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# GEOGRAPHICAL ANALYSIS OF THE LAND FRAGMENTATION PROCESS BASED ON PARTICIPATORY MAPPING AND SATELLITE IMAGES. CASE STUDIES OF CIOROGÂRLA AND VĂNĂTORII MICI FROM THE BUCHAREST METROPOLITAN AREA

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**Abstract.** Farm fragmentation, in which a household operates more than one separate parcel of land, is common phenomenon in the Romanian agriculture. Two case studies of land fragmentation in Bucharest metropolitan area were conducted to develop appropriate techniques for quantifying it since 1990. Methods were derived from participatory mapping approach, based on satellite images and land registers, and were rendered at a commune level by use of GIS. This study emphasizes that an approach based on participatory mapping and deep level interviewers provides valuable results relevant for land consolidations strategies in changing urban area. Policymakers should focus instead on mitigating the root causes of land fragmentation: inefficiencies in land, labour market, loan, and food markets.

**Key words:** land fragmentation; land use; participatory mapping; GIS; remote sensing

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## Introduction

Land fragmentation, also known as *pulverization* (Clout, 1972:106), *parcellization* (Roche, 1963) or *scattering* (Farmer, 1960), is the type of land ownership pattern where “a single farm consists of numerous discrete parcels, often scattered over a wide area” (Binns, 1950:5). Land fragmentation within a farm may be caused by several factors that can be classified as follows: socio-cultural factors, economical factors, geographical factor and operational factors (King and Burton, 1982).

Social and cultural processes have an important influence leading to land fragmentation. Most important are the laws regarding inheritances that favour an equal division of a land property among the heirs. Once the process of land fragmentation has started it continues with geometrical progression at each succeeding generation. The economical processes are important when economical or technological changes take place within a farm. Sometimes a farmer, in the intent of expanding his farm, will buy land that doesn't have

spatial contiguity thus increasing the degree of the land fragmentation. The geophysical factors like slopes, climatic conditions can affect the contiguity of a farmland. An important element in land fragmentation is transhumance that leads to an economical rational land fragmentation, by the seasonal process of migration from the mountains to the plains area. The operational processes for example the building of a road, a canal, a railway, a factory or other artificial construction can break a plot that was compact from the point of view of a single owner having numerous plots. In the same category can be considered a series of political decision (for example the Turkish government initiative of distribution of each member at village community a small plot from the village common land; in Greece distribution of state and the expropriated properties lands has led to one recipient owning 4 to 18 tiny plots).

Geographical studies on land fragmentation reached the conclusion that it has both advantages and disadvantages but the predominant ones are

disadvantages (Chisholm, 1979; King and Burton, 1982), although detailed empirical analyses of these effects are relatively few.

The disadvantages of land fragmentation refers mainly to the “*time wasted*” meaning the extra travel time that needs to be allocated to reaching each plot, as well as the energy additional wasted for cultivating the corners or along the borders of each plot where the machines operate with high difficulty. The second drawbacks disadvantage of fragmentation is the difficult position its puts a farmer who wish to modernize his farm, by introducing new crops, machinery, irrigation systems, drainage and laying out works, pest control. Land fragmentation makes almost impossible the conservation and improvement of the soil quality, the land productivity reduces drastically and their farming can become unprofitable. Another characteristic of land fragmentation is more concerned with the social and administrative aspects of the rural life. Fragmentation increases the number of people involved in implementing process in an area thus the consensus becomes less likely and cooperation more difficult (Busch *et al.*, 1979).

While most researchers portrayed the negative effects of agricultural land fragmentation, there are some that analyzed its positive effects. Land fragmentation allows farmers with scattered plots on a large area to practice a risk management through the presence of different geophysical conditions and crops scheduling.

Risk management though the presence of different environmental conditions. A farmer which has several plots cultivated with the same crop but in different locations undertakes the risk of having different productions depending on local conditions,

but his annual productions will remain the same (Netting, 1972; Friedl, 1974). The profit can be kept at a high level by practicing different crops on each plot. This is considerate to be the main reason for keeping land fragmentation mainly by having the possibility of practicing different crops and reducing the risk of the farm bankrupt.

