Estudos em Ciências Exatas e da Terra

Desafios, Avanços e Possibilidades

Alireza Mohebi Ashtiani
(organizador)

VOL III

EDITORA ARTEMIS
2025

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Editora Chefe	Profª Drª Antonella Carvalho de Oliveira
Editora Executiva	M.ª Viviane Carvalho Mocellin
Direção de Arte	M.ª Bruna Bejarano
Diagramação	Elisangela Abreu
Organizador	Prof. Dr. Alireza Mohebi Ashtiani
Imagem da Capa	Abstract Style Landscapes /123RF
Bibliotecário	Maurício Amormino Júnior – CRB6/2422

Editora Artemis
Curitiba-PR Brasil
www.editoraartemis.com.br
e-mail:publicar@editoraartemis.com.br

Editora Artemis
Curitiba-PR Brasil
www.editoraartemis.com.br
e-mail:publicar@editoraartemis.com.br

Dados Internacionais de Catalogação na Publicação (CIP)
(eDOC BRASIL, Belo Horizonte/MG)

E82 Estudos em Ciências Exatas e da Terra: Desafios, Avanços e Possibilidades III / Organizador Alireza Mohebi Ashtiani. – Curitiba, PR: Artemis, 2025.

Formato: PDF
Requisitos de sistema: Adobe Acrobat Reader
Modo de acesso: World Wide Web
Inclui bibliografia
Edição bilíngue
ISBN 978-65-81701-75-8
DOI 10.37572/EdArt_101225758

1. Ciências exatas e da terra – Pesquisa – Brasil. I. Ashtiani, Alireza Mohebi.

CDD 509

Elaborado por Maurício Amormino Júnior – CRB6/2422

EDITORA ARTEMIS
2025

Editora Artemis
Curitiba-PR Brasil
www.editoraartemis.com.br
e-mail:publicar@editoraartemis.com.br

PRÓLOGO

O volume III de **Estudos em Ciências Exatas e da Terra: Desafios, Avanços e Possibilidades** reúne um conjunto plural de pesquisas que refletem a vitalidade, a complexidade e o caráter interdisciplinar das ciências contemporâneas. Os dez capítulos aqui apresentados, provenientes de diversos países e contextos institucionais, oferecem um panorama abrangente dos desafios científicos atuais e das soluções inovadoras que emergem do diálogo entre matemática, física, química, engenharia, geociências, sustentabilidade ambiental e desenvolvimento territorial, reafirmando a amplitude teórica e aplicada dessas áreas.

Para favorecer a leitura e destacar as afinidades conceituais entre os temas, a obra foi organizada em três eixos temáticos que evidenciam os diferentes modos pelos quais o conhecimento científico se articula com problemas reais e necessidades sociais urgentes, propondo uma aproximação integradora e contemporânea das Ciências Exatas e da Terra.

1. Modelagem Matemática, Simulação, Processos Físicos e Engenharia Aplicada

O primeiro eixo reúne estudos orientados pela lógica da modelagem, da caracterização de materiais e da investigação de sistemas físico-químicos complexos. Aqui, a matemática desempenha um papel central, seja na descrição do crescimento populacional, na interpretação de curvas de relações molares ou na análise termoestrutural de concretos refratários usados na indústria siderúrgica. A ênfase comum está na busca por métodos rigorosos de análise, na construção de modelos interpretativos e na compreensão dos comportamentos materiais sob diferentes condições. Esses capítulos mostram como a formulação matemática e a experimentação se complementam, de forma decisiva, na explicação de fenômenos fundamentais para a ciência e a engenharia, evidenciando a potência dos métodos quantitativos na resolução de problemas complexos.

