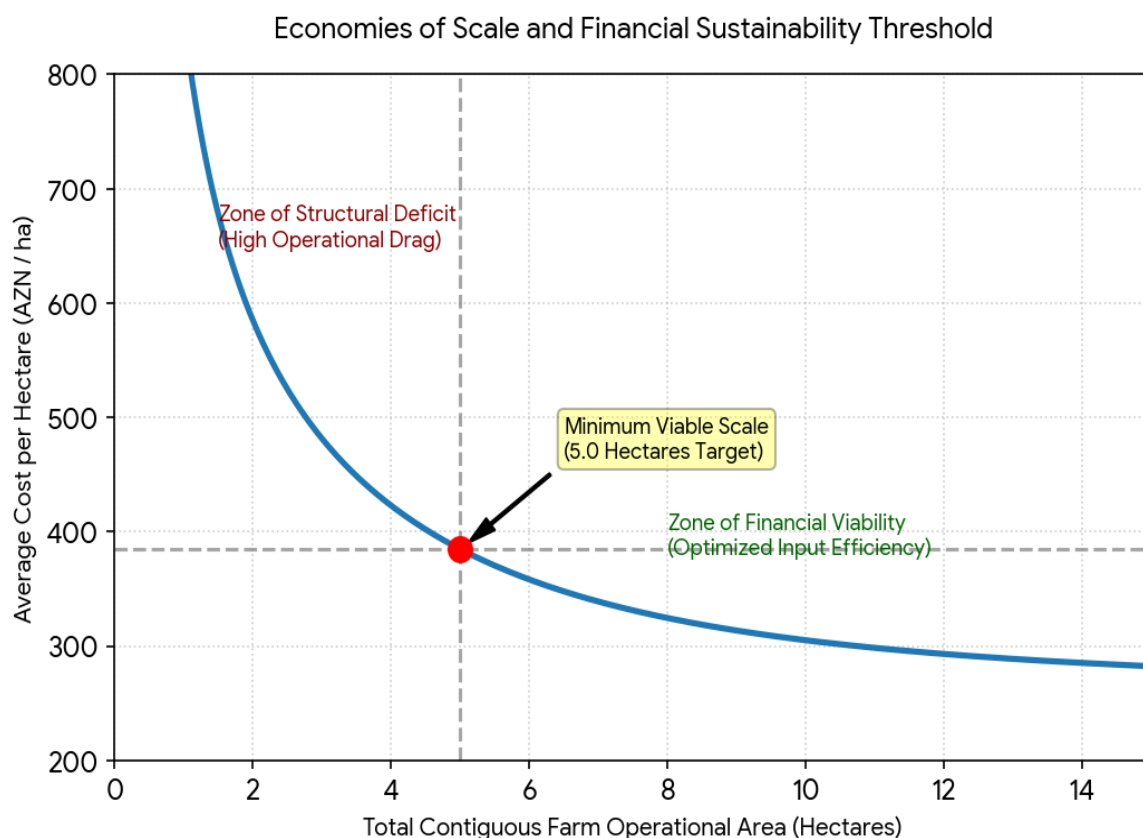


Figure 3. The Geometry of Economies of Scale: Average Total Costs per Hectare (ATC) as a Function of Smallholder Operational Plot Size in Azerbaijan.

As mathematically and visually conceptualized in Figure 3, the cost function of smallholder operations in Azerbaijan undergoes a profound non-linear transition at the 5-hectare threshold:

- **The Zone of Structural Deficit (< 5 ha):** Within the 0.5 to 4.0-hectare range, the curve exhibits an exponential cost inflation. This steep trajectory is driven by the severe structural drag of indivisibility penalties. Fixed costs (FC) are concentrated on an insufficient volume of output, while variable costs are artificially inflated by excessive machinery turnaround movements and extreme transit-fuel overheads.
- **The Viability Equilibrium (The 5-ha Point):** At exactly 5.0 hectares, the marginal cost reduction stabilizes, marking the minimum efficient scale ($A_{\min}$). At this inflection point, the farm achieves baseline optimization where the savings

from mechanization and rational irrigation infrastructure offset the baseline fixed overheads.

- **The Zone of Financial Viability (> 5 ha):** Beyond 5.0 hectares, the cost curve flattens into a sustainable asymptotic plateau. Farms operating within this zone achieve a stabilized cost environment (AZN/ha), allowing them to accumulate a capital investment surplus, mitigate production risks, and comfortably generate income above the national opportunity cost threshold.

4.3.3 Irrigation Efficiency and Opportunity Cost Thresholds

In highly arid regions such as the Kur-Araz lowland, irrigation access acts as the primary determinant of land productivity.

- **Capital Expense Constraints:** The per-hectare capital expenditure (CAPEX) for constructing secondary earthen canals or installing modern drip/pivot irrigation networks scales exponentially downward. On plots smaller than 5 ha, the unit cost of hydraulic infrastructure becomes prohibitive.
- **Livelihood Sustainability:** Dynamically, a contiguous 5-hectare threshold represents the baseline critical mass required to generate a net farm income capable of matching the average regional off-farm wage. Holdings below 5 ha incur severe opportunity costs, failing to sustain a standard rural household of 4–5 members. This deficit drives a long-term pattern of land abandonment and rural-to-urban labor migration.

SECTION 5: INSTITUTIONAL CHALLENGES AND POLICY

RECOMMENDATIONS

5.1 Systemic Post-Privatization Cadastral Errors

The empirical fieldwork exposes a critical institutional crisis rooted in the first stage of the 1990s agrarian reforms. Due to the technical inaccuracies of initial land-allotment mapping and geodesic measurements of that era, a severe discrepancy has emerged between legal ownership titles (*çixarış*) and actual spatial boundaries on the ground.