Crops scheduling takes place when the plots are located at different altitudes, and their ripping takes place at different times. By spreading out the agricultural works (e.g. seeding, weeding, harvest) to several weeks it is possible to avoid household labour bottlenecks (Forbes, 1976). By scheduling crops the framers can be auto-efficient in terms of labour by distributing the workforce according to each crop requirements.

#### ***Agricultural land fragmentation and consolidation in Romania***

Excessive land fragmentation in Romania is a direct consequence of the implementation of the laws of the agrarian reform after 1989 (fig. 1). These laws translate into restoring the agricultural plots to the people that were forced to attend the CAP and donate their lands to the village property. In the mean time, many of the former landowners deceased and their property was divided among heirs; it is also of great importance to mention that inheritance tradition is the rural areas usually means that the children will divide the farmland in order to continue separately the agricultural activities.

Chircă and Teșliuc (1999) shown that at the present moment, the structure of the agricultural property is more fragmented then before the collectivization period. In 1948 the percentage of farms with less than 1 ha is 36%; in 1998 the same indicators reached 45% (fig. 2). The Romanian

Agricultural Census from 2002 count 4.3 million individual farms that own 14.3 million plots. The average number of plots of an individual farm was 3.3 and the average area of a plot was 0.5 ha. A

chart based on fragmentation classes show us that 66% of them have less than 3 plots, and 18% have between 4 – 6 plots and 16% have more than 6 plots (table 1).



Figure 1. Effects of the agrarian reform from 1991:  
a. 1988 – compacted plots; b. 2005 – excessive land fragmentation

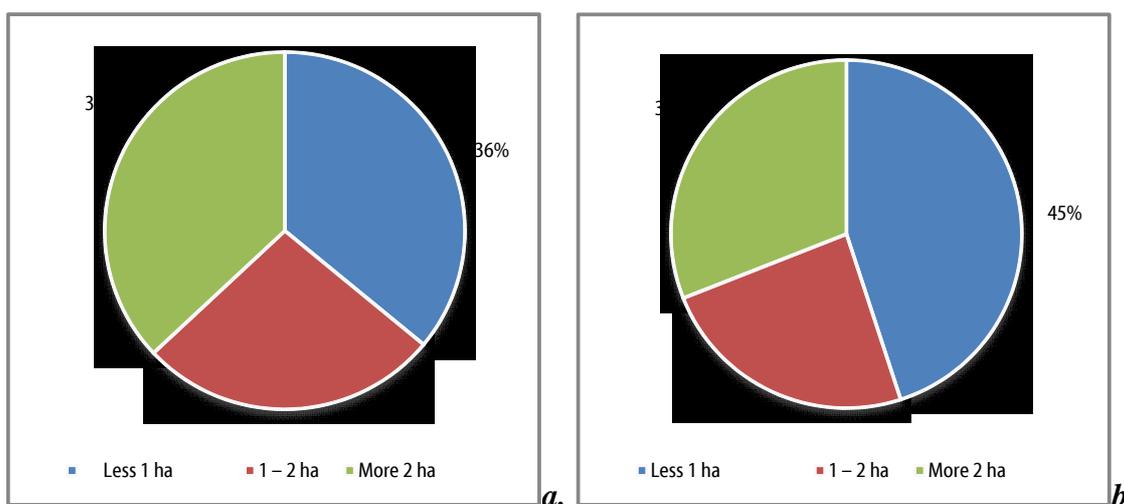


Figure 2. Farms by size classes in Romania:  
a. Year 1945; b. Year 2002

Table 1. Individual farms by degree of land fragmentation

Individual household fragmentation	Scale	Value
Total number of plots in Romania	Millions	14.5
Total number of plots in individual households	Millions	14.3
Average area of an individual household	Hectare	1.7
Average number of plots of an individual household	Number	3.3
Average plot area	hectare	0.5
Individual households by classes fragmentation		
Compact (1 plot)	%	30
Moderate fragmentation (2-3 plots)	%	36
Heavily fragmentation (4-6 plots)	%	18
Excessive fragmentation (more than 6 plots)	%	16