2. Sustentabilidade, Meio Ambiente, Tecnologias de Remediação e Ecodesign

O segundo eixo destaca pesquisas alinhadas aos desafios ambientais contemporâneos, trazendo propostas inovadoras para o desenvolvimento de tecnologias limpas, novos materiais sustentáveis e soluções de remediação ecológica. Os capítulos abordam desde práticas de ecodesign em produtos plásticos, passando pela criação de adsorventes de origem agroindustrial, até aplicações de biomassa vegetal para remoção de contaminantes e estratégias que ampliam o desempenho energético de sistemas fotovoltaicos, articulando ciência de materiais e preocupações ambientais. O núcleo

unificador deste eixo é o compromisso com a sustentabilidade, com a valorização de resíduos, com a mitigação de impactos ambientais e com a promoção de alternativas tecnológicas responsáveis e acessíveis que dialogam diretamente com demandas sociais emergentes.

3. Território, Geociências e Desenvolvimento Agrário-Industrial

O terceiro eixo aborda temas relacionados à organização do espaço, à história das indústrias de base e às dinâmicas socioeconômicas ligadas ao uso da terra. Os capítulos discutem a trajetória de figuras marcantes das geociências, analisam políticas e práticas de consolidação fundiária em escala nacional e refletem sobre as transformações industriais que moldam setores-chave como o agrícola e o petrolífero. Ao articular perspectivas históricas, econômicas e territoriais, este eixo evidencia como as ciências exatas e da terra também se expressam na compreensão dos processos sociais e produtivos que estruturam países e regiões, demonstrando que a pesquisa científica contribui igualmente para interpretações críticas sobre o desenvolvimento nacional.

A estrutura temática proposta pretende, portanto, facilitar a leitura e realçar o alcance multidisciplinar das pesquisas reunidas. Cada eixo demonstra, a seu modo, como o rigor científico pode contribuir para o entendimento de problemas concretos e para o desenvolvimento de soluções inovadoras, sejam elas de caráter teórico, tecnológico ou socioambiental, reforçando o papel estratégico da ciência na construção de futuros possíveis.

Esperamos que esta obra inspire pesquisadores, estudantes e profissionais a aprofundar o diálogo entre diferentes áreas do conhecimento e a reconhecer, na diversidade temática aqui apresentada, novas possibilidades de investigação e ação.

Desejo a todos uma excelente leitura!

Alireza Mohebi Ashtiani

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https://doi.org/10.37572/EdArt_1012257581

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DEVELOPMENT OF AGRICULTURAL LAND CONSOLIDATION IN RUSSIA ON THE PLATFORM OF LAND MARKET

Data de submissão: 03/11/2025
Data de aceite: 28/11/2025

Alexander Sagaydak
State University of Land Use Planning
Professor, Director of Department of Agricultural Economics and Farm Management
Moscow, Russia
https://orcid.org/0000-0002-6316-6134

Anna Sagaydak
State University of Land Use Planning
Professor of Department of Agricultural Economics and Farm Management
Moscow, Russia
https://orcid.org/0000-0003-4389-8570

ABSTRACT: Addressing global hunger is directly linked to the need to increase food production in individual countries. Unfortunately, the potential for agricultural growth in most of them has long been exhausted. In this regard, Russia has unique opportunities, as its agricultural land is virtually unlimited. Therefore, increasing the efficiency of the agricultural sector through land consolidation is particularly urgent. However, this process is currently being implemented haphazardly, often in violation of the rights of smallholders, which contradicts the fundamental principles of private property and a market economy. In this context, developing a land market and regulating agricultural production based on land rent determinism is crucial.
KEYWORDS: agricultural land; land rent determinism; agricultural land consolidation; agricultural land market; Oryol region; Russia.

DESENVOLVIMENTO DA CONSOLIDAÇÃO DE TERRAS AGRÍCOLAS NA RÚSSIA NA PLATAFORMA DO MERCADO DE TERRAS

RESUMO: Combater a fome global está diretamente ligado à necessidade de aumentar a produção de alimentos em cada país. Infelizmente, o potencial de crescimento agrícola na maioria deles já se esgotou há muito tempo. Nesse sentido, a Rússia possui oportunidades únicas, visto que suas terras agrícolas são praticamente ilimitadas. Portanto, aumentar a eficiência do setor agrícola por meio da consolidação fundiária é particularmente urgente. Contudo, esse processo está sendo implementado de forma desordenada, frequentemente violando os direitos dos pequenos agricultores, o que contradiz os princípios fundamentais da propriedade privada e da economia de mercado. Nesse contexto, o desenvolvimento de um mercado de terras e a regulação da produção agrícola com base no determinismo da renda da terra fundiária são cruciais.