- **The 'Missing Land' Paradox:** A frequent manifestation of this error is the deficit of physical land area. For instance, a household legally entitled to 1.5 hectares

often discovers a real-world deficit of up to 0.23 hectares. Because the entire regional land fund has already been distributed among citizens and municipalities, there is no available reserve land to compensate for these technical deficits, triggering intensive, unresolved litigation.

– Boundary Shifts and Asset Overlaps: Inaccuracies in boundary coordinates have caused systemic spatial shifts. In practice, this results in high-value assets—such as established perennial fruit orchards developed by one smallholder—legally overlapping onto a neighbor's property layout. These overlapping digital polygons spark chronic tenure insecurity and paralyze land market transactions.

5.2 Digitalization Bottlenecks

While state-led initiatives toward cadastral digitalization are underway in Azerbaijan, the process is highly constrained by two factors: low operational speed and the replication of historical measurement errors. Digitalizing outdated paper records without rigorous on-site geodesic verification fails to resolve the structural issue, merely transferring historical analog errors into a digital format.

5.3 Policy Roadmap: The "Nizamzade Expert Commission" Framework

To break this institutional deadlock, a comprehensive legislative and structural overhaul is urgently required, moving beyond passive adjustments to a new stage of land reform. The author proposes a three-tiered policy matrix:

1. Legislative Consolidation Act: The government must adopt a dedicated *Law on Land Consolidation* or insert comprehensive amendments into the *Land Code* alongside specialized legislation '*On Land Management, Cadastre, and Land Monitoring*' (Nizamzade, 2020a).
2. Inter-Agency Expert Commissions: Instead of fragmented judicial battles, the Cabinet of Ministers should establish specialized, ad-hoc commissions comprising land management engineers, lawyers, cartographers, and local municipal experts. These commissions must aggregate localized fragmentation profiles and hold the legal mandate to deliver binding, optimal cross-boundary adjustments (FAO, 2020; Nizamzade, 2020c).

3. The Consolidation Legal Override: Solutions and consensus layouts engineered by these expert commissions must be granted immediate, streamlined legal and statutory force to automatically correct title deeds without forcing impoverished smallholders into multi-year court costs. Furthermore, this coordinated land management acts as a baseline factor for the preservation and ecological improvement of the republic's soil resources (Nizamzade, 2020b).

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To break this institutional deadlock, a comprehensive legislative and structural overhaul is urgently required, moving beyond passive adjustments to a new stage of land reform. The author proposes a three-tiered policy matrix (Table 2):

Table 2. Proposed Three-Tiered Policy Matrix for Cadastral Correction and Land Consolidation in Azerbaijan.

Phase / Tier	Core Instrument	Policy Key Mechanisms	Institutional Action Strategic Expected Policy Outcomes
Tier1: Legislative Foundations	<i>Dedicated Law on Land Consolidation Amendments the Land Code.</i>	Legal anchoring of consolidation procedures; integrating specialized legislation to <i>"On Land Management, and Land Monitoring"</i> (Nizamzade, 2020a).	Establishes a clear legal definition, voluntary and statutory frameworks for large-scale agrarian restructuring.
Tier2: Administrative Execution	<i>Inter-Agency Expert Commissions (Cabinet Ministers).</i>	Deployment of specialized ad-hoc teams comprising land-use engineers, cartographers, legal experts, and municipal leaders (FAO, 2020; Nizamzade, 2020c).	Bypasses fragmented, costly judicial battles by aggregating local fragmentation profiles and delivering binding, optimal cross-boundary adjustments on-site.
Tier 3: Statutory Validation	<i>The Consolidation Legal Override Mechanism.</i>	Granting immediate, streamlined statutory force to consensus-based layouts engineered by the Expert Commissions.	Automatically updates and digitizes property title deeds (<i>çixarış</i>) without forcing impoverished smallholders into multi-year court costs; preserves and ecologically improves soil resources (Nizamzade, 2020b).

SECTION 6: CONCLUSION

This study provides an empirical and institutional assessment of land fragmentation and post-privatization cadastral inefficiencies in Azerbaijan, focusing on the Guba-Khachmaz, Kur-Araz, and Lankaran-Astara economic regions. The findings from the structured field survey of 178 smallholder farmers demonstrate that the current atomized land structure acts as a major barrier to agrarian modernization and rural sustainability.

Econometric and operational modeling indicates a clear financial sustainability threshold: individual smallholder farms must operate a minimum contiguous area of 5 hectares to break even, achieve baseline economies of scale, and maintain long-term production profitability. Below this threshold, farms are trapped in a vicious cycle characterized by inflated fuel (POL) expenses, severe irrigation water distribution losses, and total exclusion from formal agricultural credit markets.

Furthermore, the investigation highlights a deep institutional crisis. Technical inaccuracies inherited from the initial 1996 land reforms have caused systemic cadastral coordinate shifts, creating structural anomalies such as the 'missing land' paradox (e.g., -0.23 ha deficits) and the asset overlap paradox, where high-value perennial fruit orchards legally conflict with neighboring property boundaries. Current passive digitalization efforts replicate these historical errors without solving the underlying tenure insecurity.

To resolve these bottlenecks, Azerbaijan must move beyond minor regulatory adjustments toward a comprehensive, state-supported Voluntary Land Consolidation Framework. Crucially, the Cabinet of Ministers should establish specialized, inter-agency expert commissions consisting of land management engineers, jurists, and municipal authorities. These commissions must hold the statutory mandate to aggregate localized fragmentation profiles, execute binding cross-boundary coordinate corrections, and provide streamlined, free legal title updates. Implementing these measures is economically imperative to fulfill the

modernization goals of Azerbaijan's national sustainable rural development strategies.

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