THE IMPACT OF PLOT SPATIAL PROPERTIES ON THE CONVERSION OF ARABLE LAND INTO BRUSHWOOD

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Abstract
Land use change has caught scientist's attention all over the world and in the perspective of globalisation the pressures on agricultural land are increasing. However, the agricultural land abandonment is still evident. This phenomenon has no single definition and its driving forces are varying among different regions and countries. In this paper agricultural land is considered as abandoned while there is evidence of shrub and bushes on agricultural land according to the orthophoto and Estonian base map comparison. The aim of this paper was to test the impact of arable land plot spatial properties: plot area, ratio of arable land area in the surrounding of plot and plot compactness. General hypothesis is that brushwood will more likely occur on the arable land plots with poor spatial properties than on arable land plots with good ones. The study was conducted in 15 rural municipalities across Estonia. Results are showing some impact of the spatial properties on the arable land plots conversion into brushwood. In nine municipalities out of 15, there was an arable plot area without brushwood larger than plots with brushwood and the percentage of arable land area surrounding plots without brushwood was higher in other 9 studied municipalities. As expected, the uncompact arable land plots tend to have more likely brushwood on them than the compact ones. Study results show that the impact of plot area and the ratio of arable land in surroundings of plots on the conversion of arable land plots into brushwood need further studies.
Key words: plot area, shape of the plot, land abandonment.

Introduction

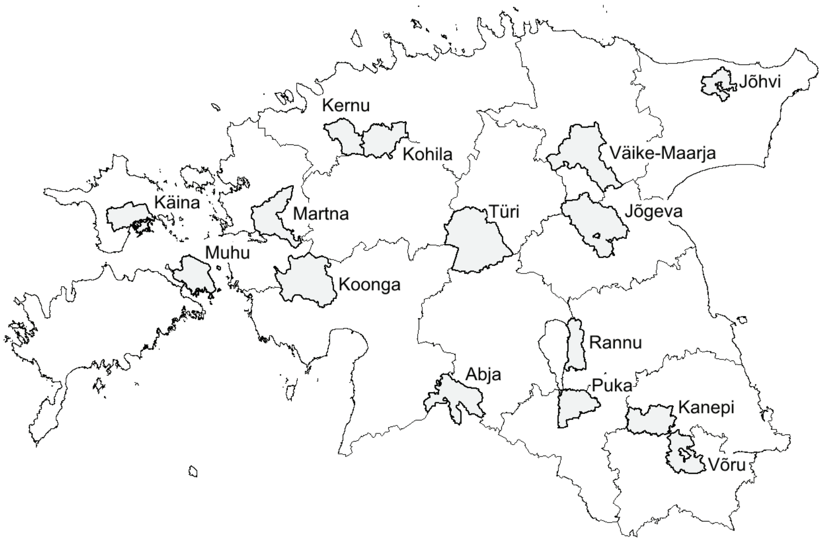
The conversion of arable land into brushwood often occurs if the plot is not cultivated for a certain period of time. It means that land is not used and one can say that land is abandoned. Therefore, the conversion of arable land into brushwood can be studied from the land abandonment point of view. The land abandonment is complicated phenomenon and has been studied in different scales. Some of land abandonment studies are conducted in European scale (Keenleyside and Tucker, 2010; Pointereau et al., 2008) while other studies focused on the smaller problematic areas in different countries: Spain (Zaragozi, et al. 2012), Austria (Silber and Wytrzens, 2006), Poland (Szostak et al., 2013), Latvia (Ruskule et al., 2012), European Russia (Prishchepov et al., 2013).

Abandonment of arable land has manifold character and may be caused by socio-economic, ecological or political factors (Rey Benayas et al., 2007; Zaragozi et al., 2012; Pointereau et al., 2008; Prishchepov et al., 2013; Silber and Wytrzens, 2006; Mander and Kuuba, 2004). Such land abandonment in remote areas may be associated with declining subsidies, low accessibility (distance from roads, farming centres and markets), demographic factors (population density, farmer age and the labour market) and ecological aspects (Baumann et al., 2011; Gellrich and Zimmerman, 2007; Pointereau et al., 2008; Prishchepov et al., 2013; Rey Benayas et al., 2007). In addition, it has been one topic in political discussions (Gellrich and Zimmerman, 2007).

The knowledge about the processes of land abandonment is needed in order to take the right measures at the national or local level (Keenleyside and Tucker 2010). This knowledge is also important because of the pressure from other land use types that affects the future use of agricultural land (Benjamin et al., 2007). The need for agricultural land is increasing worldwide. N. Alexandratos and J. Bruinsma (2012) pointed out that worldwide the area of arable land per capita in 1960 was 0.44 hectare; in 2010 this figure was 0.23 hectare; the projection for the 2050 is 0.181 hectare. J. Bruinsma (2011), B. R. Döös (2002) and FAO (2002) made similar prognoses and projections. All mentioned above refers to the need to study the land abandonment questions. At the same time Keenleyside and Tucker (2010) pointed out that it is difficult to measure and study land abandonment and it is difficult to obtain land abandonment data (Land abandonment..., 2004).

