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From Land Consolidation to Diversification: Cost Recovery and Agricultural Transition in Rural Türkiye

Orhan Ercan*[a], Abdurahman Tursun[a], Erdem Ercan[a]

[a]*Faculty of Applied Sciences, Department of Real Estate Development and Management, Ankara University, Ankara, TÜRKIYE*

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Corresponding Author: Orhan Ercan, E-mail: orhanercan@ankara.edu.tr
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ABSTRACT
The present study explores how land consolidation (LC) can bring about meaningful changes in rural Türkiye, with a particular attention to cost recovery and the diversification following consolidation. Using the case of Ikitepe Village, it shows that LC is more than just reorganizing land boundaries; it acts as a strategic policy tool that helps reshape rural areas. The project resulted in a 50% reduction in the number of parcels, nearly eliminated shared ownership, and enhanced mechanization suitability from 40% to 99%. These changes helped improve land use efficiency, farming infrastructure, and ownership clarity. Alongside these technical outcomes, the study observed a notable shift toward high-value crops, suggesting that farmers are now making more market-oriented choices. The fact that investment costs were recovered within 41 months points to the strong economic feasibility of such projects. While research on either economic returns or cropping patterns exists, it is rare to find studies that examine both together. By placing Türkiye's experience within a broader global context, this study calls attention to the importance of forward-thinking, inclusive planning that continues even after the physical work of consolidation ends. It highlights LC not just as a technical intervention but as a key to rural transformation, connecting land use, fairness, and agricultural modernization.

Keywords: Land consolidation, Cost recovery, Crop diversification, Agricultural policy, Rural transformation, Spatial equity

1. Introduction

Land consolidation (LC) has long been implemented as a key land management policy in regions where fragmented land ownership reduces agricultural productivity and hinders rural development. The technical outcomes of LC projects, such as the reduction in parcel numbers, creation of parcels with more productive shapes and sizes, and improvement of irrigation and road infrastructure, have been widely documented in the literature (Thomas 2006; Kvistgaard 2015). LC extends beyond parcel reorganization, incorporating social and economic dimensions alongside physical restructuring (Thomas 2006). The long-term success of such projects depends not only on technical achievements but also on the trust, participation, and perceptions of fairness developed at the local level.

LC functions as a tool to improve land use efficiency and prevent further fragmentation by directly intervening in existing parcel structures (van der Molen et al. 2005; de Vries 2022). In Central and Eastern Europe, where fragmented ownership has been a major obstacle to the effective distribution of agricultural subsidies, LC has been promoted both as a means of infrastructure improvement and as a driver of rural modernization. Moreover, it has become a prerequisite for accessing development funds under Pillar II of the European Union's Common Agricultural Policy. As a result, countries such as Poland and Serbia have adopted LC as a strategic instrument (Thomas 2006; Hartvigsen 2014; 2015b).

This strategic approach extends beyond the regulation of property rights and aims to harmonize production, living, and ecological spaces in an integrated manner. Luo et al. (2023) underline that Comprehensive Land Consolidation (CLC) plays a key role in aligning production-living-ecological space systems (PLES), contributing not only to rural modernization but also to environmental enhancement.

While LC is widely recognized as a tool to support rural development, enhance productivity, and promote sustainability, its implementation strategies vary across countries. In the Netherlands, for example, LC is carried out in close integration with environmental conservation and spatial planning objectives. In Lithuania and Latvia, it has been used to address fragmented land ownership that emerged in the post-socialist period (Van Dijk 2003; 2005; Hartvigsen 2015a). Vietnam has adopted a gender-

sensitive model that prioritizes the needs of smallholder farmers (Nguyen et al. 2019). In Germany, LC is supported by strong legal and administrative frameworks and is directly linked to national sustainability goals (Thomas 2006).

These examples demonstrate that LC is not a universal model but rather a multidimensional policy tool shaped by specific social, legal, economic, and environmental contexts. Among the 13 Eastern European countries supported by FAO, Türkiye, Serbia, and North Macedonia currently maintain active national LC programs.

Many international organizations also consider land consolidation LC a strategic instrument. The World Bank (2005) defines land consolidation as a key policy for simplifying fragmented landownership and improving land-use efficiency, and emphasizes that the process should be participatory, transparent, and guided by a strong legal framework. The Food and Agriculture Organization of the United Nations (FAO 2012) describes LC in its *Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries, and Forests (VGGT)* as a process based on principles of voluntariness and equity, with active engagement of rights holders. FAO (2019) further highlights that crop transition can enhance ecological resilience and climate adaptation.

The International Federation of Surveyors (FIG 2008) links LC not only to property readjustment but also to infrastructure development, improved rural living conditions, and environmental sustainability. UNECE (1996) considers LC an integral part of modern land administration systems, while the European Commission (2018) sees it as a key component of the Common Agricultural Policy (CAP). GIZ (2017) and UN-Habitat (2020) underscore the importance of gender equality, the inclusion of vulnerable groups, and social justice in implementation practices. Although the High-Level Panel of Experts on Food Security and Nutrition (HLPE 2019) does not refer to LC directly, it supports the principles of integrated and multipurpose land-use planning. The OECD (2020) stresses the importance of integrating LC policies across national, regional, and local governance levels.

In this context, LC should be regarded as a key instrument for rural transformation, linking social inclusion, land governance, and sustainability. Moreover, it aligns strongly with the 2030 Agenda and the Sustainable Development Goals (UN 2015), particularly Target 2.3, which aims to double the incomes of small-scale food producers.

In recent years, there has been a growing interest in assessing the economic efficiency and cost recovery timelines of LC projects. A case study conducted by Lazić et al. (2018; 2020) in the Apatin region of Serbia showed that LC contributes not only to technical outcomes but also directly to local economic development and can be evaluated within a cost–benefit framework. Such analyses also point to the necessity of integrating cost recovery-based planning into LC practices in Türkiye.

While LC projects in Europe typically take between 5 and 12 years to complete, the model developed by GIZ in Serbia reduced this duration to less than 26 months (Vasiljević et al. 2018). In projects implemented through collaboration between NALED and GIZ, the average implementation period decreased to approximately 3.5 years, with reported annual savings of €28-35 per hectare (NALED 2022). Approximately 27% of these savings stemmed from reduced fuel consumption, 6% from lower seed costs, and 4% from decreased machinery expenses.

