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Land Governance and Fragmentation Patterns of Agricultural Land Use in Southern Romania during 1990–2020

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Abstract: In Romania, excessive fragmentation of croplands remains persistent in areas of significant agricultural potential as a consequence of combined factors involving both land governance and farms' characteristics. This paper examines the fragmentation of agricultural land use in the Romanian Plain, focusing on the impact of land policies implemented in Romania during the past three decades. The analysis relies on a survey of local policies that helps to distinguish three phases that marked the evolution of the fragmentation of agricultural land during 1990–2020. Additionally, metrics derived from remote sensing time series further assist in capturing the fragmentation levels during the identified phases and the spatial differences for the analyzed period. The fragmentation levels appear strikingly contrasting between the western part of the Romanian Plain and the Danube alluvial areas; this has been attributed as being the joint result of various land governance components which both enabled and constrained proper utilization of agricultural land, and concurrent factors related to economic and sociodemographic changes. We find excessive fragmentation emerged in plain field areas, triggered by the high overall rates of institutional change. The findings underscore the importance of jointly considering the fragmentation phenomenon in its evolution, intensity and spatial differences for effective land use policy formulation, emphasizing the need for proactive governance to support the efficient use of agricultural resources.

Keywords: fragmentation of agricultural land use; land governance; remote sensing derived metrics; spatial differences; Romania

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1. Introduction

Land fragmentation has been a salient topic in both environmental conservation and agricultural development literature, showing its multifarious relationship to land governance [1–6]. One much debated aspect has concerned agricultural land fragmentation (ALF), in the sense of being a positive trait for biodiversity and conservation reasons, or as an impediment for higher crop productions [1,7,8]. Ntihinyurwa and de Vries have analyzed cases of agricultural fragmentation and consolidation processes, and their underlying causes, forms and implications for productivity, also highlighting the relevance of local contextual factors in decision making [9]. Their study has revealed alternative methods of land management in view of the conditions and linkages between different local factors under which cropland fragmentation should be preserved or revoked. Similarly, Ciaian

et al. have argued that land fragmentation might generate both positive and negative effects specific to each case considered [10]. While a more fragmented farmland is likely to enhance biodiversity, and thus the landscape value, more consolidated plots might reduce farmers' direct costs of working the land, and ultimately increases farmers' performance and income [10].

Referring only to the Central and Eastern European countries (CEECs), it is often stated that ALF is a direct consequence of land privatization processes during the transition period from a centralized system to a market economy [10–15]. During this process, consecutive land reforms were implemented, aiming to transfer the property rights from state and collective ownership to former owners or their heirs, and then to private individuals and/or agricultural holdings. In this setting, ALF occurred either in the form of physical division of the land use area, of the ownership rights, or both.

Changes in land use significantly influence the structure of agricultural land use, developmental patterns of farms and rural development. Many inquiries on land use changes discuss, for instance, the dynamics [16,17] and the causal drivers of change [18,19], jointly displaying a purposeful array of conceptual approaches and methodological tools [20–22]. However, such changes remain understudied in the context of ALF. This is also the case for ALF spatial patterns in large agricultural regions, and regarding what the appropriate forms of development for farms in particular are, and for the rural communities in general.

In the case of Romania, previous studies have articulated the need for transparent and national protective solutions, specifically with respect to land grabbing [13,23] and less to ALF. Studies on the topic of land fragmentation have usually addressed the local scales with methodologies including interviews and household and farm indicators analyses, with results that have allowed for generalization and national outlook for each case study [8,10,24]. Other researchers have focused exclusively on synthesis analyses on multiple cases facing ALF to conclude on countries' particularities and differences, governance limitations and/or developmental perspectives [9,11,25]. That is why researchers have called on specific contexts of ALF and land grabbing for designing integrative solutions [23,26].

We choose to investigate agricultural land fragmentation in southern Romania to showcase the effects of land governance in a socioeconomic context marked by a series of normative processes during the transitions toward a private system of the agricultural sector. The importance of our study develops from the dominance of numerous agricultural farms of very small and small size (88% of the country's total) at the European Union (EU) level. In 2020, Romania registered 2.5 million agricultural holdings, counting for more than 45% of small farms of under 5 ha in the EU [27]. The novelty of this study is the mix of a deep analysis of land policies to identify their impact on the ALF dynamics and the use of remote sensing images-derived metrics to map the dynamics and spatial differences of the ALF phenomenon in the study area. Against this background, we (i) characterize the role of land reforms during 1990–2020 on ALF in southern Romania, with an emphasis on spatial differences and magnitude of ALF expressed through remote sensing-derived metrics and maps, and (ii) recommend ways to improve land governance, considering the effects of past land reforms.

The paper advances with the specific context of Romania in relation to ALF and the particularities of other CEE countries concerning this topic. The next sections overview land regulations and standards which led to the three temporal phases related to the evolution of ALF. Further, the spatial patterns and magnitude of ALF are exemplified through fragmentation metrics derived from satellite images, using FRAGSTATS 4.2 software. Finally, we discuss our findings and their implications for land governance.

2. The Context of Agricultural Land Fragmentation

ALF encompasses two distinct perspectives: physical fragmentation of land use and ownership fragmentation. The first case considers the physical fragmentation of land use, as in situations where farms consist of numerous distinct plots scattered over wide areas, while in the latter case the agricultural land is subject to partible inheritance, being split

between many owners of small plots [2]. Fragmentation of land use covers indicators like the plot size, the shape of individual plots, the distance of plots from farm buildings, and distances between plots [8]. Ownership fragmentation is intrinsically related to land tenure aspects and refers to the particular packages of rights regulating who can benefit from land, as well as to land tenure security, which is the overall assurance that those rights will be upheld [10,28].

ALF vs. land consolidation remains a debated topic in rural economic development [29–33]. Most authors argue the need for integrated and sustainable rural development, which includes a land consolidation role and fragmentation alleviation to propel farms' development and crop productivity. On the same line, Sabates-Wheeler suggests that positive outcomes of land consolidation at the local level could inspire overall governance attempts of public agencies to reduce fragmentation [26]. Usually, views toward a coordinated governance and an adaptive future of common and efficient use of agricultural resources hold true for local sustainable development [34]. Moreover, research has illustrated contradictions between land reforms involving agricultural privatization in former socialist countries as a way of increasing rural entrepreneurship, and where ALF is considered an effect of it, and the impoverishment of farmers and escalations in subsistence agriculture [25]. It is particularly evident that in a capitalist system commercialization and commodification of land and agricultural goods strongly influence rural economies and have effects on local farms, their development trajectories, and patterns of land usage. In relatively uniform agroecological and market-oriented economic conditions, the consolidation or elimination of any fragmentation also improves farm efficiency and may boost agricultural productivity [9,12,35]. As such, fragmentation of land use does not always denote generic inefficiencies, but depends more on the socioeconomic context, legislative framework, and environmental conditions.

2.1. The Case of Romania in Relation to ALF

In Romania, the latest land reform was associated with the privatization of state-owned agricultural land and, essentially, involved the restitution of land ownership rights to the form they were in before communism, in 1947. The policies aimed for the integral return of lost properties to former owners and implemented a process of restitutio in integrum without sound studies on the determinants of viable and sustainable agriculture under private status, including the functions of agricultural lands as common goods. Plots were not always returned to the owners, but to their heirs, due to the time passed since the land had been confiscated. These heirs often lacked the know-how needed for performing agriculture. For instance, Grădinaru et al. considered that land abandonment was a precursor of urbanization, especially in the rural areas close to large cities [36]. Agricultural land was at first fragmented, and then some of the owners did not cultivate it.