PALAVRAS-CHAVE: terras agrícolas; determinismo da renda da terra; consolidação de terras agrícolas; mercado de terras agrícolas; região de Oryol; Rússia.

1. INTRODUCTION

Agricultural land consolidation is a merging, enlargement, eliminating of mosaic land ownership and improvement of configuration, as well as optimization of the size of land plots in order to increase the efficiency of agricultural production via rational use of scarce resources: land, labor, and capital based on reduction of transaction costs.

The specific objectives of agricultural land consolidation are the following: increasing the efficiency of agricultural production; providing sustainable development of the agrarian sector; rational use of land, labor, and capital in agriculture; optimization of agricultural production structures both in territorial and production aspects; increasing the competitiveness of agricultural producers in domestic, as well as foreign markets; environmental protection; development of production, as well as social infrastructure in agriculture. The main functions of agricultural land consolidation are the following: elimination of hunger and poverty, as well as reducing the gap in living conditions and incomes between urban and rural areas.

Agricultural land consolidation should be carried out based on the following principles: voluntariness; openness and transparency; financial and economic feasibility; considering the interests of the population groups involved, including women and youth, as well as indigenous people; step by step implementation; consideration of local conditions; state and NGO support.

In theory, agricultural land consolidation can be carried out as voluntary land consolidation and compulsory land consolidation. Both administrative and economic methods, for example, the development of the agricultural land market could be used for agricultural land consolidation. In our opinion, preference should be given to voluntary land consolidation. In that sense, the development of the agricultural land market is very important for the stimulation of agricultural land consolidation.

Agricultural land consolidation is a complex socio-economic phenomenon, which includes technical, institutional, financial, economic, environmental and social aspects, reflecting the methodology of project analysis in agriculture.

Due to it, the formulation of the main idea of the project on the consolidation of agricultural land involves the development of a methodology of implementation and evaluation of the projects on agricultural land consolidation, as well as carrying out summarize, scrutinize and analyze the domestic and international experience of agricultural land consolidation.

In this regard, the super goal of agricultural land consolidation projects is to implement and develop agricultural land consolidation in order to increase the efficiency of agricultural production to eliminate hunger and food shortages, as well as poverty due to the rapidly growing world population.

The technical aspect of agricultural land consolidation projects is the implementation of land use planning activities focused on the elimination of mosaic land ownership, improvement of configuration, and optimization of the size of land plots, as well as the development of the road network and production infrastructure in a rural area in order to increase the efficiency of agricultural production.

The institutional aspect of agricultural land consolidation projects involves the selection of a legal entity interested in the implementation of land consolidation projects in agriculture based on the criteria of financial and economic efficiency. The beneficiary may be private farms, agricultural holdings, as well as other legal entities.

The financial aspect of agricultural land consolidation projects is to determine the financial efficiency of land consolidation for legal entities directly involved in its implementation. It should be noted that with increasing the size of land plots used for agricultural production, the efficiency of farming is increasing due to the relative reduction of transaction costs per unit of land area. The maximum efficiency of agricultural production is achieved in the case when the level of transaction costs per unit of land is reduced to a minimum.

However, further increasing the size of land plots used in agriculture leads to a decrease in the efficiency of agricultural production due to the increase in transaction costs per unit of land area. In that sense, the major problem is to evaluate the effectiveness of projects related to the consolidation of agricultural lands. In our opinion, evaluation of the effectiveness of the above- mentioned projects should be carried out based on benefit-cost analysis.

