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Assessment of land fragmentation of agricultural enterprises in Ukraine

Abstract
Introduction. Agriculture is one of the leading sectors of the Ukrainian economy, however it still remains underdeveloped. The latest analysis shows an increasing number of farms with agricultural land over 10,000 ha. Nevertheless, family farms with an average size of 0.9 ha comprise 44.7% in the structure of gross agricultural production in Ukraine. Despite this fact, they occupy twice as less of arable land than agricultural enterprises and farms. Ukrainian scientists believe that the main reason why such a situation is observed is the fragmentation of agricultural land.
The purpose of this paper is to identify some metric indicators for the assessment of land fragmentation of agricultural enterprises and analyse how land fragmentation prevents agricultural enterprises from using agricultural land.
Results. Conducted analysis has shown that the dispersion, the edge density, the number of land owners and land parcels, the small size and the shape of land parcels are not associated with the problem related to land fragmentation. It has been found out that the fragmentation of land ownership and the fragmentation of land use exists only in theory and in legal documents. Moreover, the internal agricultural land fragmentation does not represent a major problem for agricultural enterprises.
Conclusions. Land fragmentation is not a major problem for agricultural enterprises due to the excessive lease of agricultural land and virtual boundaries of land parcels (land ownership), projected field roads and projected shelterbelts. Nowadays, the main problem related to the use of agricultural land is the discrepancy between land ownership and land use.
Keywords: Land Fragmentation; Land Parcel; Agriculture; Farm; Enterprise; Metric Indicator; Land Ownership
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Оцінка рівня фрагментації земель сільськогосподарських підприємств в Україні
Анотація
У статті визначено показники фрагментації земель сільськогосподарських підприємств та зроблено аналіз впливу фрагментації на умови сільськогосподарського землекористування. З'ясовано, що фрагментація земель суттєво не впливає на землекористування сільськогосподарських підприємств в Україні за рахунок розвитку суцільної оренди земельних ділянок сільськогосподарського призначення. Основною проблемою сільськогосподарського землекористування виступає неможливість використовувати земельну ділянку власником через її відчуження.
Ключові слова: фрагментація земель; земельна ділянка; сільське господарство; фермерське господарство; підприємств; метричний показник; землекористування.

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Оценка уровня фрагментации земель сельскохозяйственных предприятий в Украине
Аннотация
В статье определены показатели фрагментации земель сельскохозяйственных предприятий и сделан анализ влияния фрагментации на сельскохозяйственное землепользование. Установлено, что фрагментация земель существенно не влияет на землепользование сельскохозяйственных предприятий в Украине за счет развития сплошной аренды земельных участков сельскохозяйственного назначения. Основной проблемой сельскохозяйственного землепользования выступает невозможность использования земельного участка собственником в связи с его отчуждением.
Ключевые слова: фрагментация земель; земельный участок; сельское хозяйство; фермерское хозяйство; предприятие; метрический показатель; землепользование.

1. Introduction

Agriculture is one of the leading sectors of the Ukrainian economy, however it still remains underdeveloped. After the implementation of land reform, Ukraine's agricultural land resembles a chessboard with an average size of land parcels equal to 4 ha. Such a situation is observed because of the socialisation of land or fair land distribution among the rural population. It is estimated that almost 63% of agricultural land is used by only 5.9% of all existing farms. The latest analysis shows an increasing number of farms with agricultural land over 10,000 ha. Since 2006, the average size of agricultural enterprises has increased from 419.4 ha to 478.8 ha, excluding private farms with the total area to 1,289 hectares [1; 2]. Nevertheless, family farms with an average size of 0.9 ha comprise 44.7% in the structure of gross agricultural production in Ukraine. Despite this fact, they occupy twice as less of arable land than agricultural enterprises and private farms. Ukrainian scientists believe that the main reason why such a situation is observed is the fragmentation of agricultural land [3-6].