Furthermore, due to other economic changes in this period, farmers' motivation was often the land itself. The return of land rights was received with enthusiasm among former owners, who considered the restitution as an appropriation and a source of capital.

Such dynamics led to a series of transformations of land uses and their structures, affecting crop productions, livestock and agricultural development. The infrastructure that previously served the agricultural systems became inappropriate for the new conditions of land exploitation due to the widespread division of landholdings and agricultural operations. The poor performance and lack of subsequent investments showed a discrepancy between formally recognized rights, landowner's expectations and dependencies related to their lands. Excessive fragmentation of agricultural land use was associated with the presence of numerous small (family) farms, of low, unstable incomes, weak economic performances, and with land management practices which were usually improper for sustainable agriculture. Against this background, ALF added to the challenges facing Romanian agriculture, such as droughts, land degradation and lack of major investments, or aging in and depopulation of rural areas.

2.2. The Case of Representative Central and Eastern European Countries in Relation to ALF

Changes in land ownership and the associated effects of ALF have been discussed in the literature as a common issue for the CEE space [6,11,25,26]. The extent of fragmentation phenomenon in agricultural areas, either from the point of view of ownership or land use, depended on specific conditions and legacies underlying the land reforms in each country. For instance, in Poland, agricultural land privatization remained an effect of land sales in auctions and the direct sale to eligible groups, but with a preference for the former owners [6,14]. Additionally, individual-level farming existed throughout communism in Poland, with about 76% of all agricultural land being under the management of private farms, which made the agricultural landscape diverse, especially in southern Poland. There, fragmentation was a secondary issue for agricultural production and land consolidation [14].

In Czechia and Slovakia all the agricultural land of communist cooperatives and state farms were subject to privatization, yet the ownership status for much of the land there remained under the management of associative structures like agricultural companies and holdings, or private farmers established according to commercial law [37,38]. In Slovakia, the fragmentation of land ownership has been a long, persistent challenge that led to problems in land use and development (difficulties in legal transactions of (agricultural) land, inadequate management, efforts to access subsidies, etc.), requiring sustainable solutions of land consolidation [39,40]. In Hungary, compensation represented the main measure of land reform. There, expropriated owners in the communist regime received compensation in the form of coupons, amounting to the value of lost property. The result was that land properties and nationalized assets could be traded on the basis of coupons [11,14]. Thus, Hungary decided on compensation instead of physical restitution, transforming the farm cooperatives and the state farms into private farms or entities. As a consequence, private owners held small farms of just a few hectares, while agricultural holdings managed several hundred hectares at least [14].

3. Methodology

In this paper, we documented the ALF phenomenon in the Romanian Plain during 1990–2020 based on land fund policies and strategies, and visually displayed its spatial patterns and magnitudes in four selected areas spread in representative locations over the analyzed area, utilizing remote sensing (RS) techniques. Specifically, the methodology relies on (a) qualitative analyses of laws and relevant policies, complemented with previous field work and discussions with farmers and local authorities (interviews), and (b) quantitative analyses of geospatial data. Figure 1 represents an outline of the combined methodology of the paper.

Policies, socioeconomic trends and cultural characteristics determine the patterns, structure and functionality of the agricultural land in a region, while parametrization and monitoring of land use inform about the intensity at which the land is being used. The latter aspect is approached by RS techniques, Earth observation data and geographic information systems, enabling contextualized outcomes and advancing the understanding of land use processes, including fragmentation.

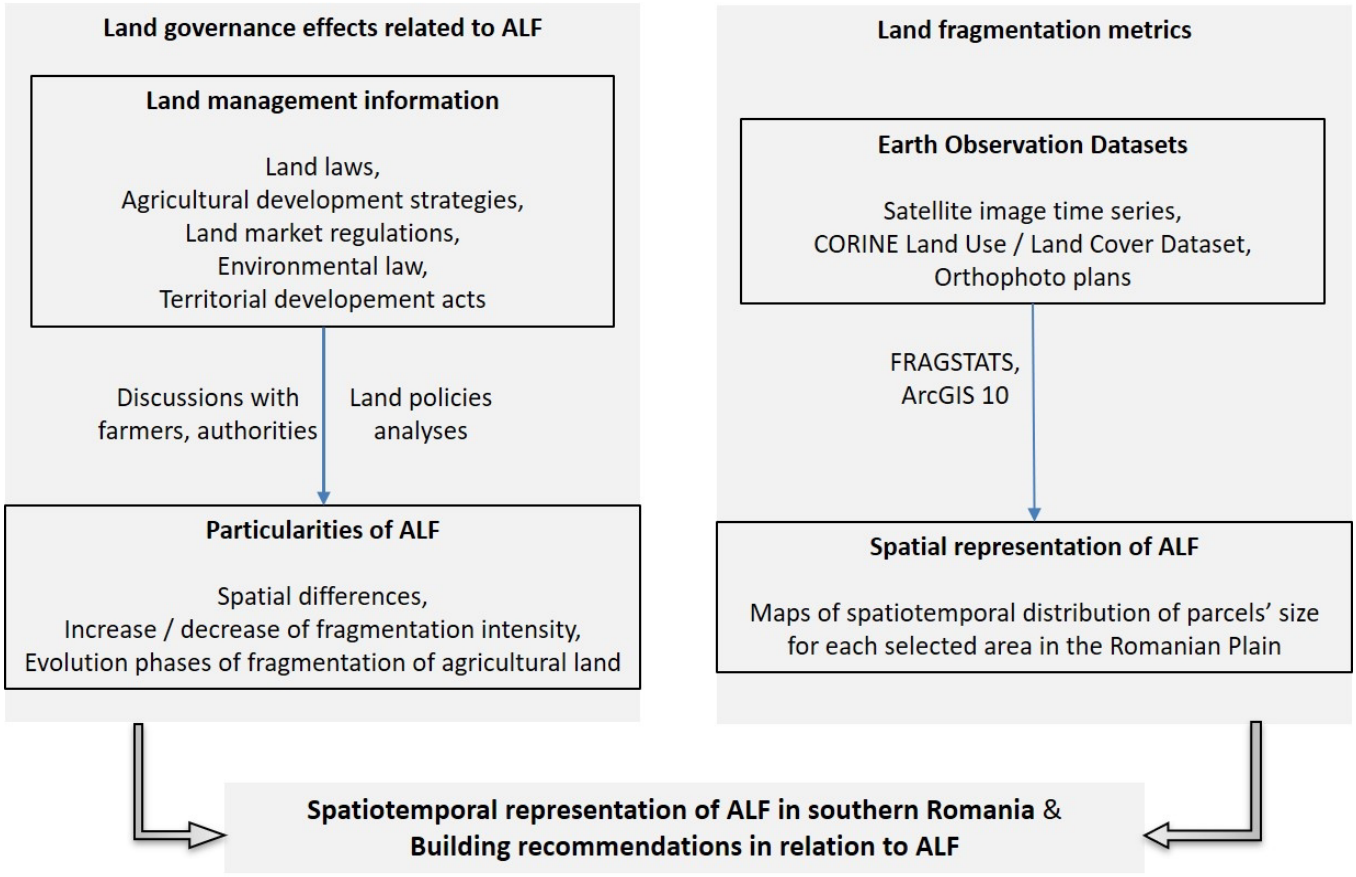


Figure 1. Outline of the study methodology.