One often overlooked aspect of LC projects is the shift in agricultural production patterns following consolidation. Janus and Markowski (2017) suggest that, beyond economic benefits, such changes may contribute to climate adaptation and environmental sustainability. According to FAO (2019), if these post-consolidation transitions are supported through planned interventions, they can lead to higher farmer incomes and enhanced cost-sharing capacity.

Since 2008, Türkiye has positioned LC at the core of its rural development policies and has implemented one of the most comprehensive national LC programs in Europe (Hartvigsen 2022). Demirbaş (2023) reports that the average cost recovery period for LC projects in Türkiye is approximately four years, while Gülsever et al. (2016) estimate this duration to range between three and five years. In a project carried out in cooperation with FAO in Konya, the number of parcels was reduced by 38%, and average parcel size increased by 63%. As a result of full integration with road and irrigation infrastructure, farmer satisfaction reached 84%, a 25% increase in income was achieved with an investment of €492,000, and private sector engagement was successfully stimulated (Kvistgaard 2015).

This study shows that land consolidation is more than a physical reorganization of parcels. It is closely connected to social inclusion, economic and ecological balance, and rural development policies. The main contribution of the paper is the joint analysis of cost recovery and crop diversification two dimensions that are rarely examined together in the literature. In this way, the study offers a clear, data-driven and policy-relevant perspective on the broader impacts of land consolidation.

2. Land Consolidation in Türkiye

2.1. Legal framework

The legal basis for land consolidation (LC) in Türkiye can be traced back to Article 44 of the 1982 Constitution and Article 755

of the Turkish Civil Code (Law No. 4721). The implementation of LC projects has been supported by additional legislation, including Laws No. 5403, 3083, and 7139. A legal amendment introduced in 2018 designated the General Directorate of State Hydraulic Works (DSİ) as the primary implementing authority. Other public institutions and organizations are authorized to act as project administrators only with formal permission from DSİ.

Within the scope of Law No. 5403, LC in Türkiye encompasses not only the merging of fragmented parcels but also the development of village settlements, the improvement of on-farm infrastructure, and broader rural land planning. Accordingly, LC practices implemented in Türkiye follow a multipurpose approach.

Projects are initiated based on the principle of public interest upon presidential approval. Local municipalities, as well as public agencies responsible for highway and railway infrastructure, may also participate in the process. In Türkiye, LC and on-farm development services (TİGH, from its Turkish acronym) are implemented through two legal pathways: mandatory and voluntary. The overarching aim is to transform fragmented and low-efficiency agricultural land into more economically viable and functionally coherent units.

In line with public infrastructure needs, up to 10% of each parcel may be deducted as a contribution share for common facilities (e.g., irrigation, roads, drainage), in accordance with the in-field development (on-farm infrastructure) provisions of the project. Despite this deduction, landowners are not subject to any additional financial burden.

All land registry and cadastral procedures within the scope of the project are carried out free of charge. In this context, Article 16 of Law No. 3083 provides exemptions from taxes and fees in line with the project's objectives. These exemptions represent a form of guiding taxation, aiming to encourage socially beneficial outcomes (Göker 2011). All project-related costs are fully covered by the state budget.

If the land allocated for common facilities through participation deductions proves insufficient, additional land is first sourced from treasury properties or other state-controlled lands. Should these sources fall short, the necessary land may be acquired through mutual agreement or expropriation. Moreover, pastures, meadows, and other public property holdings may also be brought into the LC process by applying participation deductions. These areas are then made eligible to benefit from irrigation, drainage, and road infrastructure improvements.

2.2. Technical processes and implementation practices

In Türkiye, land consolidation (LC) is one of the foremost rural development programs aimed at preventing the degradation and excessive fragmentation of agricultural land caused by both natural and human-induced factors. According to Article 4/d of the Regulation on the Implementation of Land Consolidation and On-Field Development Services, LC refers to the reorganization of fragmented agricultural land by considering natural characteristics, property ownership, and land use integrity (MOF.a 2019). This process involves not only legal adjustments to ownership structures but also physical improvements such as the construction of farm roads and the establishment or modernization of irrigation infrastructure.

Accordingly, LC in Türkiye serves not only as a physical intervention but also as a multidimensional rural development instrument with objectives such as enhancing agricultural productivity, improving rural infrastructure, and promoting a more rational use of land ownership structures.

LC programs are coordinated primarily by the DSİ and implemented in a multi-stakeholder framework involving other public institutions such as the General Directorate of Agricultural Reform, the General Directorate of Land Registry and Cadastre, the General Directorate of Highways, and the General Directorate of State Railways. Field implementation is carried out by surveying and mapping firms selected through public procurement. These projects are finalized officially after cadastral verification and registration processes are completed by the relevant cadastral offices. Throughout the implementation phase, access from each plot to farm roads and irrigation canals is ensured. New access roads are constructed, and irrigation infrastructure is reinforced as needed.

Project areas typically range between 20,000 and 30,000 hectares, although smaller-scale projects are also implemented (Gülsever et al. 2016). The average implementation period is between 3 to 5 years, with some sources reporting it as approximately 4 years (Demirbaş 2023).

Field assessments highlight the necessity of complementing LC efforts with additional mechanisms such as land banking (MOF.b 2019; Küsek et al. 2023; Şanlı et al. 2023; Batykova et al. 2024; Ercan 2024). In line with this need, Türkiye through its cooperation with the FAO, is currently developing a national land banking system for the 2022-2025 period. This mechanism aims to increase farm sizes and reintegrate abandoned agricultural land into productive use. It is also expected to extend the scope and effectiveness of land consolidation efforts.

The rationale behind LC in Türkiye is rooted in the multilayered structural problems observed in rural land ownership. As summarized in Table 1, major factors that justify the need for consolidation include limited landholding sizes, high levels of co-ownership due to inheritance, the large number of fragmented parcels, and deficiencies in on-farm road and irrigation infrastructure.

Table 1- Reasons for the Necessity of LC in Türkiye

1	Suboptimal Farm Sizes (Scale Problem)	3.1 million agricultural holdings, with an average size of 5.9–6.1 hectares
2	Excessive Parcel Fragmentation	32.5 million agricultural parcels, with an average of 11 parcels per holding
3	Inheritance-Based Co-ownership	Over 40 million shareholders, but only 3 million active land users
4	Lack of Legal Access to Parcels	More than 50% of existing parcels lack legal road access; road quality is low
5	Limited Access to Irrigation	About 50% of parcels have no direct access to irrigation canals

Source: Demirbaş 2023

Figure 1 illustrates the implementation process of LC projects in Türkiye, structured under three main stages: (i) integration of mapping, land registry, and cadastral data; (ii) soil surveys, soil classification, and reallotment planning; and (iii) stakeholder consultations and on-field development services.