The most important condition for the application of benefit-cost analysis for the evaluation of land consolidation projects is to ensure comparability of indicators of costs, benefits, as well as efficiency based on the international financial reporting system. It could create additional incentives to attract outside investors in agriculture.

Thus, the consolidation of agricultural land is the basis for the development of the investment process in agriculture, which allows increasing its efficiency by reducing transaction costs and attracting outside investors to allocate their capital in agriculture.

The economic aspect of agricultural land consolidation project is to determine the economic efficiency of land consolidation projects for society as a whole based

on the analysis of economic costs and benefits. It should be noted that the economic costs and benefits of the above- mentioned projects should be evaluated based on their "shadow" prices.

The environmental aspect of the agricultural land consolidation projects is the environmental assessment (EA) of its impact on the environment based on direct and indirect valuation methods.

The social aspect of the agricultural land consolidation projects is the assessment of its impact on the socio-cultural and demographic characteristics, a social organization of productive activities, cultural acceptability, as well as different groups of population such as women, indigenous people, youth and etc.

The life circle of the agricultural land consolidation project consists of creative design and implementation phases. In turn, the creative design phase consists of identification, feasibility study, preparation, detailed design, and appraisal stages. The implementation phase consists of negotiation, loan approval, implementation, supervision, and completion stages.

The goals and objectives of the agricultural land consolidation project are determined at the identification stage. Technical, institutional, financial, economic, environmental and social analysis of the agricultural land consolidation project is carried out at the feasibility stage.

A business plan for the agricultural land consolidation project is developed at the preparation stage. Clarification of the business plan of the project for the consolidation of agricultural land due to changes in the macroeconomic situation is carried out at the stage of detailed design. The external expertise of the agricultural land consolidation project is carried out at the appraisal stage.

Further, the business plan of the project on the consolidation of agricultural land is submitted to the bank to resolve the issue of allocation of loans for its financing. To this end, the owners and beneficiaries of the agricultural land consolidation project and the bank negotiate a loan to finance it. The signing of the loan agreement is carried out at the stage of approval of the loan to finance the project on the consolidation of agricultural land.

The agricultural land consolidation project starts at the stage of its direct implementation. Land use planning works focused on the consolidation of small parcels into larger land plots are carried out here. Monitoring the progress of the project on agricultural land consolidation in terms of cost and implementation time is carried out at the supervision stage using the PERT and GERT methodologies.

As a result of the agricultural land consolidation project, large land plots should be formed, allowing effective agricultural production, and using modern agricultural machinery and technologies. At the stage of completion of the project on the consolidation of agricultural land, a retrospective analysis of its implementation is also carried out, which allows identifying all the pros and cons of its implementation.

Training capabilities and public information programs should be included in the framework of the projects on the consolidation of agricultural land to support the implementation and developing of agricultural land consolidation.

The main take-offs of agricultural land consolidation projects should assist national and local officials and decision-makers involved with agricultural land consolidation to analyze policy and procedural constraints and opportunities to ensure that the above-mentioned process is a viable option and to strengthen movement towards eliminating hunger and food shortages, as well as poverty due to the rapidly growing the world's population.

Currently, to accelerate the process of consolidation of agricultural land and improve the efficiency of the agricultural sector of the national economy, it is necessary to develop a working digital model of the project on land consolidation in agriculture.

The present stage of agricultural land consolidation in Russia is featured by the development of agricultural holdings and the increasing size of private farms. After the implementation of land consolidation projects, agricultural producers are less sensitive to the disparity of prices for agricultural and industrial commodities, as well as can conduct their investment activities more efficiently based on self-financing.

In theory, as we mentioned before, agricultural land consolidation can be carried out as compulsory land consolidation and voluntary land consolidation. In that sense, the development of the agricultural land market is very important for the stimulation of agricultural land consolidation.

The objective of this paper is to analyze the current stage of agricultural land consolidation in Russia, evaluate its socio-economic, institutional, and environmental determinants, and assess the role of the land market in strengthening agricultural efficiency and sustainability.