3.1. Study Area

The Romanian Plain was chosen because it represents the largest agricultural region in Romania (south of Romania, 52,600 sq. km, 22% of the country's area), being of significant production potential, and of economic relevance. Although the landscape appears relatively homogeneous, the physical geographical diversity depends on different genetic types of plains, river floodplains and terrace distributions, climatic variations and influences from west to east and north to south, as well as by loess thickness differences throughout the area [41]. Particularly in the eastern part of the Romanian Plain, the agricultural landscape overlays geomorphologies of extended river terraces and tabular plains covered by thick loess layers. The landscape differs in the western part where the Danube River terraces are mainly covered by sand dunes. The entire region comprises nutrient-rich soils, i.e., chernozems, spread over the tabular plains and river terraces, and alluvial soils, which are formed over floodplain areas along the Danube and its major tributaries (Figure 2). Less fertile soils (i.e., sand soils) mark relatively large areas in the Oltenia Plain, the south-western part of the region. Together with other local characteristics, landscape varieties impose a need for specific farming practices.

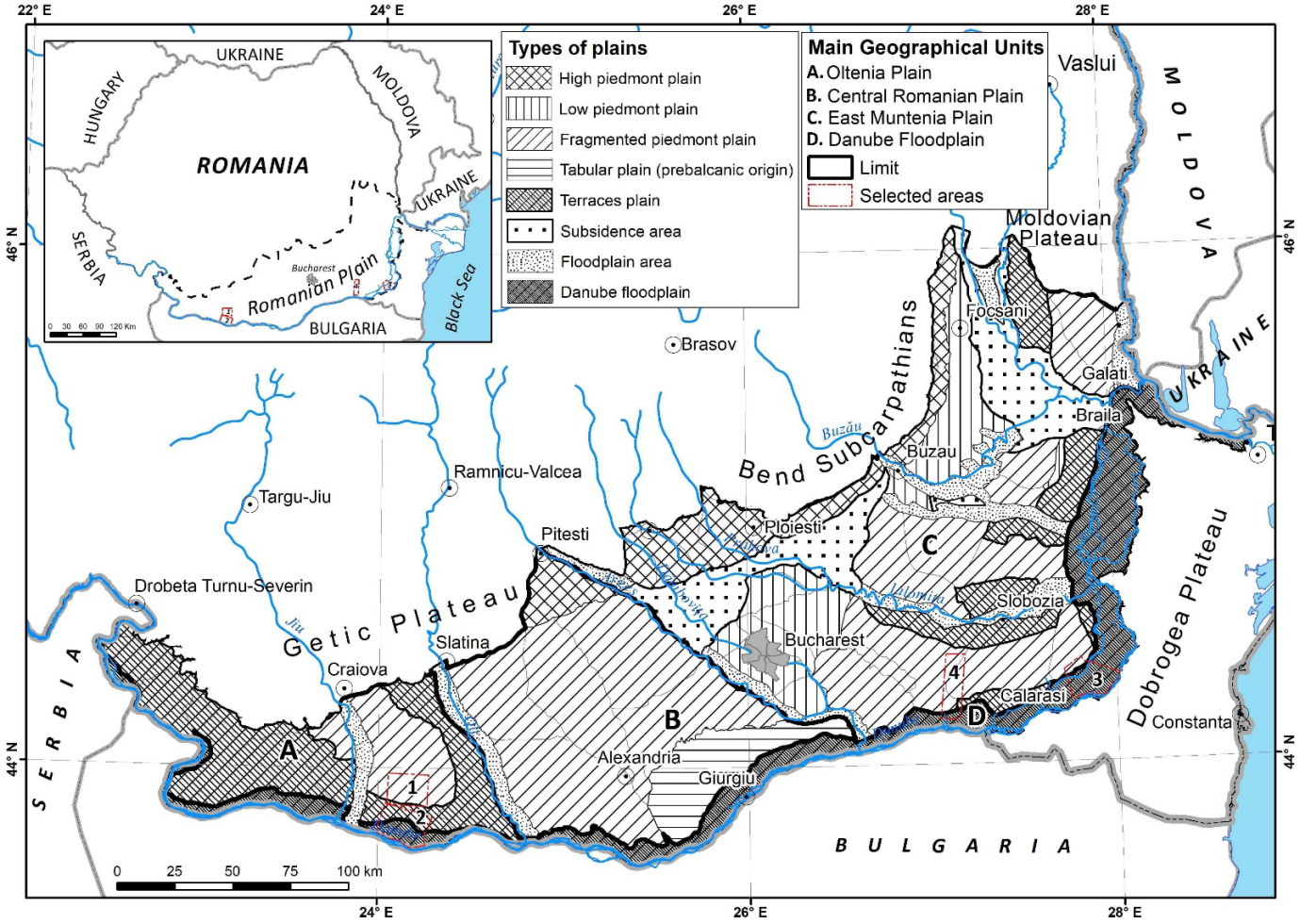


Figure 2. Romanian Plain and location of selected areas.

3.2. Legislative Acts Related to the Land Fund

Legislative acts and norms concerning land property rights, land markets, and institutional structures in agriculture formed the basis of the synthesis of agricultural land management and its impacts on land use patterns, demonstrating the complex character of the situations concerning land tenure as well as its heterogeneity from the 1990s until now. The Supplementary Materials of this paper include the consulted policies along with their characteristics, including prerequisites, conditions and implementation institutions in relation to land fragmentation. Such documentation allowed for the identification of distinct phases of agricultural fragmentation dynamics.

3.3. Selected Areas of Fragmentation

To represent the fragmentation phenomenon in the Romanian Plain, we selected four representative areas (Figure 3). They were chosen considering relief particularities, soil types, land use history, local farming practices, and their having surface areas sized about 23,000 ha each. Adding the fieldwork observations from 2018 and 2019 throughout the Romanian Plain [42], we chose the four representative agricultural areas comprising fields of chernozems (selected area 1 and 3), alluvial (selected area 2 and 4) and sand (parts of the 1 and 2 areas) soils, a variety of farm sizes and representative agricultural practices respective to each location.