Source: based on the Romanian Agricultural Census (2002)

Rusu *et al.* (2002) have analyzed the problems associated to the Romanian agriculture due to land fragmentation. The main causes for land fragmentation were identified in the agrarian laws and sometimes its imperfections. In this regard the laws stated: limiting land retribution at 10 ha through Agricultural Fund Law no 18/1991, the same law stated that the persons that worked within a former Agricultural Cooperatives for Production (CAP) but that don't own land are the rights to receive up to 0.5 ha if such land was available, the ambiguous stipulation from law no 18 that stated that the lands are to be reattributed "*usually on the previous locations*". Instead of prioritizing the land retribution in a smaller number of plots the Romanian Parliament choose to refund the land on the former locations.

### Study Area

I had conducted on site studies in the villages Vânătorii Mici (Giurgiu county) and Ciorogârla (Ilfov county), from the Metropolitan Area of Bucharest, by using participatory mapping. The two villages were chosen due to their geographical location (figure 3). Ciorogârla commune is situated near to Bucharest, and is, at present time, being submitted to a strong process of suburbanization due to the fact that local people or Bucharest's inhabitants build houses here or there is the land of

industrial parks that occupy more and more of the agricultural land. The people are more interested selling their properties then investing in agriculture. Vânătorii Mici commune is situated far from Bucharest (approximately 40 Km), with a good accessibility to the transportation infrastructure close to the Pitești-Bucharest highway and the national road DN61 crosses it.

The comparative analysis of geodemographical aspects (number of inhabitants, population over 60 years old) and economical aspects (number of employees) shows different aspects between the potential of these two villages (table 2). From the number of inhabitants' point of view the two villages have similar sizes (Ciorogârla – 4,675 inhabitants, Vânătorii Mici – 4,792 inhabitants). The differences appear when analyzing the population dynamics between 1990 and 2002 (-7.7% in the case of Ciorogârla and -12.5% for Vânătorii Mici). The significant differences between the two villages are given by the elderly population and the dynamics of the employees, Ciorogârla registered between 1990 and 2002 a decrease of the labour market (-69.5%) while Vânătorii Mici only lost -37.8% of the number of employees. The percentage of elderly population is higher in Vânătorii Mici (26.08%) compared to Ciorogârla (19.08%).

Table 2. Dynamics of the population number and labour force between 1990 and 2002

Indicator	Ciorogârla		Vânătorii Mici	
	1990	2002	1990	2002
Population number	5063	4675	5477	4792
<i>Dynamics of population number (%)</i>	-7,7		-12,5	
<i>Population over 60 years old (%)</i>	19,08		26,08	
Employees	780	238	370	230
<i>Dynamics of the employees number (%)</i>	-69,5		-37,8	

Source: INS processed data, 1990, 2002 (Statistical charts of the two villages)