2. Brief Literature Review

An analysis of recent Ukrainian research and publications shows that V. Kilochko [7], A. Martyn [3], L. Tkachuk [5], A. Tretiak [6] and A. Shvorak [8] gave consideration to the issues of land fragmentation regarding it to be an obstacle for the efficient use of agricultural land. Foreign experience concerning land fragmentation is presented in the works by T. van Dijk [9], M. Hartvigsen [10], J. Januszewski

[11], R. King and S. Burton [12], M. McPherson [13], A. Simmons [14], etc. However, today there is not a single scientific work by Ukrainian researchers which would comprehensively cover the indicators of land fragmentation and its impact on agricultural development.

3. The purpose of the article is to find out what types of land fragmentation present a major problem for the land use of agricultural enterprises in Ukraine and analyse how land fragmentation prevents the use of agricultural land. For this purpose, it is necessary to carry out three tasks:

- to identify the indicators of agricultural land fragmentation;
- to select metric indices for the assessment of agricultural land fragmentation;
- to assess the level of agricultural land fragmentation by village councils of Kharkiv and Poltava regions (two village councils for each of the regions).

This article deals with four types of land fragmentation: ownership fragmentation, internal fragmentation, land use fragmentation and low percentage of owner-occupancy.

4. Results

Fragmentation of land use refers to a situation when the number of land users, who are also tenants of the land parcels, shows the actual use of land. By internal fragmentation we understand the number of land parcels used by each land user. Land ownership is considered to be all land parcels used by one private farmer, the farmer's family or an agricultural enterprise regardless of whether those land parcels are in ownership or leased.

R. King and S. Burton [12], M. McPherson [13], T. van Dijk [9] consider land fragmentation to be a situation when a separate farm possesses several non-contiguous land parcels, often scattered over a wide area, small in size and of irregular shape. Land fragmentation is a spatial problem relating to the following factors: the landholding size; the number of land parcels belonging to the landholding; the size of each land parcel; the shape of each land parcel; the spatial distribution and the size distribution of land parcels [12]. Based on the available information relevant to the present analysis of land fragmentation, we have singled out three types of indicators:

- the indicators relating to the size and number of land parcels;
- the indicators concerning the total edge and shape of land parcels;
- the indicators of the level of land fragmentation.

The indicators that characterise the size and number of land parcels at an agricultural enterprise or a private farm are the number of land parcels; the mean number of the land parcels per a single landowner; the mean size of a land parcel; the modal value of the size of land parcels; the mean size of land parcels per single landowner. For our research, we used the modal value of the size of land parcels in order to reflect the most widespread size of one land parcel assuming that the mean size of land parcels does not explain the actual state of land distribution without planning and cartographic materials. We do not take into account the natural factor, since the whole study area is located in the forest-steppe zone of Ukraine.

The edge density (*ED*) and shape of land parcels are important parameters affecting the efficiency of the land use in agriculture. In order to conduct a length analysis of the boundaries of land parcels, we selected the edge density ratio. The edge density is the amount of the edge length per one unit of area [15] and is calculated by equation:

$$ED = \frac{\sum_{i=1}^{n} p_i}{A} \times 10000, \quad (1)$$

where, p_i is the perimeter of the i land parcel and A is the total area of the agricultural landholding.

The shape of land parcels and the agricultural landholding in general are characterised by three indicators: the Shape Index, the Area-weighted Mean Shape Index, the Double Log Fractal Dimension.

According to J. Gąsirowski [16], the Shape Index (*SI*) is calculated by means of the following equation:

$$SI = \frac{4\pi A_i}{p_i^2}, \quad (2)$$

where, A_i is area of the i land parcel; p_i is the perimeter of the i land parcel. This index has values between 0 and 1, where 1 is the best shape represented by a circle.

The Area-weighted Mean Shape Index (*AWMSI*) [15] overcomes the size dependence by comparing the perimeter and takes into consideration the area value of the land parcel:

$$AWMSI = \frac{\sum_{i=1}^{n} \left(\frac{p_i}{2\sqrt{\pi a_i}} \right)}{n}, \quad (3)$$

where, p_i represents the perimeter of the i land parcel and a_i represents the area of the i land parcel. If *AWMSI* equals 1, it means that the land parcel is circular or square and increases without limit as the shape of the land parcel becomes more irregular.