There are few studies about land abandonment in Estonia. Large-scale abandonment was evident in the country in the early 1990 when the major driving force behind this process was socio-economic changes (Mander and Kuuba, 2004). The rate of abandoned arable land was about 32% at this time (Peterson and Aunap, 1998). The study of M. Mandel and S. Maasikamäe (2013) showed that the distance of plots from roads have an impact on the conversion of arable land into brushwood. However, this is not sufficient in order to understand all aspects of arable land abandonment in Estonia.

The aim of this study was to test if there was an impact of spatial properties of arable land plots on the conversion of those plots into brushwood. The general hypothesis of the study is that the occurrence of brushwood on the arable land is more likely on the



Source: author's construction on the basis of Estonian Land Board data.

Figure 1. The location of studied municipalities (study area).

arable land plots with poor spatial properties than on the arable land plots with good spatial properties. The study focuses on the area of plots, the ratio of arable land in surroundings of plots and the shape of plots as the indicators that describe the spatial properties of arable land plots.

The results of the study showed that the spatial properties of arable land have some impact on the processes of conversion of arable land into brushwood. However, this study showed also some methodical problems of such kind of studies and the need to continue the researching the issue.

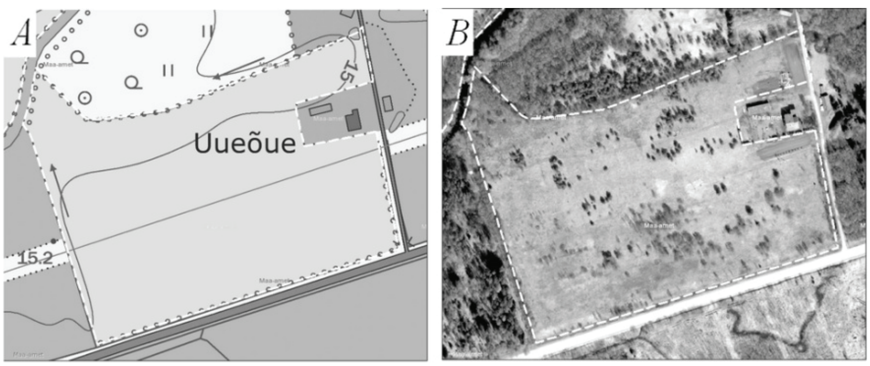
Materials and Methods

According to the administrative division, there are 15 counties in Estonia and one rural municipality from each county was selected for the study. The location of those municipalities is presented in Figure 1. The percentage of arable land of municipalities was the criterion for selection them for the study. The average percentage of arable land in the selected municipalities was the closest to the average percentage of arable land in the respective county. This way different regions of Estonia were included in the study.

The study consisted of the following tasks:

- formation of study units (arable land plots);
- checking the occurrence of brushwood on the arable land plots;
- determination of arable land plots spatial properties;
- testing the hypotheses of the study.

Formation of study units was carried out in the ArcGIS environment and the Estonian National Topographic Database (ENTD) (digital topographic



Source: author's construction on the basis of Estonian Land Board data (http://xgis.maaamet.ee/xGIS/XGis).

Figure 2. Example of brushwood determination process on arable land. There is no brushwood on the arable land according to the topographic map of Estonia (Picture A). The ortophoto map shows the brushwood on the arable land (Picture B). Such arable land plots (marked with a dotted white dashed line) were classified as arable land with brushwood.

map) was used for that purpose. The content of the ENTD is updated continuously and some arable land areas were from the year 2006 while some of them were from the year 2011. The arable land of investigated municipalities was split into undivided and complete pieces (plots). Undivided and complete study units are contiguous areas that are delimited by other types of land (e.g. forest), by roads, ditches, or other linear objects. Study units with the areas less than 0.2 hectares were excluded from the study because small arable land plots are usually a part of small landholdings and not important for contemporary agriculture. Different ArcGIS overlay procedures were implemented for the study unit's formation.

The ortophoto maps of Estonian Land Board geoportal (http://xgis.maaamet.ee/xGIS/XGis) were used for checking the occurrence of brushwood on the arable land plots. Ortophoto maps were available from the period of 2007 to 2011 in geoportal. All arable land plots were divided into two groups: arable land without brushwood and arable land with brushwood. Figure 2 illustrates the case if the study unit was classified as arable land with brushwood. The trees and bushes are clearly visible on the formerly cultivated land.

Three indicators were used to characterize the spatial properties of arable land plots. The area of plots was the first parameter. It is the most common parameter to characterise any piece of land. The second parameter to characterize the spatial properties of arable land plots was determination of arable land ratio (percentage) in the circle with the radius of 700 meters. Figure 3 illustrates that procedure.

Firstly, the centroid was determined for all plots and then the circles with the constant radius R were constructed around all centroids. Figure 3 shows only one circle as an example. Actually, the circles were constructed for all plots and they overlap with each other. Finally, the ratio of arable land inside of each circle was calculated. To do so, the area of arable land inside of each circle was determined by ArcGIS intersect procedure. Then, the area of arable land inside of each circle was divided by the area of circle with 700 metre radius (153.9 hectares).