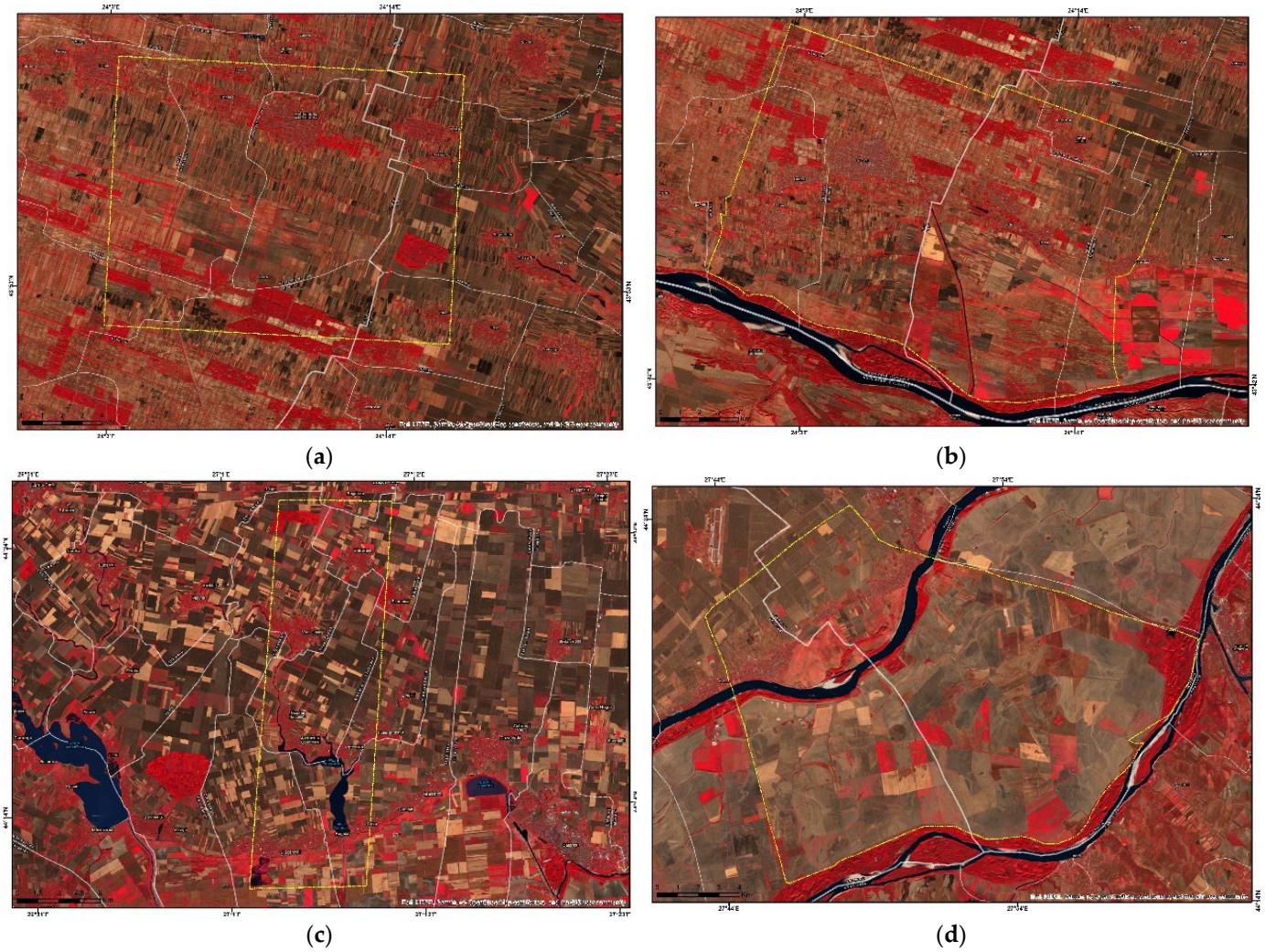


Figure 3. Sentinel-2 satellite images of selected areas. (**a**) Selected area 1: Oltenia Plain (western part of the Romanian Plain), close to Amărăștii de Jos locality, Dolj county. Source: COPERNICUS Sentinel Hub, Sentinel-2 L2A, (843), 16 October 2018; (**b**) Selected area 2: Danube floodplain, south of Dăbuleni locality, Dolj county. Source: COPERNICUS Sentinel Hub, Sentinel-2 L2A, (843), 16 October 2018; (**c**) Selected area 3: Bărăgan Plain (south-eastern part of the Romanian Plain), Călărași county. Source: COPERNICUS, Sentinel Hub, Sentinel 2, L2A, (843), 28 September 2018; (**d**) Selected area 4: Danube floodplain, Balta Ialomiței (wetland), close to Borcea locality, jud. Călărași. Sursa: COPERNICUS Sentinel Hub, Sentinel-2 L2A, fals color (843), 15 October 2018.

The dynamics and spatial patterns of fragmentation over the last 30 years were analyzed using FRAGSTATS metrics derived from satellite image time series for each selected area (Table 1). The FRAGSTATS 4.2 software offers the possibility to identify the patterns of a landscape structure helping to quantify the spatial heterogeneity of the landscape, revealing the landscape components and their spatial distribution [43,44]. In terms of satellite image time series, Landsat images for 1988, 2010 and 2018 were used (Table 1). This was configured according to the landmark conditions in the evolution of land use changes. The selection indicated a clear spectral representation of scenes, which were acquired at the beginning or end of the vegetation growing season, in order to allow for observation of the magnitude, pattern and directionality of change with regard to fragmentation. Our decision was built on the significance of three representative moments for the dynamics of political, economic, institutional and social spheres that lead to ample land use changes and pattern reconfigurations. Three key moments counted as turning points on the country's roadmap to political and socioeconomic development: the fall of the totalitarian regime

(December 1989), Romania's addition to the EU (2007), and the recent focus on agricultural services (the last few years).

Table 1. Satellite images used in the analysis.

Time Scale	Satellite Image	Acquisition Date	Resolution
Before 1990s	Landsat 5 TM	2 May 1988 (selected area 1 and 2) 11 October 1988 (selected area 3 and 4)	30 m
1990–2010	Landsat 8 OLI	22 October 2010 (selected area 1 and 2) 22 September 2010 (selected area 3 and 4)	30 m
2010–present	Landsat 8 OLI	30 October 2018 (selected area 1 and 2) 28 September 2018 (selected area 3 and 4)	30 m
	Sentinel 2B L 2A	16 October 2018 (selected area 1 and 2) 13 October 2018 (selected area 3 and 4)	10 m

3.4. Deriving Fragmentation Indices

The steps applied to derive the land use fragmentation metrics consisted of the following: (1) automatic vector extraction of the parcel limits from each satellite image; (2) land segmentation analysis using eCognition Developer software [45], applying the multiresolution segmentation algorithm in the case of Landsat imagery, and one algorithm of the Estimation Scale Parameter (ESP2) library of the software in the case of Sentinel-2 data; (3) saving the resulting limits of parcels as vector files and manually rectifying them using very high-resolution Google Earth imagery and, where possible, orthophotos. Because the selected areas included other categories of land usage than agricultural lands, such as built-up areas and shrubs, the remotely sensed-derived segments were overlaid with Corine Land Cover (CLC) datasets to extract the arable land category of land use. We used three temporal versions of CLC datasets, specifically 1990, 2012 and 2018, to relate them with the temporal series of the processed satellite images; (4) converting the final vector files of the segmentation process into raster files of 30 m spatial resolution using the ArcGIS software; (5) finally, importing the resulting raster files into FRAGSTATS and saving them with the automatic filename_id8.tif, corresponding to the identification file for raster segmentation. FRAGSTATS allowed the computation of fragmentation indices under .patch files. These last files were exported in .txt format and further joined with the corresponding filename_id8.tif raster using ArcGIS. Therefore, the fragmentation results could be spatially represented to reveal the distribution of agricultural patches.

4. Results

4.1. Legislative Regulations and Their Impact on ALF

Based on the documentation of land use policies over the last 30 years, we singled out three intervals of major changes concerning land property rights and agricultural land management (Table 2). The first period (1990–2000) describes the fast privatization process of the land fund, while the focus of the second period (2000–2010) is on land market particularities. The third interval (2010–present) emphasizes the regulations that strengthened the development of services in agriculture and their influence on land management.

Table 2. Overview of the legislative characteristics in relation to agricultural land.

1990s~2000 Period The Phase of Accelerated Privatization and of (Re)gaining Property Rights	2000~2010 Period The Phase of Institutional Arrangements and of the Dynamics of the Land Market	2010~Present The Phase of the Development of Services in Agriculture (Current Phase)
• Lands of the former communist cooperatives were restituted to the owners; • The owner rights were reconstructed; • Up to 10 ha/family were allocated (Law 18/1991). • The occurrence of a large number of small (family) farms; • Low degree of association among land owners; • Excessive fragmentation of the agricultural land, especially in plain areas; • Changes in the structure and surface area of croplands; • Poor agricultural skills, improper infrastructure and low production.	• Continuation of the privatization process and involving the entirety of land rights up to 50 ha/owner (Law 1/2000); • Privatization of commercial agricultural companies of and of agricultural infrastructure; • Legislative rectifications and changes in the structure of agricultural properties; • Little competition from small land-owners on the land market; • European subventions (particularly in favor of large commercial-oriented agricultural holdings)	• Stronger development of direct and connected services for agriculture; • Investments in large agricultural infrastructure, e.g., irrigation systems; • Increase in socio/demographic dynamics in the rural areas, such as in depopulation and ageing; • Law 175/2020 introducing new and powerful rules for the sale of agricultural lands, in favor of the consolidation of cultivated parcels; • New challenges in the context of the European Green Deal Pact, especially in what regards biodiversity and ecological agriculture.