The Double Log Fractal Dimension (*DLFD*) Index is used to characterise the shape of the land parcel. The fractal dimension is commonly used to measure the degree of the shape complexity [17-20]. *DLFD* equals 2 divided by the slope of regression line obtained by the regressing of the logarithm of the land parcel area against the logarithm of the land parcel perimeter [15]:

$$DLFD = \frac{2}{\left(\frac{\left[n\sum_{i=1}^{n} (\ln p_i \times \ln a_i) \right] - \left[\left(\sum_{i=1}^{n} \ln p_i \right) \times \left(\sum_{i=1}^{n} \ln a_i \right) \right]}{\left(n\sum_{i=1}^{n} \ln p_i^2 \right) - \left(\sum_{i=1}^{n} \ln p_i \right)^2} \right)}. \quad (4)$$

DLFD approaches to 1, which indicates very simple shapes such as squares, and to 2, which indicates highly convoluted and more complex perimeters.

The fragmentation of agricultural land will be measured by using the Simmons Index (*FI*) and the Januszewski Index (*K*). The land fragmentation index developed by *A*. Simmons [14] took into account the number of the land parcels belonging to a farm and a relative size of each land parcel. The formula for this indicator is:

$$FI = \frac{\sum_{i=1}^{n} a_i^2}{A^2}, \quad (5)$$

where, a_i is the size of the i land parcel; A is the total size of the farm; n is the number of the land parcels belonging to the farm. Obtaining a value equal to 1 indicates that the farm consists of only one land parcel while the values that tend towards 0 indicate a high level of land fragmentation. The Simmons Index becomes the Simpson Index if it is subtracted from 1 [21]. A higher value of this index corresponds to a high level of land fragmentation.

The Januszewski Index (*K*) [11] is similar to the Simmons Index and is defined as:

$$K = \frac{\sqrt{\sum_{i=1}^{n} a_i}}{\sum_{i=1}^{n} \sqrt{a_i}}, \quad (6)$$

where, a_i is the size of the i land parcel; n is the number of land parcels (Januszewski, 1968). This index is located within the range from 0 to 1. The smaller the K value is, the higher the degree of the land fragmentation we observe. The analysis of

literature shows that Simmons's and Januszewski's indices are the most popular indices used to measure land fragmentation.

A study of the current situation related to the use of agricultural land according to the information given by four village councils in Poltava and Kharkiv regions shows a high level of land fragmentation. Here, the average values of Simmons's and Januszewski's indices are 0.003 and 0.044 respectively (Table 1). One landowner has on the average slightly more than one land parcel. Firstly, it is due to the method of sharing the land and the procedure for distribution of agricultural land in physical parcels among landowners (the rural population). Each landowner could receive two land parcels with the sum of the normative monetary value of the land, which does not exceed the average value of the land share at the farm. Secondly, it is possible to inherit agricultural land parcels. Thirdly, while distributing land parcels, they can be demarcated as a single array (area) at the request of the persons who become owners of two or more land parcels. However, according to the results of the study, such cases are very few (Table 1).

The mean and the modal values of the size of land parcels are different because the size land parcels depends on soil quality and the total number of persons who became owners of land parcels during the distribution of agricultural land in physical parcels. The maximum size of land parcels is presented by the owners who cultivate their land.

It is necessary to carry out a research concerning the level of land use fragmentation and the internal land fragmentation of the agricultural landholdings because these types of fragmentation influence the agricultural production. For this reason, we have selected ten indicators which are calculated separately for each agricultural enterprise. They are the total area of the agricultural farm; the number of land parcels; the modal value of the size of land parcels; the Area-weighted Mean Shape Index; the Double Log Fractal Dimension; the Shape Index; the Januszewski Index; the Simmons Index; the edge density of land parcels and the boundary length of the agricultural farm.

On average, only 3% is presented by the owners who cultivate their land, other land owners (77%) do not cultivate their land parcels themselves and lease land (Table 2). This means that the landholding of agricultural enterprises consists of a great number of land parcels, and therefore the coefficient of the edge density is quite important. Thus, in each of the studied village councils there are agricultural monopolists that lease land parcels of more than 200 landowners (Prydnipranske, Klymivka and Zarozhne village councils). Seven hundred landowners lease their land to *Kachalivske* LLC in Kachalivka village. It is common for all regions of Ukraine when private farmers and agricultural enterprises (companies) do not cultivate the land they own but lease it.