2. METHODOLOGY

The methodology of the research presented in the article is based on the concept of land rent determinism, which presupposes the implementation of the following principles, which are theoretically, historically and logically interacted:

- land and mining rents generated in the agricultural sector and the fuel and energy complex directly correlate with the progressive reproduction of food and fuel, respectively, i.e. priority guidelines, trajectories and potentials of human activity;
- states seek to expand their territories in order to increase the appropriation of land rent;
- landlords try to increase the area of their agricultural land in order to generate higher land rent values;
- implementation of classical, neoclassical, and Keynesian theories to determine the paradigm of rent regulation of agribusiness;
- a dialectical synthesis of the classical and neoclassical theory of land rent, which is ultimately summarized in the economic rent arising in the process of rent formation as a result of the convergence of absolute, differential and monopoly land rents, reflecting the scarcity of agricultural land, especially arable land, which, of course, are the most important components of the country's land fund, since they serve as a starting point for the generation of food and the escalation of the value added of agricultural raw materials;
- economic rent is a platform for establishing land tax in agriculture, determining the collateral value of agricultural land, and paying compensation to agricultural producers for the illegal seizure of their land for non-core commercial purposes, as well as for environmental pollution;
- step by step transition of taxation of agricultural producers to a single agricultural land tax;
- development of auction and exchange trade in agricultural land;
- analysis of the effectiveness of the investment application, as well as an assessment of its static and dynamic effects based on the platform of rent dominants of agricultural sector.

3. RESULTS

As we mentioned before, the present stage of the development of agricultural land consolidation in Russia is featured by the further development of agricultural holdings and the increasing size of private farms.

The consolidation of agricultural land by legal entities, in essence, manifests itself as a modified form of integration of agricultural land, since the average size of agricultural land ownership in agricultural holdings in April 2025 compared to July 2022 progressed

by 19.2%, and also by 30.3% compared to May 2021, reaching almost 770.2 K ha with volatility from 443 K ha to 1,380 K ha (3.1 times) [1] (Table 1). It is also characteristic that compared to July 2022, the differentiation of agricultural land ownership in the top ten agricultural holdings progressed by 20 p.p. from 290% to 310%.

Table 1. Agricultural land ownership of the top ten agricultural holdings, Russia, 2025[1].

#	Agricultural holding	Area, K ha	%
1	Miratorg	1,380	17.9
2	Agrokompleks	1,230	16.0
3	Prodimeks	900	11.7
4	Rusagro	815	10.6
5	GAP Resurs	680	8.8
6	GK EkoNiva	632	8.2
7	BIO-TON	600	7.8
8	Agroholding Step	578	7.5
9	Agroinvest Group	444	5.8
10	Avangard-Agro	443	5.7
	Total	7,702	100.0

In 2023, the number of private farm decreased by 8.0% compared to 1995, while the total area of agricultural land occupied by private farm increased by 72.8% during this period. The average area of agricultural land occupied by a private farm increased due to agricultural land consolidation in 2023, compared to 1995.In 2023, it was estimated at 80.6 ha and increased by 87.9% compared to 1995 (Table 2)[2].

Table 2. Private farms, Russia, 1995-2023[2].

Item	1995	2010	2015	2020	2023	2023/1995,%
Number,K	279.1	261.7	261.6	262.0	256.9	92.0
Area,K ha	11,982.1	16,284.1	18,130.4	20,107.5	20,699.3	172.8
Average size,ha	42.9	62.2	69.3	76.7	80.6	187.9

In the Oryol region in 2024, the area of agricultural land was 2,034.9 K ha, which constituted 82.5% of its territory. Compared to 1990, the size of agricultural land regressed by 261.4 K ha - from 2,296.6 K ha to 2,035.2 K ha, which is equivalent to a reduction of 11.4%.