4.1.1. The Period of Accelerated Land Privatization (1990–2000)

After 1990, property rights monopolized agriculture development. The reconstitution of land rights and the return of lands to former expropriated owners triggered a fast privatization process. The application of land law (i.e., Law 18/1991) had major effects on land structure, on the usual coordinates of people's lives, in the rural areas in particular, and the development of agriculture in general. The effects led to the creation of many small farms with low, unstable incomes and poor capital for proper and profitable land exploitation. In addition, the absence of financial instruments (e.g., credits to encourage and help the local farmers in agriculture) weakened the position of local investors on the land market, making it vulnerable in front of foreign investors [46].

The way land rights were reconstructed and returned contributed to the design of a land tenure system which was in many cases discriminatory, interpretable, or even unjust [47]. As the restitution was in principle in integrum, people who contributed lands of more than 10 ha could not receive beyond this limit according to the law. The reconstruction of the owners' land rights was ambiguous and delayed under a contentious atmosphere marked by acts of corruption by people enforced in administrations [47]. Also, the absence of a cadastral system made the process arduous, being that it was difficult to return plots on the same location as land properties' borders were erased and the agricultural landscape, including rural settlements, had changed. Furthermore, the recipients of agricultural land were new, physically challenged by age and unfamiliar with modern farming practices or the functioning of land and food markets in a capitalist economy, and were thus affected by the new situations of managing their lands [48].

Along with the weak enforcement of land laws and norms, this period included a lack of environmental protection and frequent cases of pollution of water resources due to agricultural practices. The general atmosphere was of environmental ignorance from both villagers and the local government [49].

All the above characteristics led to excessive fragmentation in many parts of the analyzed regions, negatively enhanced with extensive destruction and degradation of the agricultural infrastructure.

4.1.2. The Period of Dynamic Land Market (2000–2010)

The second decade (2000 to 2010) could be associated with two milestones in the evolution of land reforms in Romania. The first one, linked to Law 1/2000, aimed to improve and amend the legal norms for the reconstruction of agricultural/forest property rights claimed previously. The second milestone related to the preparation and adhesion of Romania to the EU, which meant compliance and coherence with the legislative acquis communautaire, including new norms for the land market. Accordingly, people could regain rights over larger areas, the restitution of land was conditioned by the existence of cadastral documentation, and compensations were granted. However, delays in clarifying the ownership rights inhibited the possibility to operate on land markets, hindering land consolidation [47].

Under the new status of EU member, Romania complied with the communitarian legal frameworks which included the possibility for foreign citizens and stateless persons to acquire private ownership of land. In this sense, the effect of Law 312/2005 was perceived as a land-grabbing phenomenon, being described as land acquisition or concession, i.e., leasing of agricultural land on long term by private or public entities, to multinational private or domestic companies or investors [13,25,50]. While the objectives of this law remained mixed in its character (from land consolidation, agricultural infrastructural development and biofuel production to speculative transactions), its concrete effect materialized into investments in agricultural lands whose returns were almost entirely externalized. A negative influence manifested on small farm holders due to increased concurrence and growth of market-oriented agriculture, which amplified the vulnerability of local agriculture to price shocks [51].

The environmental conditions, particularly fertile soils, and the permissive legislation in Romania attracted large-scale investments in farmland. An estimation showed that foreign investors managed up to 10% of the agricultural land [50]. Significant consequences emerged on the structure and configuration of agricultural lands, including on land concentration in certain areas. This was the case in large areas along the Danube floodplain, a well-favored and legally easily accessible region for such investments given the high agricultural potential and the historical administrative background (i.e., many of these lands were former state farms). These were, however, at the expense and to the disadvantage of the local (potential) investors who had weaker capacities for investments.

In parallel, excessive land fragmentation proliferated in many plain areas, such as in the western part of the Romanian Plain, and overlaid other social difficulties (particularly ageing, as well as a lack of workforce and of capital for infrastructural and technological development, etc.). Corroboratively, they formed a conscious impediment for profitable agricultural performance. In this context, Law no. 247/2005—which established the life annuity program in agriculture—attempted to tackle the problems of rural areas. For example, the law provided monetary incentives for landowners willing to alienate or lease lands for cultivation, within a limit of 10 hectares. The objective was to ensure a constant income for aged people, to restore a good level of the active population in agriculture, to increase the economic and physical size of exploitations and their orientation in the market, including among others' land consolidation, and considerable reduction in the production costs of farmers, as well as to concentrate agricultural areas in efficient farms. Owners often preferred to lease the land instead of alienating it, benefitting from state payment and leasing incomes while keeping ownership rights.

New programs and support schemes had also started to be framed and enabled during this period, allowing farmers the possibility to access the European and national funds for agricultural development and benefit from incentives to increase the economic viability and extension of their farms among others.

4.1.3. The Period of Agricultural Services Development (2010–Present)

The last decade (2010–present) centers around developments of services in agriculture, stronger legal previsions concerning land and agricultural commodity transactions on the

market and increased accessing of European and national funds for agricultural development. In this regard, Law 175/2020 enforced stronger preemption rights in the case of transactions of agricultural land (favoring firstly relatives, co-owners, neighbors or lessees, and then other categories including foreign citizens), and imposed firmer conditions in the case of reselling the lands before eight years since purchase had passed (i.e., supplementary taxes). In fact, this law received revisions and improvements at the request of the associations of local agricultural producers, who thus influenced enhancement of tenure security rights. This was particularly relevant as low land prices in Romania as compared with those in other EU member states led to new dynamics for transactions of agricultural lands, especially regarding the speculative nature of investments.

Such legislative changes attempted to encourage land exchange and transactions between local owners, increasing the opportunities for land consolidation. The local farmers, however, expressed mixed perspectives on land concentration, farm association and/or land exchange and transactions. Among local farmers and stakeholders, including mayors and consultants of regional development agencies, the consensus conveyed that high fragmentation impeded the performance of profitable agricultural productions, and the agricultural resources remained unexploited and/or were impacted by drought, land degradation, water stress, and confusion about property rights. Most holders of small farms confided that the process of land consolidation was not always straightforward due to insecure financial benefits and opportunities, although they commonly agreed on the advantages of managing large, spatially continuous fields instead of very small or small farms composed of fragmented plots [42]. Farmers often invoked poor quality of land or disadvantageous offers as major constraints in the land consolidation process. This situation was spatially different because in many parts land fragmentation remained high, like in the Oltenia Plain (selected area 1), while in others, like in the Bărăgan Plain (selected area 3), an upward trajectory of land consolidation formed.

The national or EU funds allocated during this period appeared to mainly support large, market-oriented cropping systems. Consequently, investments were directed toward acquisition and modernization of agricultural infrastructures, such as investments in irrigation systems and the purchasing of machineries that could serve and/or survey cultivated areas. In certain cases, such investments outclassed the potential of medium-sized farms to use the new infrastructure to its full capacity due to insufficient land capital.