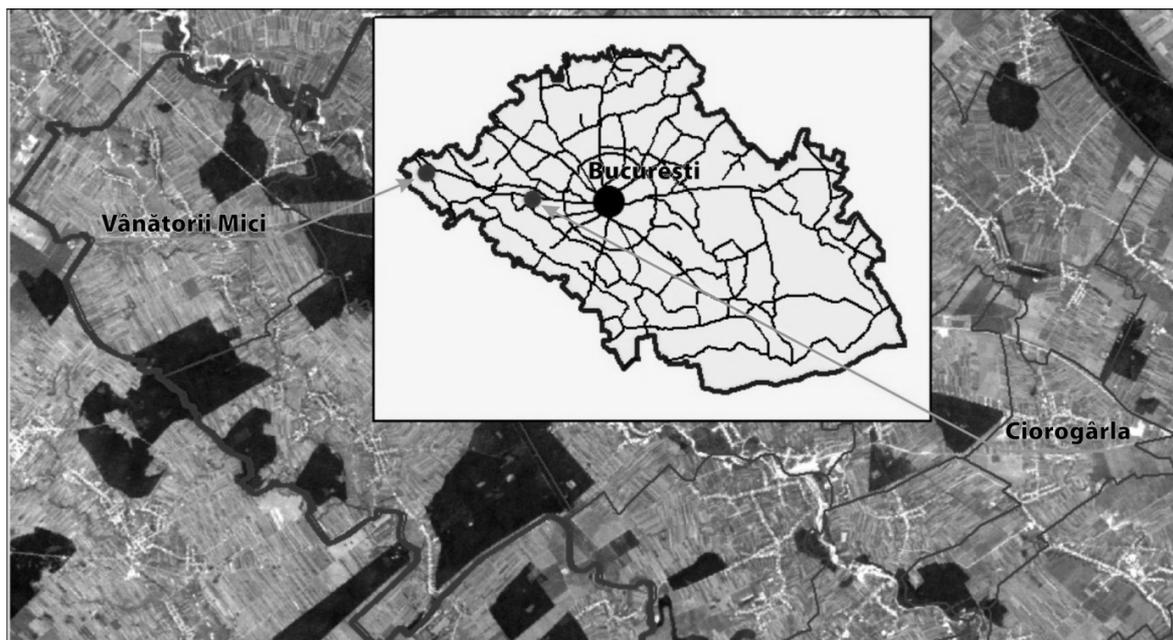


Figure 3. The geographical position of Ciorogârla and Vânătorii Mici within the Bucharest Metropolitan Area (BMA)

### Materials and methods

By analyzing the participatory map we can obtain information that can be transferred into a Geographical Informational System (GIS). The transfer of these data allows for different ways of processing, analysis and graphic representation that can easily be updated according to the specific objectives. The purpose of this method is to allow the local population to be involved in processing a series of specific aspects like agricultural resources that are of vital importance for them.

This method allowed us to analyze, with the help of satellite images, the degree of land fragmentation of the agricultural exploitation and the dynamics of the land use market. The research was done by interviewing a series of local stakeholders and farmers. As far as the field researching was concern the mayors of the two villages and representatives of the farmers have outlined with a marker on a printed satellite image covered with tracing paper a series of farms and the plots they are divided into. The reason for involving

farmers and local authorities was to make the result regarding the land fragmentation more precise.

The research process that involves participatory maps has the following stages: 1. The preliminary lab stage, 2. The field research, 3. Data analyzing and processing.

**The preliminary lab stage.** In this stage there the following activities took place:

- a. *Gathering information* about the socio-economical and environmental resources of the selected villages;
- b. *Printing the satellite images* at an A1 format, depending on the resolution of the images and the local conditions that were observable on the maps. The satellite images were acquired from Google Earth<sup>2</sup> for Ciorogârla and a 2005 Aster satellite image for Vânătorii Mici. Both images were introduced into a geographical reference system in UTM projection in

<sup>2</sup> <http://earth.google.com/>

ArcView GIS 3.2a, by using the Image Warp extension and topographical map at a 1:50.000 scale in order to identify common georeferencing points.

- c. *The tracing papers* were placed on top of the printed satellite image. On the tracing papers a series of common points needs to be traced down in order to allow their entering into a geographical reference system

**The field research mapping.** I had interviewed representatives of the local authorities and farmers. The mapping on tracing paper begun with the first farmer that received a unique code in a questionnaire chart (P1, ..... Pn – for each farmer) and their plots were codified based on this aspect (for example P1.3 means the owners code P1, and .3 is the number of one of his plots). Each farmer mapped on the satellite image the location of each of his plots and specified its dimensions, how he acquired it and what intentions had about it.