In 2022, the percentage of agricultural land in the total territory of the region regressed by 10.7 p.p., comparable to 1990, from 93.2% to 82.5%. In 2024, the distribution of land in the region was as follows: state and municipal - 965.0 K ha (39.2%), private - 1,161.3 K ha (47.1%), legal entities - 338.9 K ha (13.7%).

In 2024, state and municipal land decreased by 2.8 K ha compared to 2020, when it amounted to 967.8 K ha, i.e. regressed to 965 K ha, which is equivalent to a reduction of .3%.

Private agricultural land regressed by 8.5 K ha, from 1,169.8 K ha to 1,161.3 K ha, which is .7%. In 2024, the land of legal entities increased from 327.5 K ha by 11.4 K ha to 338.9 K ha (3.5%).

Compared to 2023, in 2024, state and municipal land decreased slightly from 965.5 K ha to 965 K ha by .5 K ha, private land – from 1,161.9 K h to 1,161.3 K ha by .6 K ha, and land of legal entities, on the contrary, increased – from 337.8 to 338.9 K ha by 1.1 K ha (.3%).[3]

In 2022, compared to 1994, the number of private farms in the region decreased by 25.7%, while the average area of a private farm increased by 3.4 times, indicating positive dynamics in the consolidation of agricultural land (Table 3).

Table 3. Private farms, Oryol region, 1994-2022[4],[5].

Item	1994	2000	2010	2015	2020	2021	2022	2022/1994,%
Number,K	1,754	1,420	1,247	1,292	1,297	1,303	1,303	74.3
Area,K ha	89.2	124.6	177.5	201.0	221.9	222.5	224,5	2.5 times
Average size,ha	50.8	87.7	142.3	155.6	171.1	170.8	172.3	3.4 times

To encourage land consolidation, it is necessary to develop the agricultural land market based on land auctions and exchange trade of agricultural land plots. In turn, the market price of land is the basis for agricultural land taxation and agricultural land mortgage transactions.

The share of agricultural land market transactions, which legal entities acted as participants, was calculated on average in 2020-2021 as 74.7% of their number. The share of agricultural land that was the object of land market transactions in 2023 amounted to 99.8% of all land transactions executed by legal entities in the region (Table 4). The average share of agricultural land value in the total land value that was the object of market transactions by legal entities in the region in 2023 was 73.0%. The average share of agricultural land leased in 2023 was 99.0% of all land leased in the region by legal entities. Legal entities entered into agricultural land lease agreements in 2023, accounting for an average of 71.6% of all lease agreements in the region. The share of agricultural land used as the object of land market transactions by legal entities increased from 97.8% to 99.8% (2.0 p.p.). During the same period, the value of agricultural land transactions increased from 67.5% to 73.0% (5.5 p.p.).

Table 4. Land Market, Oryol Region, 2023.

Transactions	Total		Including agricultural land		%	
	Private	Legal Entities	Private	Legal Entities	Private	Legal Entities
1. Buying and selling:	-	-	-	-	-	-
Number	7,665	846	1,232	644	16.1	76.1
Area, ha	8,154	184,466	6,815	184,015	83.6	99.8
Value, K rubles	5,184,153	3,932,008	2,175,220	2,871,802	42.0	73.0
2. Lease	-	-	-	-	-	-
Number	2,140	1,805	854	1,293	39.9	71.6
Area, ha	17197	83355	15608	82,509	90.8	99.0
3. Average Value, rubles/ha	635,780	21,316	319,181	15,606	-	-

In 2023, compared to 2020-2021, the share of legal entities' agricultural land leasing agreements increased to 71.6% from 63.6% (8.0 p.p.) of the total their lease agreements in the region. The price of agricultural land in land market transactions in 2023, compared to 2020-2021, increased by 6.9 times for individuals, while for legal entities, it decreased by 61.1%, indicating an increase in its purchases by them.