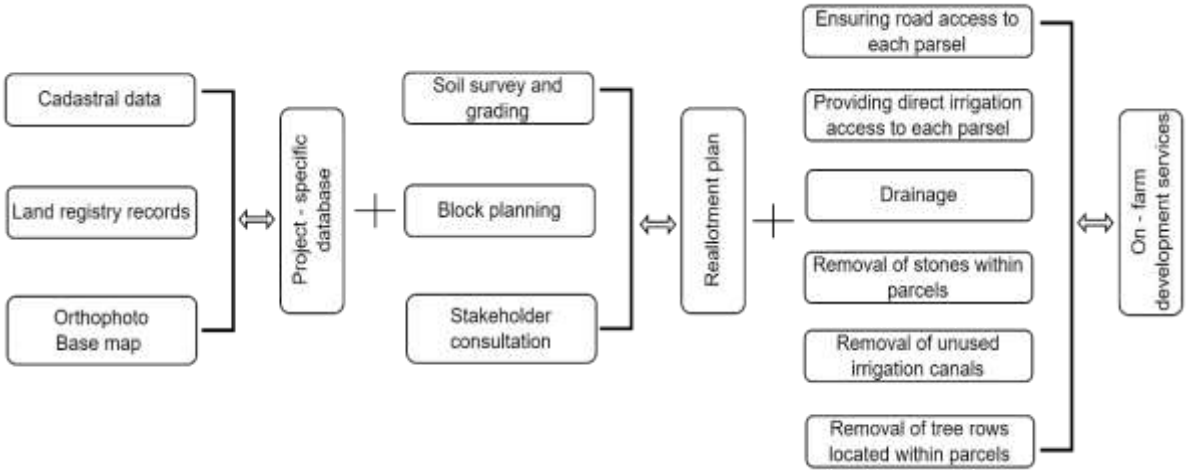


Figure 1- LC process

Türkiye has the largest national LC in Europe (Hartvigsen 2022). Although LC activities in Türkiye began in 1961, they gained significant momentum after 2008, evolving into a large-scale rural development policy. The increase in both completed and ongoing projects during this period has reinforced the strategic role of LC within the country's national development agenda. Implementation data from the 2018–2025 period clearly demonstrate the scale and dynamic progression of the process (Table 2). The table below provides a detailed overview of the number of projects completed and officially registered each year, along with the respective consolidated land areas.

Table 2- LC Statistics and Status in Türkiye (2018–2025)

Description	*Number of Projects*	*Area (ha)*
Area registered by the end of 2018 (of which 496,000 ha and 23 projects were completed in 2018)	23	3.600.021
Area completed and registered in 2019	46	619.000
Area completed and registered in 2020	31	544.832
Area completed and registered in 2021	44	1.258.117
Area completed and registered in 2022	21	759.365
Area completed and registered in 2023	24	492.252
Area completed and registered in 2024	15	312.440
Area completed and registered in 2025	-	12.408
Total area registered (after reallotment approval)	367	7.598.435
Total LC area completed	571	9.592.668
Area under ongoing LC works	204	1.994.233
Area suitable for LC in Türkiye	-	14.300.000
Remaining potential LC area in Türkiye	-	4.806.492

Source: DSİ 2025

According to Table 2, as of July 2025, approximately 9.6 million hectares of land have been consolidated across 571 projects in total. Of this area, 7.6 million hectares have been officially registered, marking the successful completion of these projects. Currently, LC efforts are ongoing over an area of approximately 2 million hectares.

It is estimated that the total land area suitable for LC in Türkiye amounts to 14.3 million hectares. Accordingly, the remaining 4.8 million hectares are expected to be consolidated in the coming years under the annual implementation programs of the DSİ.

3. Data and Methodology

3.1. Study area

This study was conducted within the scope of the Elazığ Uluova Land Consolidation and Agricultural Infrastructure Improvement Project, which covers 23 villages and a total area of approximately 26,500 hectares. For the in-depth spatial analysis, the village of Ikitepe was selected as a case study area.

3.2. Data sources

The spatial data used in this study were obtained from DSİ and include geospatial layers related to land parcels, irrigation infrastructure, and topographic features. Agricultural production-related data, including crop types and cultivation patterns, were collected from the Elazığ Provincial Directorate of the Ministry of Agriculture and Forestry.

3.3. Methodological approach

Spatial analyses were conducted using GIS software, where parcel, irrigation, and topographic data were processed to produce thematic maps and calculate spatial statistics. In this study, analyses were carried out using ArcGIS (Esri) and LICAD GIS, the most widely used platforms for land consolidation projects in Türkiye. The findings were then presented in tabular format to support the evaluation of the existing conditions and spatial characteristics of the project area.

3.4. Project scope

As shown in the map on the left side of Figure 2, prepared by Kılıç et al. (2019), the project area is located within the boundaries of Elazığ Province, in the Upper Euphrates Basin of the Eastern Anatolia Region of Türkiye. The Google Earth image on the right side of the same figure illustrates that the project area lies within a distinct irrigation basin. The Elazığ Uluova Land Consolidation and On-Farm Development Services Project was coordinated by the DSİ's Elazığ Regional Directorate and implemented across 23 villages and neighborhoods in the Central District of Elazığ. These include Akçakiraz, Mollakendi, Yazıkonak (Fatih and Konak Neighborhoods), Yurtbaşı, Akçakiraz (Kıraç and Yenice Neighborhoods), Altınçevre, Güntaşı, Karşıbağ, Acıpayam, Akmezra, Ballıca, Çağlar, Doğankuş, Hoşköy, Ikitepe, Karasaz, Sarıyakup, Tohumlu, Yalnız, Yedigöze, and Yünlüce.

The 23 villages included in the project were officially registered by the Land Registry Directorate in the years 2018, 2019, 2020, and 2021 following verification procedures. The project covered a total area of 26,500 hectares. Since the irrigation infrastructure had already been established by DSİ in earlier years, an irrigation component was not included in the project. Ikitepe Village, where comprehensive and well-organized project data were made available, was selected as the case study area for this research.