**Data analyzing and processing** had the following stages:

- a. *Preparing the tracing papers.* After the field research was complete the data were introduced in ArcView GIS 3.2a. In order to introduced them into a geographical reference system the extension Image Warp for ArcView 3.2a was chosen. This extension allows transferring of the projection system and the coordination points on an image or vector in *.shp* format (shapefile) already introduced into a geographical reference system (in our case the satellite image).
- b. *Introducing geo-informational attributes.* Each polygon that was introduced in the shapefile theme *.shp* was given a unique identification code corresponding to each farmer and the plot number. The additional attributes were introduced by adding new fields in the table of attributes. Once these activities were completed, different statistical indicators were calculated for the two villages.

### 3. Realizing the land fragmentation map

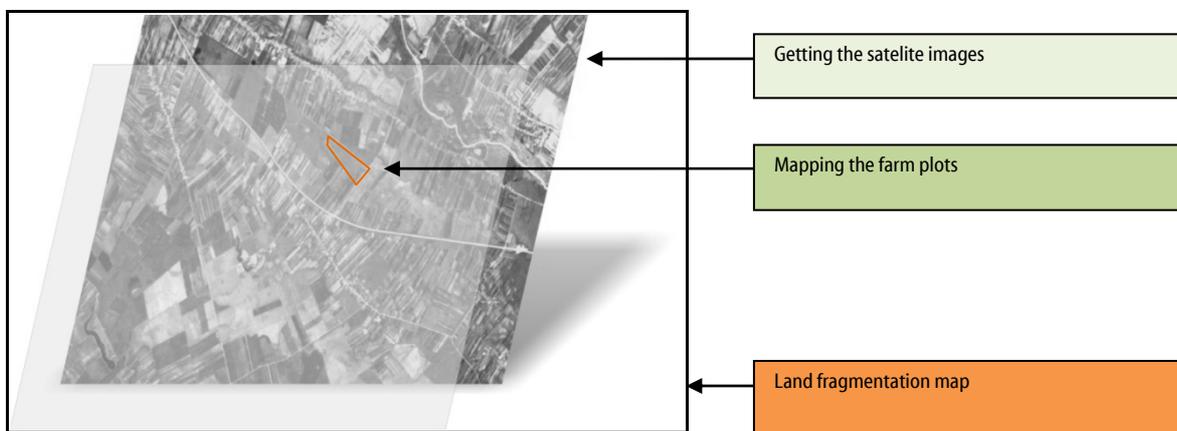


Figure 4. Stages in analyzing the land fragmentation of the agricultural fields based on satellite images

### ***Index of the land fragmentation***

It is very difficult to evaluate whether a farm is *too fragmented* due to the absence of standardized methods for evaluating the degree of land fragmentation. Most authors that studied the phenomena approached the issue by analyzing the average number of plots within a farmland and the average area of the farm or another indicator that consists of the percentage of farms that have more than 10 plots (Bentley, 1987). These evaluation methods are not that precise because they do not take into consideration the distance and the necessary time consumed for reaching each lot. King and Burton (1982) identify the following indicators for land fragmentation: number, dimension, form, spatial distribution of plots, and spatial distribution within the field. They also mention other land fragmentation indicators:

*The Simmons index (1964)* which states that the degree of land fragmentation is given by the squared sum of the plots dimensions (a) divided to the squared of the farmland dimensions (A). The formula for this indicator is:

$$FI = \frac{\sum a^2}{A^2}$$

Obtaining a value equal to 1 indicates a compact area (totally consolidated) of the farmland while values that tend towards 0 indicate a high degree of land fragmentation.

*The Januszewski index (1968)* divides the squared root of the total area of the farmland to the squared roots of the plot's dimensions. A feature of this indicator is that the land fragmentation decreases when the larger lots are more numerous and the smaller ones are lesser in number.

$$K = \frac{\sqrt{\sum a}}{\sum \sqrt{a}}$$

Similar to the Simmons index, this index has values between 0 and 1, higher values indicating a high degree of farmland consolidation. This indicator has three properties: the degree of land fragmentation increases with the number of plots, the degree of fragmentation increases when the dimension of the plots are lower, and the degree of fragmentation decreases when the area or the number of large lots increases and the number of small lots decrease. Also, this indicator can be used to point out the degree of land fragmentation of agricultural crops within a farm or a region.