Associated largely with subsidies and incentives from the state and the EU, the agricultural land market development in Romania had a particular relevance. This was determined not only by the role of land as a production factor, but also because of the improvement of land ownership and increases in farm size, which resulted in more competitive farming systems, and, partly, in reductions in ALF. With respect to land fragmentation, the National Plan for Rural Development of Romania (2014–2020) prioritized concentration of land as a countermeasure to excessive division of agricultural lands under norms and measure of support, e.g., the sub-measure 6.5 "Scheme for small farmers" [52].

Overall, the legislative frameworks bore resemblance to trial-and-error situations in an effort to respond to societal expectations concerning the use of their rights on land resources and also to allocate resource-related benefits to support different public and private interests. The land reform-related disruptions were expressed through new structures of land ownership, incoherencies among policies' objectives, as well as sharp changes in the natural environment [46,49].

4.2. Representation of ALF Dynamics in the Romanian Plain

The magnitude of ALF in southern Romania was suggestively rendered through several FRAGSTATS metrics: (1) the average size of patches, which measures the subdivision of a sample area, (2) the edge density, which standardizes the perimeter of patches to a per-unit area basis facilitating comparisons among landscapes of varying size, and (3) the number of patches, which reflects the magnitude of fragmentation. These reveal the degree of land use fragmentation within one category of land use (i.e., arable areas). It is important

to mention that the resulting FRAGSTATS metrics reflect the boundaries of use managed by different landowners and not the boundaries of plots of individual farms. Although this is a methodological shortcoming which could be solved with finer resolution data and analysis of additional information, the derived FRAGSTATS metrics could display the changes among the three time points, reasonably indicating the intensity of ALF throughout the Romanian Plain.

Figure 4 indicates significant transformation in land fragmentation indexes over the past three decades. From 1988 to 2010, a high increase in the number of patches (about 1000) and a sharp decrease in their mean size (about 60–70 percent) were found for terraces or field plain areas (areas 1 and 3). This corresponds to an intense fragmentation process in these areas. Considerable difference in area configuration between the fields of the Romanian Plain and the agricultural areas of the Danube alluvial plain is suggested by the edge density metric for the first interval of the analyzed period. For the former (selected areas 1 and 3), fragmentation is made evident by sharply increased values of edge density, whereas the floodplain areas (selected area 2 and 4) remain relative stabile in this respect. Actually, in the floodplain areas, specifically in the case of area 4, the number of patches increases by about 200, while the patches size decreases from 2 to 5 percent between 1988 and 2010, reflecting that the agricultural areas of the Danube alluvial plain maintained a consistent pattern over time. For the last years, from 2010 to 2018, a slight enlargement in the mean patch size (6 to 14 percent) alongside a contraction in the patch number (about 100 patches) is observed in the field plain areas, suggesting a trend towards consolidation. For the same interval, the fragmentation metrics for the Danube floodplain areas (selected areas 2 and 4) remain relatively stable, indicating minimal changes for these areas.

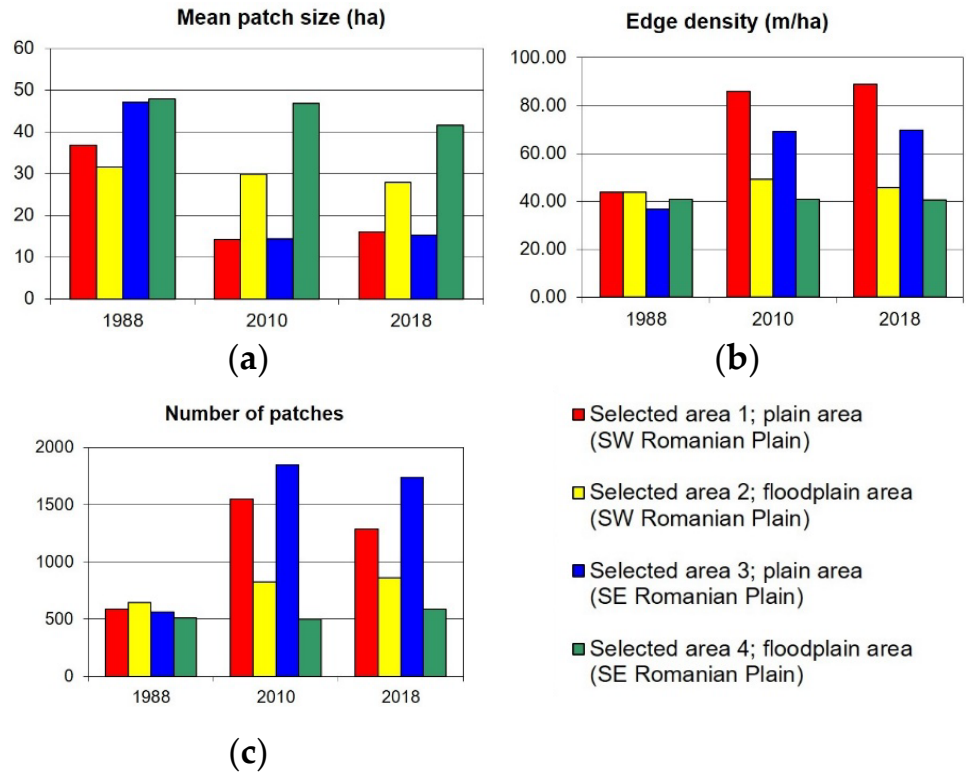


Figure 4. Temporal comparison of land fragmentation indexes derived from satellite image time series for each selected area in the agricultural region of southern Romania. (**a**) Mean patch size, (**b**) edge density and (**c**) number of patches for field plain areas (selected areas 1 and 3) and floodplain areas (selected areas 2 and 4) over the 1990–2020 period, rendered here through three representative time moments, 1988, 2010 and 2018, respectively.

Figure 5 suggests the spatial patterns of fragmentation of arable lands between the field plain areas and the Danube alluvial fields over the last 30 years. It renders that excessive fragmentation characterizes agricultural areas located in the field plain areas and on the terraces of the Danube River (or its main tributaries), and is less present in the lowest alluvial areas of Danube floodplain. Specifically, restituted lands in the plain areas were subject to intense division, while the vast majority of agricultural lands in the Danube floodplain remained consolidated under privatized farm associations. Therefore, fragmentation was particularly intense during the initial decades from 1988 to 2010 in selected areas 1 and 3, while over the past decade, from 2010 to 2018, the pattern of fragmentation has remained consistent throughout the study area. The agricultural lands in the Danube alluvial plain (selected areas 2 and 4) have been little affected by the fragmentation phenomenon over the entire analyzed time interval (Figure 5).