Figure 2- Geographical representation of the project area. The map on the left is adapted from Kılıç et al. (2019)

4. Village-Level Assessment: Ikitepe

4.1. Pre-Consolidation Land Structure

A detailed analysis of the existing land structure prior to LC is crucial for identifying key challenges related to land fragmentation, ownership patterns, and farm size. The tables presented in this section provide a comprehensive overview of parcel characteristics in Ikitepe Village, including the number of parcels, their size distribution, ownership types, and levels of co-ownership. These data collectively demonstrate the highly fragmented, small-scale, and scattered nature of the landholdings in the area. The findings also underscore that LC in Ikitepe was not only a spatial necessity but also a legal and institutional requirement.

Table 3 presents a detailed distribution of parcel numbers and land use by agricultural holding size. The data reveal that nearly half (49.60%) of all farms fall within the 0–5 decare range, marking them as the most common category. In this group, the average farm size is just 2.18 decares, with an average parcel size of 1.09 decares pointing to extremely small-scale farming both in terms of holdings and individual parcels.

Table 3- Distribution of Parcel Numbers According to Farm Size

Farm Size	*Number of Holdings*	*% of Holdings*	*Number of Shares*	*% of Shares*	*Average Number of Parcels per Holding*	*Farm Size (Decares)*	*Average Parcel Size (Decares)*	*Total Land Area (Decares)*
0 – 5	251	49.60	502	8.51	2.00	2.18	1.09	546.12
6 – 10	78	15.42	623	10.57	7.99	8.37	1.05	653.16
11 – 20	87	17.19	2042	34.63	23.47	14.42	0.61	1 254.85
21 – 50	70	13.83	2070	35.11	29.57	31.78	1.07	2 224.67
51 – 100	18	3.56	444	7.53	24.67	65.23	2.64	1 174.20
101 – 500	2	0.40	215	3.65	107.50	138.14	1.28	276.27
501 – 1000	0	0.00	0	0.00	0.00	0.00	0.00	0.00
1000 >	0	0.00	0	0.00	0.00	0.00	0.00	0.00
Total	506	100.00	5896	100.00	11.65	12.11	1.04	6 129.28

Farms sized between 6 and 20 decares account for 32.61% of all holdings, yet they represent almost 45.2% of the total number of parcels. This disproportion indicates a deeper level of fragmentation, particularly in the 11-20 decare group, where the average number of parcels per farm reaches 23.47 highlighting how scattered and disjointed landholdings are in practice.

While holdings between 21 and 100 decares make up 17.39% of all farms and command a significant share of total land, their average parcel sizes also show only a modest improvement. In the 51–100 decare group, for instance, the average parcel size rises to 2.64 decares, but still falls short of what would be considered efficient for scale-based farming. Furthermore, the near absence of farms larger than 100 decares suggests that economies of scale remain out of reach in the study area, and that large-scale commercial agriculture is virtually absent.

While Table 3 reflects the degree of physical land fragmentation based on parcel sizes, Table 4 reveals how this fragmentation is mirrored in the structure of land ownership. Notably, 39.12% of all farms consist of 2-5 parcels, indicating the prevalence of highly fragmented farm structures. Furthermore, the disproportionate increase in the number of ownerships shares as parcel numbers rise suggests that fragmentation is not only spatial but also legal in nature. This situation makes it difficult to plan agricultural production effectively and leads to inefficient land use thereby making structural interventions such as LC and the resolution of co-ownership issues increasingly necessary.

Table 4- Distribution of parcel numbers by number of agricultural holdings

Number of Parcels	*Number of Holdings*	*Percentage (%)*	*Number of Shares*
1	174	34.38	174
2-5	198	39.12	595
6-10	53	10.47	390
11-30	37	7.32	591
60-100	29	5.75	2507
101-141	15	2.96	1639
Total	506	100	5896

Table 5 presents the distribution of parcels according to their size, showing that the largest share, 74.76%, falls within the 0–5 decare range. This clearly indicates a high level of land fragmentation in the study area. Parcels in the 6–10 decare and 11–20 decare categories account for 17.86% and 6.27% of the total, respectively. Combined, these three categories represent 98.89%

of all parcels, confirming the dominance of parcels smaller than 20 decares. This pattern also suggests that mid-sized agricultural holdings are relatively rare in the region.

Table 5- Distribution rates by parcel size groups

Parcel Size Groups (Decares)	*Number of Parcels*	*Percentage (%)*	*Total Area by Parcel Group (Decares)*
0 – 5	1013	74.76	2 621.20
6 – 10	242	17.86	1 893.68
11 – 20	85	6.27	1 236.83
21 – 50	15	1.11	377.58
51 – 100	0	0.00	0.00
101 – 500	0	0.00	0.00
501 – 1000	0	0.00	0.00
1000 >	0	0.00	0.00
Total	1355	100.00	6 129.28

In addition, the complete absence of parcels larger than 21 decares implies that large-scale agricultural land is either non-existent or land consolidation has not yet taken place in the area. The data further show that although parcels in the 0–5 decare group are numerous, they account for only 42.77% of the total land area. This indicates that the parcels are not only small in size but also widely dispersed. Overall, Table 5 highlights both a fragmented ownership pattern and potential inefficiencies in land use.

Table 6 shows the distribution of land based on ownership types and reveals that the majority of land in the project area, totalling 6,129.28 decares, is privately owned. Specifically, 1,286 private parcels make up 97.50% of the total land area, indicating that the land in the study area is predominantly held by individual owners.

Table 6- Land Ownership Distribution in Ikitepe Village

Ownership Type	*Number*	*Land Area (Decares)*	*Share (%)*
Private lands	1286	5 975.81	97.50
Treasury lands	94	65.43	1.07
Pasture lands	8	88.04	1.44
Village Legal Entity Lands	0	0.00	0.00
Total	1388	6 129.28	100.00

In contrast, treasury lands include only 94 parcels and account for just 1.07% of the total area. Pasture lands cover 88.04 decares across 8 parcels, corresponding to 1.44%. There are no parcels registered under the legal entity of the village. These findings confirm the dominance of private property and the minimal presence of publicly or communally owned land in the project area.

The data on co-ownership in land parcels show that multiple ownership remains a major structural issue in the project area. Of the total 5,896 ownership shares registered in 1,355 parcels, only 905 parcels have a single owner, accounting for 66.79% of all parcels. Although this indicates that individually owned parcels are numerically dominant, the remaining 33.21% are held under co-ownership, clearly reflecting the extent of legal fragmentation. As illustrated in the last three rows of Table 7, there are 3,501 shares registered in just three groups of parcels, each with 35, 37, and 42 co-owners, respectively. These three groups alone account for 59.37% of all ownership shares.