### **Results and discussion**

#### ***The results of the participatory maps from the Vânătorii Mici village, Giurgiu County***

The Vânătorii Mici village has a high percentage of elderly population, considering that the main income source of the village` inhabitants is represented by pensions. Also, 63 families receive social payments as stipulated by the Minimum Guaranteed Income Law. According to the information received from the village mayor there are 112 people that are abroad, more than double the number from 1995 when only 45 people were outside the country. The village has important agricultural resources represented by tillable lands most of them being in individual properties. The average dimension of the common farmland is 2 hectares divided into 4 plots.

A very important issue for the farmers is commercializing the animal and vegetal products because of the distance between the villages and Bucharest or another urban centre. The main markets for the agricultural products is the fairs from the neighbouring villages and the intermediaries or individual commercial. The most

important aspect about commercializing the agricultural products is the fact that 97% of the households consume more than 50% from the final production and only 3% sell directly to the consumers more than 50% from the total of achieved sales.

In order to supervise the spatial dimension of land fragmentation, four farmers were asked to identify on a satellite image the plots that form his/her farm (figure 5). According to the result from table 3, three out of four farms have six plots, with

the maximum area of 2.92 hectares per farm. Most plots have a small area considering that the largest of them has only 1 hectare, and the smaller one has 0.04 ha. The Januszewski indicator that calculates the degree of condensation of a farmland with values between 0 and 1 (1 meaning the highest degree of concentration of a farmland with a small number of plots), shows that most values are situated around 0.42 which means a high degree of farmland fragmentation.

**Table 3. Land fragmentation of the agricultural fields  
Examples of farmlands from the village Vânătorii Mici, Giurgiu County**

Farmland	Total number of plots	Maximum area of one of the plots (hectare)	Minimum area of one of the plots (hectare)	Total area of the plots (hectare)	Januszewski Indicator
1	6	1	0,25	2,75	<b>0,42</b>
2	4	0,87	0,2	1,98	<b>0,51</b>
3	6	0,75	0,04	2	<b>0,43</b>
4	6	0,75	0,19	2,92	<b>0,42</b>

**Source:** Author` calculation after the participative maps were applied

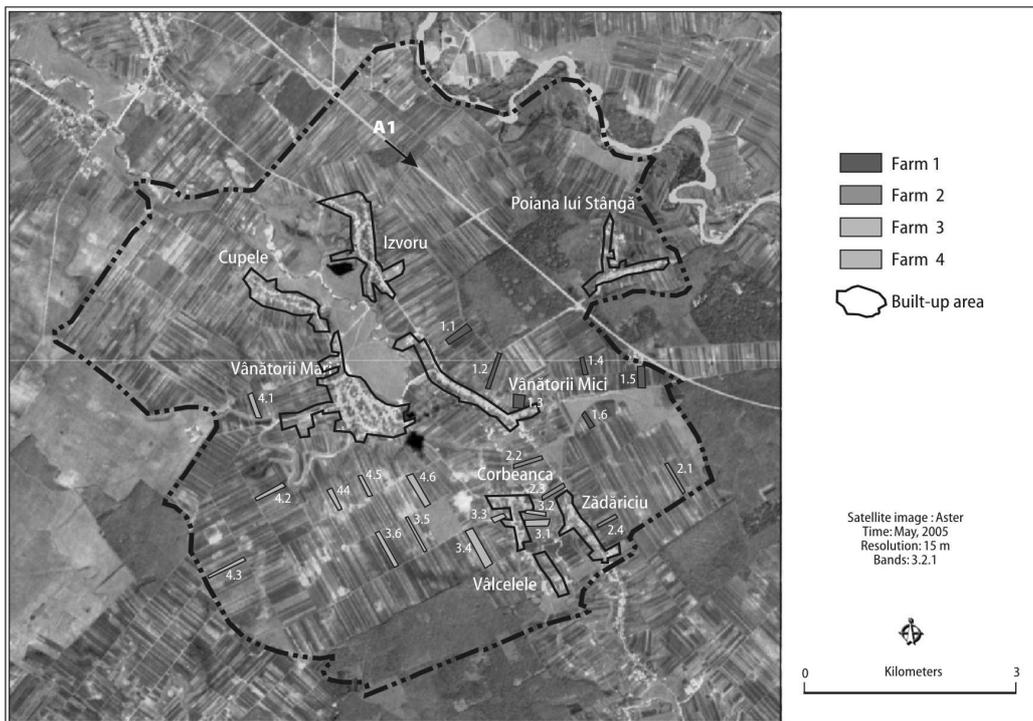
In the process of giving the agricultural lands back to their former owners, the local commission for implementing the stipulation of the agrarian legislation has distributed plots in different part of the village according to the productivity potential of the fields. In spite of this fact, the farmers` lands still reach a high degree of land fragmentation and they have to travel long distances from one lot to the other which translates into lost time and high costs due to the increase in the quantity of fuel.