The land parcels of agricultural enterprises have a simple rectangular configuration as evidenced from the value of the Shape Index by Gąsirowski and the Area-weighted Mean Shape Index. Thus, the overall shape of agricultural enterprises is rather simple. However, the Double Log Fractal Dimension for the private farm *Dariy, Dobrobut* LLC and the private company *Yarmola* is 2.3642, 2.9028 and 7.9175 respectively, which exceeds the acceptable values. This indicates that the aforementioned agricultural enterprises consist of the several scattered land parcels. The larger the distance, the greater the factor value is.

Simmons's and Januszewski's land fragmentation indices prove a high level of internal fragmentation at all agricultural enterprises except private farms and individual farmers. Such results have been obtained because the land use of private farms and family farms consist of one or two land parcels. The edge density factors of the land parcels of agricultural enterprises are quite high and are

Tab. 1: **Assessment of land fragmentation based on the information obtained from four village councils in Poltava and Kharkiv regions**

Description	Prydniprianske village council of Kobeliaky district in Poltava region	Klymivka village council of Karlivskyi district in Poltava region	Zarozhne village council of Chuhuiv district in Kharkiv region	Kachalivka village council of Krasnokutsk district in Kharkiv region
Number of landowners	741	625	256	718
Number of land parcels	753	674	292	745
Mean number of land parcels per owner	1.02	1.08	1,14	1.04
Total size of land parcels, ha	2,115.40	2,685.63	2,010.2896	2,456.7771
Minimum size of a land parcel, ha	0.48	0.15	0.5547	0.1847
Maximum size of a land parcel, ha	5.60	71.00	50.0000	5.8030
Mean size of a land parcel, ha	2.81	3.98	6.8846	3.2977
Modal value of land parcel size, ha	2.74	3.23	6.4725	3.1730
Simmons Index	0.002	0.003	0.005	0.002
Januszewski Index	0.037	0.040	0.060	0.037

Source: Calculated by the author

Tab. 2: **Assessment of internal land fragmentation of agricultural enterprises**

Land owner's / User's name	Area of landholding (farm structure), ha	Number of land parcels in use	Modal/mean value of the size of land parcels, ha	Area-weighted Mean Shape Index	Double Log Fractal Dimension	Januszewski Index	Simmons Index	Edge density of land parcels	Edge density of landholding
Prydniprianske village council of Kobeliaky district of Poltava region									
Agricultural cooperative *Radianskyi*	1324.55	472	2.74	1.3410	1.3095	0.0463	0.0022	287.2726	41.9925
Dobrobut LLC	629.94	225	2.74	1.3729	2.9028	0.0667	0.0045	290.7536	48.7172
Family farms	160.91	56	2.74	1.3105	1.2004	1	1	274.3117	-
Klymivka village council of Karlivskyi district of Poltava region									
Batkivshchyna LLC	1,539.55	415	3.23	1.3000	1.1786	0.0499	0.0027	237.8631	37.9249
Lanivske LLC	717.91	212	3.23	1.3272	1.0266	0.0698	0.0053	253.6384	28.8094
Private company *Yarmola*	17.61	3	-/5.87	1.3099	7.9175	0.5782	0.3371	191.1204	162.5838
Private farm *Apiks*	243.41	40	3.23	1.2525	1.2686	0.1745	0.0632	168.4738	63.4241
Private farm *Trud*	36.28	1	-	1.2167	1.2283	1	1	71.60777	71.60777
Private farm *Dariy*	112.87	2	-/56.44	1.4504	2.3642	0.7132	0.5333	66.3939	66.3939
Private farm *Promin*	18.00	1	-	1.4200	1.2677	1	1	119.0489	119.0489
Zarozhne village council of Chuhuiv district of Kharkiv region									
Zarozhnianske LLC	1,705.5276	261	6.4725	1.5751	2.0158	0.0627	0.0041	216.8380	36.7225
Zarozhne LLC	173.7619	26	7.1915	1.3004	0.9868	0.1997	0.0426	177.2680	49.2024
Zoria LLC	37.0000	2	-/18.50	1.5700	1.4650	0.7277	0.6055	123.4924	123.4924
Kontakt LLC	45.0000	2	-/22.50	1.2934	1.0154	0.8517	0.9284	79.9909	79.9909
Private farm *Khliborob*	50.0000	1	-	1.2119	1.2222	1	1	60.7585	60.7585
Kachalivka village council of Krasnokutsk district of Kharkiv region									
Kachalivske LLC	2,337.8299	709	3.1730	1.3710	1.4483	0.0378	0.0015	266.737	27.737
Private farm *SLA*	78.9173	25	3.1730	1.4078	1.4078	0.2004	0.0401	280.788	56.691
Family farms	40.0299	11	3.1730	1.4485	1.3105	1	1	268.148	-