Table 7- Parcels co-ownership status

No	***Number of Parcels***	***Number of Shares***	***Total Shares***	***Percentage (%)***	***No***	***Number of Parcels***	***Number of Shares***	***Total Shares***	***Percentage (%)***
1	905	1	905	66.79	10	2	10	20	0.15
2	142	2	284	10.48	11	2	11	22	0.15
3	62	3	186	4.58	12	2	14	28	0.15
4	34	4	136	2.51	13	1	16	16	0.07
5	26	5	130	1.92	14	1	27	27	0.07
6	27	6	162	1.99	15	18	35	630	1.33
7	19	7	133	1.40	16	39	37	1443	2.88
8	23	8	184	1.70	17	34	42	1428	2.51
9	18	9	162	1.33	Total	1355		5896	100.00

These findings underline that resolving co-ownership is just as important as spatial LC when it comes to effective land-use planning and land consolidation practices. Therefore, improving the ownership structure should be considered a priority intervention area, both for enhancing agricultural efficiency and for ensuring the success of LC efforts.

4.2. Observed improvements after consolidation

The most tangible way to evaluate the effectiveness of LC as a planning instrument is by systematically monitoring the changes that occur after implementation. This section presents a detailed account of the spatial, structural, and functional improvements resulting from the LC project in the study area. Indicators such as the reduction in the number of parcels, improved access to roads and infrastructure, better parcel geometry, simplification of ownership structures, and increased suitability for agricultural mechanization all contribute to assessing the outcomes of the intervention.

The following tables provide a comparative and data-based analysis of these multidimensional improvements, particularly for Ikitepe Village and the 22 other settlements included in the project. Table 8 summarizes the outcomes of LC efforts across 23 villages in the project area. A comparison of pre- and post-consolidation parcel numbers shows an overall consolidation rate of 31%, indicating a significant reduction in the number of parcels and a transition toward a more rational land ownership structure. The highest consolidation rate was achieved in Ikitepe Village at 52.03%, while the lowest was recorded in Yazıkonak Fatih Village at only 7.81%.

Table 8- Number of Parcels, Consolidation Ratios, and Contribution Rates for Common Facilities After LC

No	*Village / Neighbourhood*	*Number of Cadastral Parcels*	*Parcels After Consolidation*	*Consolidation Rate (%)*	*Contribution Deduction for Shared Facilities (%)*
1	Çağlar	432	312	27.78	1.89
2	Doğankuş	1008	676	32.94	3.15
3	Karasaz	388	256	34.02	1.89
4	Karşıbağ	462	315	31.82	1.62
5	Yedigöze	1818	1088	40.15	2.18
6	Yurtbaşı	1600	1107	30.81	1.50
7	Akçakiraz	844	603	28.55	1.19
8	Acıpayam	941	691	26.57	2.21
9	Akmezra	378	259	31.48	1.21
10	Altınçevre	1283	826	35.62	2.67
11	Ballıca	699	504	27.90	2.84
12	Gözebaşı	2862	1537	46.30	1.92
13	Güntaşı	1209	844	30.19	2.21
14	Hoşköy	974	593	39.12	0.58
15	Ikitepe	1355	650	52.03	2.23
16	Mollakendi	537	380	29.24	1.59
17	Sarıyakup	1028	619	39.79	2.86
18	Tohumlu	458	356	22.27	2.07
19	Yalnız	345	297	13.91	1.91
20	Yazıkonak Fatih	64	59	7.81	1.73
21	Yazıkonak	81	62	23.46	2.05
22	Yenikapı	215	173	19.53	3.70
23	Yünlüce	538	314	41.64	2.58
	Grand Total	19519	12521	31.00	2.08

The average contribution rate for common-use areas, such as infrastructure and roads, was 2.08%, varying between 0.58% and 3.70% depending on the settlement. These figures reflect both the spatial effectiveness of the consolidation process and the varying levels of local public infrastructure needs across different settlements.

The data for Ikitepe Village, as presented in Table 9, show that LC not only reduced the number of parcels but also significantly improved rural infrastructure access. Prior to the project, only 355 of 1,355 parcels (26%) had direct road access, while 1,000

parcels (74%) lacked any access. Following the consolidation, all 642 newly formed parcels gained direct road connectivity, raising the share of road-accessible parcels to 100%.

Table 9- Comparison of Pre- and Post-Project Status-Ikitepe Village

Ikitepe Village	*Pre-Project*		*Post-Project*	
Road Access	*Number of Parcels (and %)*	*Area (ha)*	*Number of Parcels*	*Area*
Parcel with Road Access	355 (26%)	170	642	650
Parcel without Road Access	1000 (74%)	480	0	650
Total	1355	650	642	650

Findings on parcel geometry before and after the LC are summarized in Table 10**.** Prior to the implementation, the project area contained 1,355 parcels, most of which had trapezoidal (35.79%) or irregular (33.28%) shapes. The high prevalence of irregularly shaped parcels was a limiting factor for agricultural mechanization, boundary demarcation, and in-field development services.

Table 10- Parcel Geometries Before and After LC

	Pre-Project			*Post-Project*	
Parcel Count	*Shape*	*Percentage (%)*	*Parcel Count*	*Shape*	*Percentage (%)*
29	Square	2.14	23	Square	4
281	Rectangle	20.74	451	Rectangle	70
109	Triangle	8.04	19	Triangle	3
485	Trapezoid	35.79	65	Trapezoid	10
451	Irregular	33.28	84	Irregular	13
1355	Total	100	642	Total	100

After the LC, the proportion of rectangular parcels increased significantly from 20.74% to 70%, indicating the successful establishment of a more regular and efficient land use pattern. Likewise, the share of irregular parcels decreased from 33.28% to 13%, and triangular parcels from 8.04% to 3%, reducing the occurrence of complex and impractical geometric forms.

The combined share of rectangular and square parcels reached 74%, reflecting substantial improvements in terms of field accessibility, irrigation infrastructure, and the ease of machinery use. This transformation should not be viewed merely as a visual or geometric adjustment but rather as an engineering intervention that enhances physical efficiency in agricultural production and simplifies operations.

LC, therefore, not only rationalized the number and size of parcels but also significantly improved their shapes, leading to a measurable enhancement in land use quality.