By comparing a Landsat satellite image (figure 6) from 1988 with an ortofotoplan from 2005 (figure 7), besides the different spatial resolutions at which they were realized, we can observe that the landed reform that was undertaken lead to an excessive land fragmentation. The structure of the

agricultural fragmentation is much more fragmented now than it was in the communist period. Until 1990, there weren`t any small lots with areas of less than few hectares, with the exception of those lots that were being used by the people working in the CAP associations. Ciorogârla is undertaking a strong process of suburbanization that involves a high degree of inserting the agricultural lands within the built in area either for living, industrial, commercial or storage spaces. This means that agriculture, with a high degree of land fragmentation will have a more limited role in the local economy. An intense process of selling the agricultural and non-agricultural fields takes place at the present moment.

In order to analyze the degree of agricultural lands fragmentation we also asked four farmers in Ciorogârla to localize on an ortofotoplan the lots that make up their farms. There is a significant difference between the number of lots that make up Vânătorii Mici compared to Ciorogârla. In the first village most farms are made out of 4 or 5 lots, while in Ciorogârla there are 2 up to 3 lots per farm. This

fact has made farmers sell some of their property and kept the rest to be sold later. The phenomena is known in the agricultural geography as *anticipated land value*, which means that the agriculture is maintained for a period of time in order to obtain a small profit from the agriculture lots; but what farmers really intend to do is sell the land at a later moment with a better price.



**Figure 5. Land fragmentation in the Vânătorii Mici village**  
**Aster satellite image and research based of participatory maps**  
**The results of the participatory map from Ciorogârla village in Ilfov County**