4. CONCLUSION

1. In the Russian agricultural sector, the process of concentration of agricultural land ownership and, accordingly, agricultural land rent on the platform of consolidation of agricultural lands by agricultural holdings, as well as private farms, continues.
2. This serves as a foundation for increasing the efficiency of agricultural production in Russia, the development of country's agricultural and food sovereignty, the generation of export potential for agribusiness, and the transfer from import substitution to the export of agricultural products abroad.
3. The share of state and municipal owned land and private land is decreasing, while corporate land of legal entities is growing now.
4. In the agricultural land use of parastatals, a trend has been identified of an increase in the share of agricultural holdings due to a reduction in the share of agricultural coops.
5. The trend of expansion of the average size of private farms continues, with an increase in their agricultural area, as well as a reduction in the number of them.

6. Due to the vastness of the country's territory and the differentiation of agricultural production potential in natural, soil, climatic, technical, financial, institutional, economic, ecological, and social, as well as other aspects, the above-mentioned trends in agricultural land consolidation are sometimes expressed in modified or unique ways, like, for example, in the Republic of Kalmykia.
7. Land consolidation serves as the foundation for the effective functioning of the agricultural sector, which creates the potential for increasing its efficiency via the reduction of transaction costs.

Due to it the following measures must be implemented to strengthen the organizational, as well as institutional sustainability of agricultural land market and agricultural land consolidation development in Russia:

- agricultural land consolidation legislation must be revised and improved both at the federal, as well as regional level based on the principles of land rent determinism.
- It is necessary to introduce legal regulation of the optimal size of agricultural land ownership and land use at the regional level.
- the institutional framework for implementation of agricultural land market, as well as agricultural land consolidation must be improved both at the federal, as well as regional level.
- it is necessary to make a transition to the assessment of agricultural land as a real estate in the agricultural sector.
- the agricultural land auctions and exchange trade of agricultural land plots must be introduced to stimulate the development of the agricultural land market and agricultural land consolidation.
- a reasonable and gradual legislative liberalization of the agricultural land market legislation should be carried out in order to ensure the formation of equilibrium prices for agricultural land plots.
- the establishment of land tax, the determination of the collateral value of agricultural land, and compensation to agricultural producers for the illegal seizure of their land for non-core commercial purposes, as well as for environmental pollution should be carried out based on economic rent, since it underlies these regulators.
- the training and retraining programs related to agricultural land market and agricultural land consolidation development issues must be introduced.

- the public relation campaign to strengthen people's ability to understand the role and importance of agricultural land market and agricultural land consolidation development must be initiated.
- The pilot projects focused on agricultural land market, as well as agricultural land consolidation development should be launched in some of the regions to make a demonstration effect.
- The domestic and international agricultural land market, as well as agricultural land consolidation development experience should be collected, scrutinized and disseminated.

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SOBRE O ORGANIZADOR

Alireza Mohebi Ashtiani possui graduação em bacharelado em Matemática, Matemática Aplicada, pela Amirkabir University of Technology (Polytechnic of Tehran), Teerã/Irã (2003), mestrado em Matemática Aplicada pelo Institute for Advanced Studies in Basic Siences (IASBS), Zanjan/Irã (2005) e doutorado em Engenharia Elétrica pela Universidade Estadual de Campinas (UNICAMP) na área de Automação (2012). Foi bolsista de Pós-doutorado Júnior do CNPq no Instituto de Matemática, Estatística e Computação Científica (IMECC/UNICAMP) e bolsista de Pós-doutorado da Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) na Faculdade de Ciências Aplicadas da Universidade Estadual de Campinas (FCA/UNICAMP). Desde 2013 é docente vinculado ao Departamento Acadêmico de Matemática do Campus Londrina da Universidade Tecnológica Federal do Paraná (UTFPR), e atualmente, docente permanente do Programa de Pós-Graduação em Matemática em Rede Nacional (PROFMAT) da UTFPR, Campus Cornélio Procópio.

Alireza Mohebi Ashtiani
http://lattes.cnpq.br/5025709771742662

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EDITORA
ARTEMIS
2025