The land consolidation project implemented in Ikitepe Village has brought about significant transformations both in spatial organization and in the structure of land ownership. While the total project area remained constant at 650 hectares, the number of cadastral parcels decreased from 1,355 to 642, representing a 52.6% reduction. This change indicates a substantial level of consolidation in the land structure.

In terms of ownership structure, prior to the project, 1,084 parcels were under shared ownership and only 271 parcels were fully owned. After the project, the number of shared ownership parcels decreased to 256, while the number of fully owned parcels increased to 386 (Table 11). This finding highlights the potential of LC to reduce legal fragmentation and to simplify ownership structures.

Table 11- Comparison of Pre- and Post-Project Status in Ikitepe Village

Ikitepe Village	*Pre-Project*	*Post-Project Status*
Area (hectares)	650 ha	650 ha
Number of Cadastral Parcels	1,355 parcels	642 parcels
Ownership Status	1,084 co-owned 271 full ownership	256 co-owned 386 full ownership
Suitability for Agricultural Mechanization	60% Not Suitable	99% Suitable
Total Cadastral Parcel Area	612.93 ha	599.47 ha
Average Parcel Size (before)	4.52 da	9.34 da
Average Holding Size (after)	12.11 da	11.85 da

Another key insight drawn from Table 11 is the improvement in suitability for agricultural mechanization. While only 40% of parcels were suitable for mechanized farming before the project, this figure increased to 99% post-project, demonstrating that LC has strengthened the technical infrastructure for agricultural production and supported the transition to modern farming practices.

Although the average parcel size increased significantly from 4.52 to 9.34 decares, the total usable land area slightly decreased from 612.93 to 599.47 hectares, which suggests a small land loss due to public facility allocations or geometric adjustments. On the other hand, the average farm size slightly decreased from 12.11 to 11.85 decares, implying that while individual production capacity remained relatively stable, the integrity and arrangement of parcels enhanced the efficiency of the production process. The case of Ikitepe Village illustrates that LC does not merely reduce the number of parcels but also generates multidimensional benefits such as simplified ownership structures, improved mechanization infrastructure, the reorganization of production areas, and a foundation for modern agricultural practices.

In addition, significant improvements were achieved in parcel accessibility. Based on GIS-based spatial analyses, the total average distance from farmsteads to the parcels was approximately 2,410 km before the project, which was reduced to 1,025 km after LC. This means that a one-time round trip from the village centre to all parcels now results in a distance saving of 1,385 km.

Assuming that each parcel is visited approximately 20 times per year, this translates into an annual distance savings of 55,400 km. This improvement not only brings time and cost efficiency but also offers considerable environmental benefits by reducing fuel consumption and emissions associated with agricultural logistics.

4.3. Observed trends in crop pattern diversification after LC

The LC project implemented in Ikitepe Village not only simplified the ownership structure but also created a platform for a fundamental transformation in the agricultural production model. This transformation is particularly evident in the observed trend toward diversification of crop patterns. Production and income data from 2015 to 2024 indicate that the number of cultivated crop types has increased, value-added agricultural products have become more prominent, and income levels have shown a steady upward trend.

4.3.1. Quantitative Increase: Rise in the number of agricultural crops

In the pre-LC period (2015–2020), agricultural production in Ikitepe Village was largely limited to a few staple crops such as barley, wheat, silage maize, and alfalfa. During this time, the number of actively cultivated crops ranged between 10 and 12. However, following the completion of the LC process in 2021, new crops began to be introduced into the production pattern, and by 2024, the number of cultivated crops exceeded 20.

Among the newly added crops over the past four years are market-oriented products such as strawberries, melons, watermelons, walnuts, beans, eggplants, chickpeas, and cucumbers. This trend indicates that farmers have found the opportunity to grow crops that they previously could not access or avoided due to economic risks (Table 12).

Table 12- Total Production Amount (kg) and Agricultural Income (€) by Crop Type in Ikitepe Village (2015–2024)

YEAR	2015		2016		2017		2018		2019		2020		2021		2022		2023		2024	
CROP TYPE	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)	TOTAL PRODUCTION (kg)	TOTAL REVENUE (€)
BARLEY (Forage)	819.801,23	171.018,14	726.332,88	156.574,75	746.921,56	154.097,89	653.857,38	103.970,25	642.477,66	96.118,71	252.386,86	34.573,54	777.366,60	141.069,39	1.155.994,96	299.308,25	1.333.588,80	363.517,19	1.036.301,60	233.598,56
QUINCE (Various)	12.501,30	5.174,38	12.096,00	4.526,95	12.096,00	4.403,88	12.096,00	5.129,05	12.096,00	4.000,25										
ALMOND (Various)			820,05	1.227,62	820,05	895,69	1.067,85	1.226,33	2.649,50	2.712,09	2.649,50	2.573,61	794,85	759,16						
PEPPER (various)	5.069,00	1.426,71							30.456,80	6.714,89	52.181,68	10.722,26	32.612,13	6.852,60	73.612,00	31.765,82	28.306,45	7.715,93	45.375,00	14.063,82
WHEAT (BREAD)	184.072,95	43.884,94	131.849,74	28.422,70	98.037,10	21.415,87	81.693,69	15.876,87	121.871,20	22.071,16	866.708,40	178.090,77	285.096,40	61.267,13	371.780,60	106.956,44	301.313,53	107.947,21	618.487,35	191.697,97
TOMATO (VARIOUS)	19.050,00	5.046,36							102.615,00	25.047,76	85.758,00	19.223,46	8.118,00	1.783,32	3.493,75	1.105,62	2.880,00	672,90	21.712,00	5.506,00
MULBERRY (VARIOUS)	1.210,44	4.008,08	1.210,44	3.624,07	1.367,21	3.982,15	157,91	446,37	62,50	177,15	62,50	155,65			87,50	100,69	350,00	204,44	350,00	246,55
APPLE (VARIOUS)	25.754,30	8.527,91	9.584,90	2.869,73	12.860,90	3.433,74	11.115,00	3.927,56	11.698,70	2.855,59	4.105,95	1.022,65	1.687,95	451,41	12.110,15	4.877,51	12.660,40	9.860,12	12.660,40	9.631,75
APRICOT (VARIOUS)	3.850,28	2.549,85	6.824,03	4.086,24	2.973,75	1.587,92	2.973,75	1.260,95	2.973,75	1.358,09										
SILAGE MAIZE (VARIOUS)	365.543,60	18.156,14	297.576,75	13.364,23	529.435,05	28.270,80	859.128,00	37.947,35	1.019.155,20	43.334,16	675.614,40	29.447,70	353.476,00	16.880,42	975.670,00	47.716,89	726.440,00	42.432,24	215.040,00	12.118,34
SUGAR BEET (VARIOUS)	153.490,60	9.656,69									43.694,30	1.850,07							158.064,00	10.243,65
TABLE GRAPES (VARIOUS)	41.462,10	20.593,76	24.516,00	11.010,18	25.695,20	10.602,39	29.972,00	13.238,52	39.446,40	16.151,28	10.307,20	4.492,55	9.806,94	4.308,68	8.091,72	3.259,04	15.096,00	16.165,89	14.467,47	12.229,48
ALFALFA (VARIOUS)	114.015,00	7.550,66	124.468,50	7.453,20	257.294,70	18.735,05	257.294,70	15.910,45	98.974,20	5.922,87	122.928,00	6.429,61	69.042,00	3.956,56	44.808,00	2.320,32	29.832,00	2.323,36	126.656,00	12.490,73
CHERRY (VARIOUS)			5.677,50	2.549,78	529,90	231,51	5.677,50	2.608,04	5.677,50	2.056,42										
SORGHUM (VARIOUS)																				
VETCH (COMMON VETCH)					54.024,00	2.622,52	42.508,00	1.877,56	18.532,80	758,82	21.351,60	797,69	95.689,10	3.655,74	20.200,70	1.162,30	68.531,00	5.337,31	74.349,85	6.284,86
EGGPLANT (KEMER TYPE)											14.542,00	4.527,40	32.014,40	5.198,14	1.230,50	318,60			13.027,20	3.670,67
STRAWBERRY											8.520,40	3.819,86	8.520,40	4.068,96	16.940,00	14.620,25				
BEAN (VARIOUS)													1.682,20	2.008,36						
CHICKPEA (VARIOUS)													4.305,50	3.289,78	464,66	427,77			1.322,25	1.676,56
WATERMELON															19.197,00	2.209,09				
MELON															23.993,20	4.141,52				
CUCUMBER																	306,00	95,33		
WALNUT																			3.450,80	293.318,00
TOTAL		297.593,62		235.709,45		250.279,42		203.419,30		229.279,22		297.726,83		255.549,66		520.290,09		556.271,93		806.776,94