**Figure 6. Ciorogârla village – spatial distribution of lots in 1988**  
**Landsat satellite image**

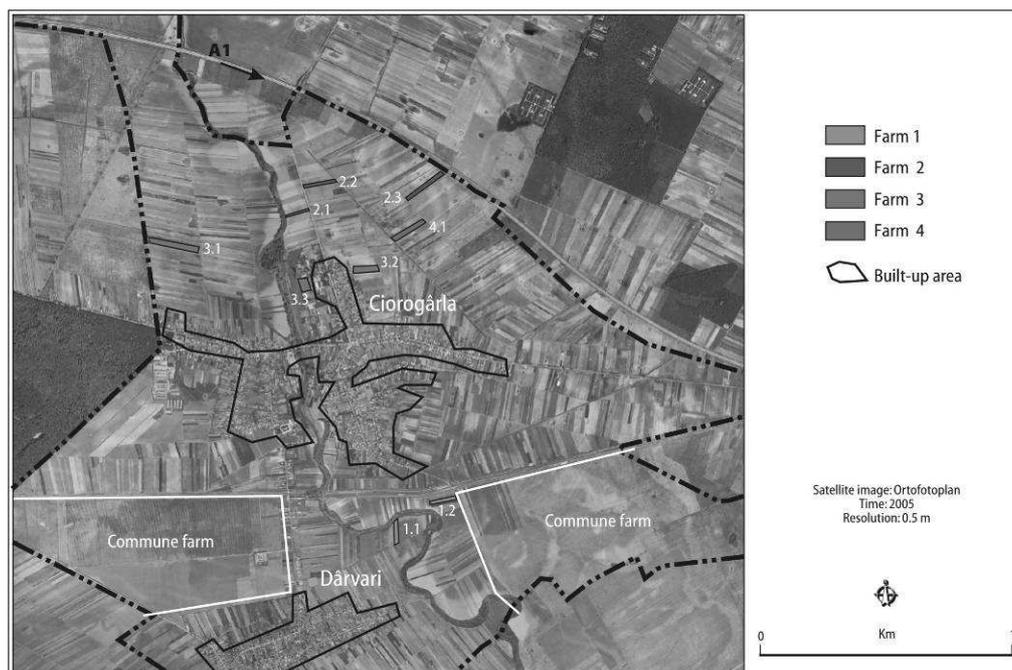


Figure 7. Agricultural land fragmentation in Ciorogârla  
Ortofotoplan and research based on the participatory map

In the case of the four analyzed farmers the total farmland area was between 0.5 ha for farmer number 4 and 2.3 ha for farmers number 1 (table 4). The Januszewski indicator has a higher value of farmland concentration compared to Vânătorii Mici.

Farmers number 2 and have registered values between 0.57-0.58 while farmer number 2 had a higher concentration degree (0.7) with a 2.3 ha farm divided into 2 lots. Farmer number 4 has a less representative case with only a 0.5 ha lot (fig. 7).

Table 4. Agricultural land fragmentation  
Examples of farms in Ciorogârla village, Ilfov county

Farmland	Total number of lots	Maximum area of one of one lots (hectare)	Minimum area of one of the lots (hectare)	Total area of the lots (hectare)	Januszewski Indicator
1	2	1,2	1,1	2,3	<b>0,7</b>
2	3	0,5	0,5	1,5	<b>0,57</b>
3	3	1	0,5	2,25	<b>0,58</b>
4	1	0,5	-	0,5	<b>1</b>

Source: Author` calculation after the participative maps were applied

### Conclusions

The issue of agricultural land fragmentation in the two analyzed villages point out several different aspects. In Vânătorii Mici, the excessive land fragmentation is an impediment in utilizing the ecological potential and its location within the metropolitan area in order to obtain maximum profit

from agriculture. In Ciorogârla the issue of land fragmentation is less important because here the role of agriculture within the local economy is diminished.

The causes that generated the nowadays situation regarding the land fragmentation include:  
*a. the pattern for property inheritance* in the sense

that after the agricultural fields were given back they were fragmented by the family members and that lead to an increase in the lots` number, *b. the historic pattern for the property structure and agrarian policy* relates to the fact that over the time, there weren't any intentions to merge the agricultural fields neither from the landowners nor the state which didn't adopt any legislative policies to favour that course of action.

The interviewed farmers perceived differently the consequences of land fragmentation, insisting that there were both advantages and disadvantages to it. They can diminish the risk of farming the same crop on a single lot by cultivating on different lots with different soils, microclimate and microenvironment and also they can lower the risk of losing production by practicing crops that reach maturity at different moments in time. This crop diversity is useful because it avoids *the top* periods

of work force needed. On the other side the farmers think that land fragmentation is the cause of low agricultural efficiency that hinders the use of optimal agricultural technologies for each crop. They consider that some measurements to merge the lots need to be taken.

The reasons that can favour lot merging are; a. the structure of agricultural lots – with most lots having similar soil-cultivating potential; b. the fact that a series of farmers don't actually live in the village their lots are or are elderly population. The arguments against merging the lots are: diminishing the associative phenomenon due to the moral prestige of the landlords (that fact that some of them administer the lots in personal interest); the land disputes due to the issues appeared from the implementation of the agrarian policies; the lack of functional agricultural lands market.

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