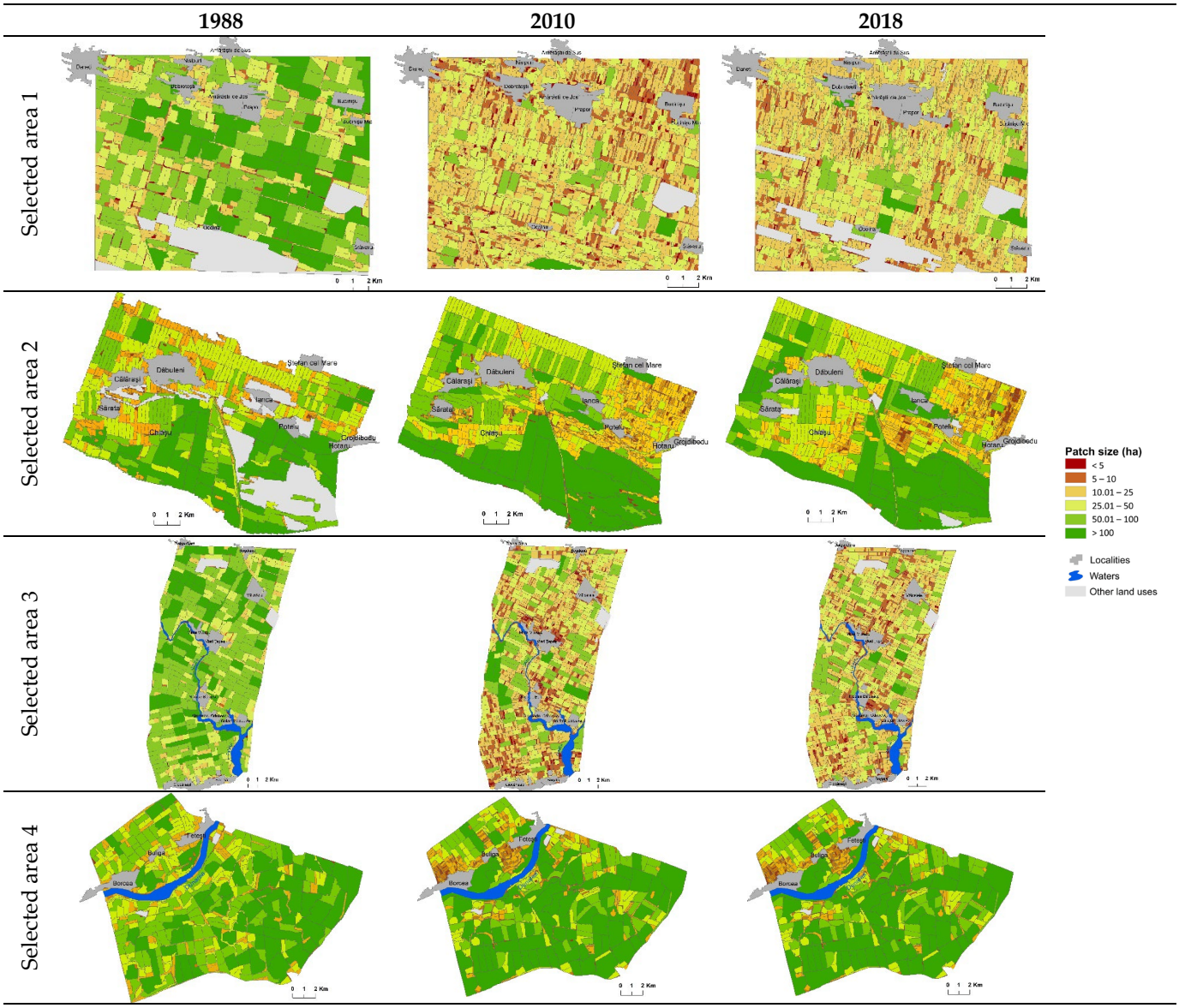


Figure 5. Spatiotemporal dynamics and patterns of ALF in the Romanian Plain (1988–2018), exemplified in the south-western part of the Romanian Plain (the Oltenia Plain—selected area 1), in the south-eastern part of the Romanian Plain (the Bărăgan Plain—selected area 3), and in the Danube floodplain (selected areas 2 and 4).

It is worth mentioning that the agricultural lands located in the Danube alluvial plain resulted from hydro-technical infrastructural works that aimed to convert the floodplain area into agricultural lands during the 1960s–1980s. Even after the first land fund ownership law, many such lands remain the property of associations and agricultural companies (some of them of foreign capital), keeping, thus, relatively large parcel sizes. Another situation relates to the controversies between former owners claiming their ownership rights to such lands and the local commission designated to conduct the restitution process. In such cases land degradation could be avoided, as the private ownership reconstitution was made on locations situated at the edge of former state farms and not on the old locations, as stipulated by the legal provisions [47].

Opposed to floodplain areas, excessive fragmentation of agricultural lands is present in the plain fields (area 1 of Figure 3), across landscapes with varying soil qualities and accessibility. Such lands follow a series of causal factors, many of them interdependent. They relate to both land use and ownership fragmentation, being a consequence of multiple legislative changes and amendments, including confusion and conflicts related to property restitution. Other indirect factors (complex socioeconomic conditions facing the rural space, including ageing, intensive migration, and poor economic prospects) are closely related to the persistence of the general modes of land resource management [42,53].

5. Discussion

5.1. Towards Sustainable Land Governance

Influenced by the multitude of legislative and institutional transformations in what regards land management over the last 30 years, our approach has suggested that the enabled land reforms have had an impact on the dynamics and patterns of agricultural land fragmentation. To support this, we have offered evidence drawn from land governance strategies, laws and plans, and graphically exemplified the magnitude and patterns of ALF thorough metrics of fragmentation derived from satellite image time series in four selected areas, representative of the Romanian Plain (southern Romania).

Fragmentation can be problematic for relatively homogeneous regions from the point of view of agro-ecological conditions that present diverse economic development prospects. Such regions require measures to consolidate land for the purpose of improving the efficiency of farms, productions and supply and distribution services, as well as food security. This is also the case in the southern agricultural area of Romania, where sustainable economic agriculture is favored, and the benefits of consolidating the land may outweigh the costs of maintaining fragmentation. In this case, the agricultural sector gains the advantage of favorable conditions for high productivity and for reaching sustainability and resilience goals through the good allocation of crops to the most suitable land, thus maximizing the farmers' profits in accordance with the concept of intensive sustainable agriculture [54].

Fragmentation throughout the Romanian Plain persists also as a farmer's option. It has been the case in selected areas we focused on that owners are economically doubly engaged and rely also on activities in the public sector or industry. Many prefer to get the subvention per arable hectare for cultivating the lands and not to associate or exchange lands in order to support land consolidation. Such results are in line with outcomes of other studies with a focus on farm economic viability and development in Europe [28,55]. Nevertheless, some legislative aspects can reduce the economic functionality of farms, particularly of those small- and medium-sized. For example, multiple legislative changes cause diffusion in their objectives as norms and laws relate to different periods [46].

Land policy reform in Romania also showed insufficient sectoral integration, especially with the water and food sectors. The efforts related to national land policy should concentrate on higher integration of the regional context within the broader European context of agricultural land policy, since south Romania and the Panonian Plain in Hungary show high agricultural potentials. It is important to recognize that there are globalized impacts and dependencies which inevitably influence the land market, farmers' behaviors and production in Romania, especially in the context of climate change adaptation

strategies and future demands for agricultural production. Consequently, improvements of the efficiency of land resource use imply structural governance features being in place. Protection and definition of resource-related rights, management of resources across sectors, continued cooperation and diverse forms of support, recognition of the importance of scales of appropriate governance reforms, and more inclusive participatory processes at the local community level are elements of better governance for resource efficiency [34,56]. For example, land consolidation based exclusively on voluntary agreements between owners and/or leasers is another governance mode that could induce sustainable situations of land governance in areas affected by excessive fragmentation such as the western part of the Romanian Plain (selected area 1). This resembles Haldrup's results, where local knowledge and mediation eventually lead to strengthening the legislation in land management and the coping capacity in civil society [57].

Recent European and national policies have increasingly focused on cross-cutting issues, including biodiversity, rural poverty reduction, climate change mitigation and adaptation, the water–food–energy nexus or green economies, aiming at new governance tactics that target circular economy aspects (e.g., Farm to Fork), resilience and sustainability in the rural space. For such an integrative perspective, the capacity preconditions and requirements are essential. In this regard, it is necessary to clarify confusions in land ownership, to complete land registration and secure funding for land consolidation. Simultaneously, increasing awareness, information and knowledge among farmers and connected users assist regions affected by agricultural fragmentation. As such, land policies and strategies call for the enclosing of elements of social capital development by increasing peoples' trust in state institutions. The expected results include a reduction in the vulnerability of small and medium sized farms located in areas where excessive land fragmentation exists and persists, as is the case in regions with low development prospectives, affected by depopulation and poverty.