4.3.2. Qualitative transformation: Transition to high-value and market-oriented production

Beyond the numerical increase, a qualitative shift in the cropping pattern was also observed. The inclusion of high-value products such as walnuts, strawberries, grapes, and melons into the production repertoire indicates not only diversification but also a growing orientation towards market integration.

For instance, walnuts, introduced in 2024, generated a remarkable €293,318 in revenue, making it the most profitable crop of the year. Similarly, strawberry cultivation yielded approximately €14,620 in 2023 and continued in 2024.
These developments reveal that farmers are not only producing more crops but are also making more strategic and market-driven decisions in their production choices.

4.3.3. Economic impact: The trend in income growth

The economic outcomes of diversification and value-added production are also significant. Between 2015 and 2020, total annual income fluctuated between €203,000 and €297,000. However, in the post-consolidation period (2021–2024), there has been a notable upward trend in revenue.

In 2022, income rose to €520,290, and by 2024, it reached €806,776. This clearly demonstrates that LC not only improves the physical structure of land but also enhances overall economic productivity. This upward trajectory is also clearly reflected in the annual agricultural income curve presented in Figure 3.

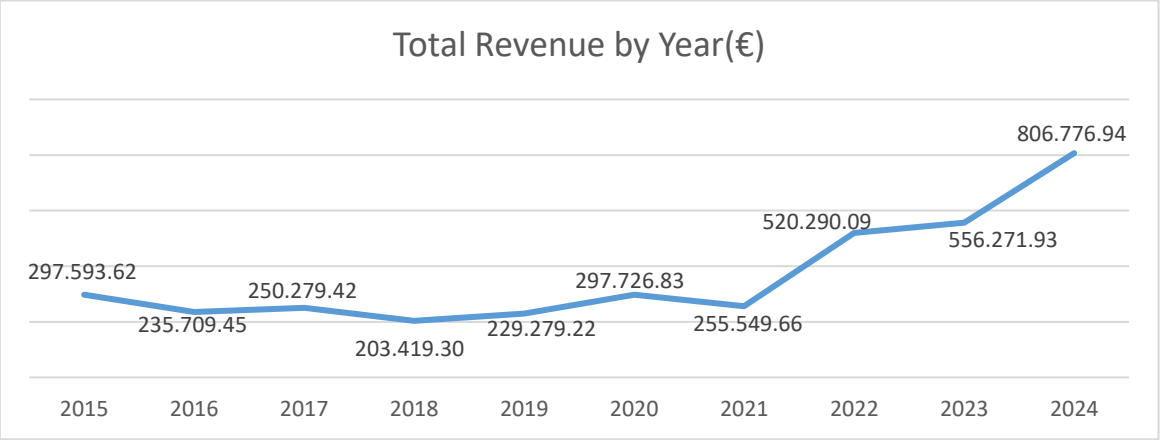


Figure 3- Annual Agricultural Income Trend in Ikitepe Village (€), (Data source: Compiled from annual production and income records.)

4.3.4. Continuity of traditional crops and their balancing role

The transformation in the cropping pattern does not imply a complete abandonment of traditional crops. Barley, wheat, and silage maize continue to hold a significant share in total production volume. However, the proportional contribution of these crops to total income has declined over time.

In 2024, barley production exceeded 1 million kilograms, yet the income generated was only €233,598. In contrast, walnuts, produced in smaller quantities, generated €293,318 in revenue, clearly illustrating the potential of high-value crops.

This suggests a shift in agricultural production priorities, emphasizing not only quantity but also diversity and value per unit.

4.3.5. Return on LC Investment: Profitability and cost recovery

Total profitability is a fundamental indicator used to assess the overall economic impacts of LC within the studied area. The observed increase in the profitability of agricultural production serves as a valuable reference for investors and policymakers, helping to justify such rural infrastructure investments.

However, this profitability indicator alone does not provide a quantitative link between the initial land consolidation investment and the resulting financial gains. In other words, it does not reveal concrete insights into the investment's financial return period or efficiency, which requires further economic evaluation.