Source: Calculated by the author

237.08 on average. However, due to the relevant land lease relations, the edge density coefficient of agricultural enterprises decreased by almost 6 times and it makes 55.38 on average. This is a result of regular development of land lease relations.

If the edge density index of agricultural enterprises does not change significantly. It means that land ownership of such enterprises consists of several scattered landholdings. For example, the edge density index for the private agricultural company *Yarmola*, if compared with the edge density index of the land parcels belonging to a farm, has decreased only by 1.17 times due to the land lease. This once again proves a high value of the Double Log Fractal Dimension for this private company.

The reduction of the edge density index is primarily caused by the fact that the borders of the land parcels in the vast majority of cases are not fixed by the boundary marks, thus the boundary between the neighbouring land parcels is not observed. Consequently, people have received legal documents confirming their right to the land parcel, but they do not know where the boundaries of the land parcel are and where the parcel is located. This is despite the fact that there is a corresponding technical land surveying documentation related to the demarcation of the boundaries of land parcels, and that the land boundaries are fixed in the State Acts on private land ownership. Thus, the distribution of agricultural land among the rural population in physical parcels was only on the map or in the project land surveying documentation.

Another point is that land management projects concerning the arrangement of the land shares promoted the creation of a network of field roads in order to provide access to every land parcel (demarcated land parcel) and shelterbelts that still remain in collective ownership. Yet, these networks of field roads and shelterbelts have not been demarcated by the boundary marks as well. There is a situation when the projected land for the field roads and shelterbelts are not in private ownership of the owners of land parcels, thus they are considered to be land reserve or the reserve fund of the village council.

Today, most of these projected field roads and shelterbelts continue to be used by the tenants of the land parcels as the land parcels that are systematically cultivated under agricultural crops or pure steam, including the crops of perennial herbs in the fields of crop rotation with the term use specified in accordance with the lease agreements.

Summing up the above-stated, one can say that there is a number of unresolved issues concerning the projected field roads and shelterbelts. They are as follows:

- the legal status of the land under the projected field roads and shelterbelts has not been determined yet;
- the items concerning the collective ownership, which includes the projected field roads and shelterbelts, have not been regulated as there is no collective ownership in the legislation in force;
- there is no legal and regulatory framework concerning the procedure of leasing the land under the projected field roads and shelterbelts;
- the tenants have to illegally cultivate the land of the projected field roads and shelterbelts;
- almost all the projected field roads and shelterbelts are ploughed;
- the state regulatory authorities impose a penalty to the tenants who cultivate the projected field roads and shelterbelts without a proper legal basis, and the tenants have problems with tax authorities because they use land without any legal documents.

Thus, the legislation in force does not fully regulate legal relations regarding the use of «virtual» network of field roads and shelterbelts and fees for using them. This means that the tenants do not pay the land tax and rent for using such land - they use land free of charge. Thus, according to the preliminary calculations as to the area of such unrecorded land, the project field roads and shelterbelts in the study area are as follows: 19 ha in Prydniprianske village in Kobeliaky district of Poltava region, 20 ha in Klymivka village in Karlivka district of Poltava region, is 22 ha in Zarozhne village in Chuhuiv district of Kharkiv region and 18 ha in Kachalivka village in Krasnokutsk district of Kharkiv region. The areas of unrecorded agricultural land may be larger due to the availability of land parcels through the dead heritage (the absentee landowners).