Future plans should focus on enhancement of biodiversity and green economy frameworks. The European Green Act and the Farm-to-Fork Strategy could strengthen biodiversity, adaptation to climate change and the support of farmers, along with encouraging increased competitiveness within the agriculture sector. From this perspective, support towards sustainable intensive agriculture might be an alternative to adaptation and agricultural resilience, including the potential to increase the consolidation of agricultural fields in highly productive areas, as with those in the Romanian Plain. Hence, local political actors need to act towards a common future of sustainable development. This is particularly obvious, as our analysis provides a comprehensive characterization of the impacts of governance on local farmers' communities and highlights specific areas experiencing greater pressure.

Since there is a connection between ALF and land abandonment, the main recommendation starts from a study looking at the land cover and use changes which occurred in Romania during the first 15 years of post-communist transition [58]. Its findings indicated the presence of coupled antagonistic transitional dynamics, such as the abandonment vs. development of agriculture, deforestation vs. afforestation or reforestation, etc. As each antagonistic dynamic occurred over a different area than its counterpart, the study suggested that this situation was due to the lack of land use policies, and that a controlled and planned development would force the development of agriculture first in the abandoned areas, instead of allowing the transformation of natural land into agricultural land. The same policies would be able to curb the fragmentation.

More recent studies [59] found a decline in land abandonment. Provided the above association between the two phenomena, this validates our results concerning a revival of agriculture and land consolidation over the last years. Essentially, property restoration came in Romania without any obligations. This should be repaired by consistent land use policies, which may be favored by the European target of No Net Land Take [60].

5.2. Strengths and Limitations of the Analysis and Directions for Future Research

This study fills in an important research gap from two perspectives. The first is geographical; there are very few studies in CEECs carried out at a regional level. Most of the existing studies use questionnaire and interview data to generalize their findings at a national level. From this perspective, it is also important to stress that our findings were able to pinpoint differences between local data and the regional situation. The current study addresses the intermediate regional level. The second perspective is methodological. Our study also uses geospatial data, corroborating spatial analyses with information obtained through other approaches.

Limitations emerge from data availability, the resolution of the data and the ownership attributes. To render the dynamic of the ALF phenomenon and its spatial patterns in the region, the number and size of parcels of arable land from three representative time points were considered to be the most appropriate fragmentation parameters. This approach applies only for the boundaries drawn between ways of using the land, regardless of the ownership of plots and specific cultivation use by owners.

The quantitative part of our study on the ALF phenomenon does not reflect the problem of ownership fragmentation or land use fragmentation because the many smaller adjacent agricultural fields might be used by one individual or many owners. Instead, it delivers a clear idea of the dynamics of the fragmentation phenomenon in the Romanian Plain during 1990–2020 and of the spatial differences among the ALF patterns in cultivated fields in plain areas vs. the cultivated fields in Danube floodplain areas. It shows the excessive fragmentation level in plain areas and the fact that floodplain areas are relatively well consolidated. The simplification of the quantitative analysis is justified by the limited availability of farms' data. The remote sensing time series data have a resolution of 30 m, the reason for which is that the identification of compact areas with a uniform use does not show the problem of fragmentation of ownership or land use of many smaller adjacent agricultural fields in a given year. To know such an answer, data from the farm register and/or cadastral data including ownership data, data from the agricultural production subsidy system and similar observations would be necessary. However, such detailed studies remain scarce and need more consideration given their relevance for land management. In this line, Janus and Ertunc managed to reflect the relevance of cadaster data in determining agricultural fragmentation metrics and their usefulness in land consolidation options by employing a comparative analysis of land fragmentation parameters between Turkey and Germany, using villages as a unit of analysis [61].

One potential direction of future research would be to improve the correlation of findings derived from data obtained from different sources. Further studies may benefit from linking ever-increasing satellite information with cadastral data in order to better understand the fragmentation. In more detail, what shows as a continuous land use in land cover data, such as CORINE or satellite imagery, needs to be correlated with ownership data for better predictions, because different owners may decide to change the use of their land. Also, policies and research should focus their attention not only on agricultural productivity and abundance, but they should emphasize the role of social capital in the sense of improving intersectoral cooperation and people's trust in state institutions. Thus, future studies may combine the information derived from geospatial data and policies with on-site data from questionnaires and interviews. Such an approach will allow leveraging of policies aimed at reducing small farms' vulnerabilities in contexts where land fragmentation exists and persists, especially in regions with higher levels of tenure insecurity, depopulation and poverty.

6. Conclusions

This paper has added insight into the evolution of the ALF phenomenon during 1990–2020 and its spatial patterns in the Romanian Plain with the help of policies analyses and spatiotemporal remote sensing-derived metrics. The main consequences of the fragmentation of agricultural land in southern Romania involve low production levels,

weak farm management and low investment capacity, particularly in the field areas where excessive fragmentation still exists (e.g., selected area 1). It should be noted that the general socioeconomic problems in rural areas amplify the difficult situations involved in land use management. Large migrations of inhabitants from rural areas, aging, and lack of labor and development prospects affect small- and medium-sized farms that commonly face the problem of fragmentation. Also, fragmented agricultural lands are susceptible to drought severities, increasing their vulnerability. This happens because of the reduced capacity of farmers to ensure appropriate management, both from the point of view of structural measures (installation of efficient irrigation systems) and non-structural measures (adequate knowledge of risks involving extreme events, alternative measures and adaptation technologies). Moreover, sustainable adaptation measures and risk management strategies are even more necessary in areas affected by fragmentation in view of the intensification of dry episodes in the future, including in the southern part of Romania.

The magnitude of ALF was high throughout the Romanian Plain, while in the Danube alluvial plain this phenomenon had low values. This latter aspect could be tightly connected to the legacy of such lands that remained consolidated as parts of the big state enterprises during communism, and after the political changes, of large private enterprises either of foreign or domestic nature. In many cases, large agricultural areas were conceded over a long period of time or leased to businesses, often capitalized by foreign investors and/or by politically powerful actors, being used as agribusiness whose profits were entirely externalized. In these areas, consolidation persisted for almost the entire analyzed period.

The difference shown between the plain and floodplain fields of the region clearly singles out distinct features of spatial organization, natural resources, economic coordinates and environmental characteristics. Our study reveals that the existing regional pathways of agricultural land use are the combined result of land governance components that enabled in some cases, but also constrained sustainable utilization of agricultural land.

Under such conditions, if fragmentation of agricultural land use remains high or similar to the images in selected areas 1 and 3, the quality of land could be further affected, and, subsequently, the farmers' capacity for development. The increasing effects of climate change and new developments add to the complexity of the local situation, requiring the need to prevent land degradation, also caused by fragmentation, and follow policies orientated to support a common approach to agricultural land use. Common scaled governance is also needed, as until now various governance instruments linked to market liberalization have weakly influenced a stable spatial distribution of croplands in terms of land use structure and farms' development.

The impacts of fragmentation on small- and medium-size farms need reconsideration. This is particularly necessary when accessing investment funds which ultimately need to be designed according to the physical particularities and farms' capital, and future plans of extension. By underlying the main impacts of governance on the management of agricultural lands, this study points out the importance of effective policy aimed at reducing fragmentation in areas suitable for sustainable intensive agriculture, and implicitly the vulnerability of rural communities facing the new challenges of future climate conditions and development goals.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/land13071084/s1, Table S1: Land fund related regulations.

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