In this context, the profitability of agricultural production following LC can be calculated using the following formula (Lazić et al. 2018; 2020; Vasiljević et al. 2018):

$Rpp = \Delta Pr / (Tk \times n)$

Where: Rpp, increase in agricultural profitability due to LC; ΔPr, Difference in total agricultural revenue before and after consolidation; Tk, Total cost of LC; n, Number of years during which the impact of consolidation on production is observed.

In the project examined, the cost of LC was covered through 24 separate payments made at different times during implementation. The total of these payments, made in Turkish Lira (TL), was calculated as approximately €6,071,778 based on the exchange rates of the Central Bank of the Republic of Türkiye.

Across 23 villages, a total of 19,519 parcels were consolidated. Of these, 1,355 parcels (about 7 percent of the total) are located within the boundaries of Ikitepe Village. Therefore, the cost allocated specifically to Ikitepe was estimated proportionally as €425,025.

The consolidation project was completed in 2021, and its effects on agricultural production were observed during the 2022–2024 period. During this time, the total agricultural income in Ikitepe increased by €374,986 compared to the previous period. Accordingly:

ΔPr=€374,986
Tk=€425,025
n=3 years

When applied to the formula:

$Rpp = 374,986 / (425,025 \times 3) = 0.2941$

This means that for each year, the increase in income corresponds to approximately 29.41 percent of the investment cost. In other words, LC has provided a high level of economic return within a short period.

The payback period of the investment can be calculated using the following formula:

$t = Ck / C$

Where: t, Payback period (years); Ck, Project cost; C, Average annual increase in income (ΔPr / n)

Given:

Ck = €425,025
C = €374,986 / 3 = €124,995

Then:

$t = 425,025 / 124,995 \approx 3.4$ years (or 41 months)

This finding indicates that the investment was recovered in about 41 months (roughly 3 years and 5 months). This relatively short return period demonstrates the value of LC both as a tool for economic development and as a strategic investment in rural infrastructure.

6. Discussion

The LC project implemented in Ikitepe Village has led to remarkable outcomes that go far beyond spatial efficiency and standard geospatial indicators. Reducing the number of parcels by more than 50% represents a comprehensive solution to the long-standing issue of land fragmentation. As a result, agricultural areas have become more organized and manageable, making daily operations easier for farmers and enabling more sustainable and effective land governance.

One of the most notable improvements observed during the project was the restructuring of property ownership. The sharp decline in jointly owned parcels shows that LC is not just about physical changes in space. It also plays a vital role in inheritance and succession processes. This shift has helped reduce conflicts among producers, fostered more stable land tenure, and supported the creation of an agricultural environment that encourages long-term investment.

Among the most tangible outcomes of success is the increase in mechanization suitability, which rose dramatically from 40% to 99%. This progress indicates that LC reconfigures land while simultaneously driving the modernization of farming practices.

The expansion of parcel sizes further reinforces this structural transformation. It also reduced unnecessary fuel use and field traffic, which has direct environmental benefits such as lower emissions and less soil compaction.

Interestingly although the average farm size decreased slightly, individual producers did not experience significant land or income losses. On the contrary, farmers transitioned into more efficient, organized, and integrated agricultural practices. The Ikitepe case shows that LC goes beyond parcel readjustment, combining spatial reorganization with improvements in ownership and production structures, while also facilitating the integration of farmers into modern agricultural systems. Taken together, these benefits suggest that LC functions as more than a supportive measure; it should be regarded as a central policy instrument for rural development.

After the project, the removal of both physical and institutional barriers led to a noticeable increase not only in the quantity of production but also in its quality. The emergence of high value-added crops brought new energy to the local agricultural economy. This shift suggests that changes in cropping patterns are not just about diversifying crops. They also reflect a growing tendency among farmers to make more strategic and market-driven decisions. The inclusion of perennial crops like walnuts and grapes also provides ecological gains by improving soil cover and supporting carbon storage.

Finally, the cost recovery analysis in this study demonstrates that LC projects can achieve payback within a relatively short timeframe. In Ikitepe, the payback period was an impressive 41 months, which serves as a strong benchmark for other rural areas with similar conditions. This result is also consistent with previous findings from Serbia, where a 42-month recovery was observed. Therefore, this study not only provides valuable insight at the local level but also contributes to comparative analyses and future projections for rural regions with similar socio-spatial characteristics.

7. Conclusions and Policy Implications

This study provides two main findings. First, the Ikitepe case shows that LC projects can recover their costs in a short period. In this case, the public investment was paid back within about 41 months, which underlines the economic feasibility of LC as a rural development tool. Second, the project created a clear diversification in cropping patterns. Farmers were able to introduce new, higher-value products and as a result, agricultural income increased steadily. These two outcomes demonstrate that LC is not only a spatial planning instrument but also a driver of economic change in rural areas.

The Turkish experience also offers a distinctive contribution to the global debate on LC. Unlike many European cases where the focus is limited to property adjustment or environmental alignment, Türkiye shows that a state-financed LC program can combine cost recovery with crop diversification and social inclusiveness at the same time.

Another important outcome relates to spatial equity. After consolidation, all parcels gained equal access to roads and irrigation networks, reducing long-standing disparities between farmers. This improvement suggests that LC also contributes to fairness in land use, not only to efficiency.

At the same time, some challenges remain. In Türkiye, LC projects often take longer than planned due to technical, administrative, and budgetary reasons. Such delays may reduce the expected benefits and weaken trust in the process. Future programs therefore need more effective management and stricter time control.

Finally, the integration of LC with land banking is a promising direction. Ongoing DSİ-FAO pilot projects (2022–2025) provide an opportunity to enlarge farm sizes and to bring abandoned parcels back into production. Linking LC with such mechanisms can increase both the scale and sustainability of rural development.

In conclusion, the Ikitepe case demonstrates that LC can address fragmented land structures while also supporting crop diversification, economic returns, and spatial equity. Expanding similar analyses to other project areas will strengthen the evidence base and help design more effective and inclusive rural land policies in Türkiye.

Author Declarations

Authors' contributions: Orhan Ercan: Conceptualization, Design, Methodology, Data Collection, Spatial Analysis, Writing-Original, Draft & Review. Abdurahman Tursun: Cost Recovery Calculations, Crop Pattern Transition Analysis, Statistical Evaluation. Erdem Ercan: Legal Framework, Institutional Context, Review & Editing.

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