Therefore, the missing of boundary markers and the «invisible» demarcation of land parcels, the projected field roads and shelterbelts allowed reducing the edge density index due to the excessive lease by combining a large number of land parcels in one landholding in such a way to, thereby, eliminate the problem of fragmentation of agricultural land.

The overwhelming majority of agricultural enterprises have access to agricultural land due to a simplified procedure of registration of land lease agreements. The introduction of emphyteusis to fight land fragmentation has led to the capture of farmland by the big capital and to the concentration of excessive economic power in agriculture within the corporate farms (agroholdings).

Today, one of the major problems in Ukraine related to the use of agricultural land is that landowners, according to their economic status, have in fact turned to be «rentiers», i.e. people receiving their income from the lease of their land property; they are those who are not personally involved in the management of their assets or agricultural activities. The role of the «rentier» is considered in scientific literature in different ways. For example, Th. Veblen believed that rentiers parasitised on the real production, whereas N. Bukharin [22] emphasised the role of this group in the development of a credit economy in his famous book «The Political Economy of the Rentier».

The described phenomenon is rather negative in the modern conditions of the land tenure in Ukraine because it proves the general inefficiency of agricultural land ownership formed during the implementation of land reform. Further evolution of the «rentiers» in Ukraine will lead to the alienation of land from the owner because land ceases to be a working place for rural residents and their families [23]. This only stimulates further gradual «dying» of rural areas.

5. Conclusions

The analysis of the studied area shows that the dispersion, the edge density, the number of land owners and parcels, the small size and the shape of land parcels are not related to the problem of fragmentation of agricultural land in the studied areas. Thus, we can confidently conclude that the internal fragmentation of agricultural land is not observed within the studied areas due to excessive lease of agricultural land and due to the «invisible» boundaries of land parcels, projected field roads and shelterbelts. The existing fragmentation of land ownership and land use exists only on the map and in legal documents, which, owing to regular development of land lease relations, does not present a major problem for the use of land by agricultural enterprises in Ukraine.

We believe that the existence of the so called virtual type of the Ukrainian land fragmentation could be in favour of large agricultural enterprises and corporate companies, because they are able to produce unaccounted «shadow» harvest of agricultural crops and, therefore, illegal income.

It is difficult to accept ideas expressed by M. Hartvigsen [24], who notes that distribution of agricultural land in physical parcels as the basis of the land reform in Ukraine has led to the excessive fragmentation of land. It means there is a large overlap between the agricultural land ownership and the land use because most land is cultivated by the owners of small family farms and land lease is not common.

Our research produces a different result. There is a little overlap between the ownership and the land use. For example, *Kachalivske* LLC in Kachalivka village of Krasnokutsk district of Kharkiv region cultivates only 10% of its own land. The distribution of agricultural land to the rural population contributes to effective development of large agricultural enterprises and corporate companies (agroholdings) in Ukraine. The main reasons why such a situation is observed is that a lot of people became owners of land parcels without being asking about their willingness to own

land; many landowners are not able or do not want to cultivate their own land parcels themselves (pensioners, city residents who have inherited the land, etc.); physical boundaries of land parcels are missing and the land lease in Ukraine is excessive. Nowadays, the main problem for Ukraine is the presence of one of the four types of land fragmentation described by T. van Dijk [9], which is the discrepancy between land ownership and land use.

Therefore, the land fragmentation in Ukraine is landowners' problem as they are often in a situation of monopsony with only one or two lessee and the dominating local agricultural enterprise which can be a unit of the corporate company or agroholding. This is a result of the absence of the formal agricultural land market and the establishment of a weak and malfunctioning land lease market. The moratorium on agricultural land sell is extended until 2018.

In our view, land fragmentation has a negative impact on other spheres such as protection of land property rights, access to credit, attraction of long-term investments, infrastructure development, land protection and may lead to inappropriate land use, increasing transaction costs associated with the transfer of ownership of land parcels, the alienation of agricultural land. These issues remain subjects for further research.

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