The third parameter to characterize the spatial properties of plots was the coefficient of compactness. This parameter characterises the shape of plots and it is calculated as the ratio of perimeter of plot to circumference of square whose area is equal to the area of that plot. Thus, the coefficient of compactness for the square equals to one. The value of the coefficient of compactness increases if the shape of the plot becomes more uncompact. More compact shapes of the plots are preferred from land cultivation point of view.

Testing the study hypotheses was the last task of the study. The average values of the spatial properties indicators were calculated for both groups of arable land plots (without brushwood on arable land and with brushwood on arable land). The comparison of average values of above mentioned indicators in two groups allows us to assess if there is difference between them. The Mann-Whitney test was used in order to check the statistical significance (p-value) between the average values of indicators describing the spatial properties of arable land plots. One can conclude that there is an impact of the spatial properties of plots on the occurrence of brushwood on the arable land if the group averages of the indicators describing the spatial properties of those plots are statistically significant. The Mann-Whitney test was used because of non-normal distribution of the indicators describing the spatial properties of investigated arable land plots.

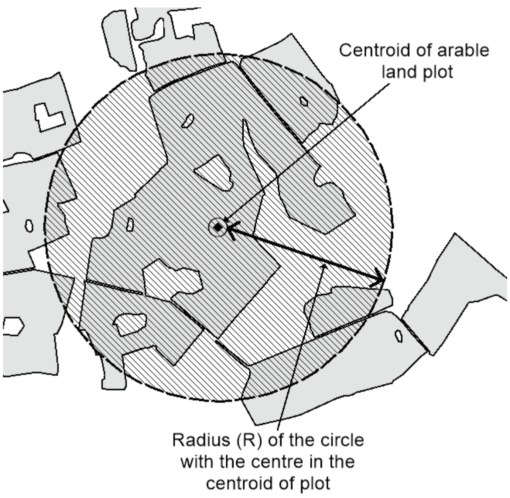


Figure 3. Example of determination of the arable land area inside the circle whose centre coincides with the centroid of an arable land plot. Grey areas are arable land plots, hatched area is the circle whose centre is coinciding with the centroid of arable land plot.

Results and Discussion

The main results of the study are presented in Table 1 and Table 2. The average area of plots (study units) is 12.4 hectares but it ranges from 5.4 hectares (Võru municipality) to 24.3 hectares (Väike-Maarja municipality), see Table 1. The difference is 4.5 times. The minimum area of studied plots (study units) in all investigate municipalities was 0.2 hectares. The reason for that is the elimination of all plots with areas less than 0.2 hectares from the study. The maximum area of plots in Väike-Maarja municipality was 424.4 hectares while in Kanepi municipality this area was 100.6 hectares. The difference is 4.2 times which is similar to the difference of average areas of plots.

The data of Table 1 show that the number of plots without brushwood is greater than the number of plots with brushwood in 12 municipalities out of 15. The number of plots with brushwood is greater than the number of plots without brushwood in Muhu, Puka and Võru municipality. In general, the number of plots with brushwood is about 1.8 times smaller than the number of plots without brushwood. It means that about 35.6 percent out of all investigated plots had in some extent brushwood on them. However, this figure varies among the investigated municipalities. In Martna municipality this figure was only 16.7 percent while in Puka municipality - 54.0 percent. It is necessary to emphasise that the area of brushwood on the investigated plots was relatively small in some cases. For example, on some large plots (100 and more hectares) the area of brushwood was only some hectares.

The comparison of the average areas of plots with and without brushwood shows some unexpected results. In total, the average area of plots without brushwood was less (11.4 ha) than the average area of plots with brushwood (14.2 ha). At the same time in nine municipalities the situation was contrary. For example, in Muhu municipality the average area of plots without brushwood was 2.8 times bigger than the average area of plots with brushwood. The possible explanation for that might be the varying land use conditions in different areas.

Data in Table 2 characterise the impact of two spatial properties on the likelihood of occurrence of brushwood on the arable land. The p-values in this table show whether the spatial properties of plots without and with brushwood are significantly different or not. The ratio of arable land in surrounding of the centroids (the circle with the radius of 700 meters) of the plots is the first spatial property described in Table 2. For all investigated municipalities the average ratio of arable land in the surrounding of the centroids of plots without brushwood is 47.4 percent and the same figure for plots with brushwood is 40.0 percent. The difference is statistically significant. The mentioned difference was not statistically significant for five municipalities (Abja, Jõhvi, Muhu, Puka and Rannu). Also, it came out that the situation among municipalities is different even if the difference

Table 1

Areas of investigated arable land plots

Municipality	Number of arable land plots	Area of plots (ha)			Number of arable land plots by groups		Area of plots by groups (ha)	
		mean	minimum	maximum	plots without brush-wood	plots with brush-wood	plots without brush-wood	plots with brush-wood
Abja	614	13.7	0.20	158.6	376	238	19.4	10.1
Jõgeva	891	15.5	0.20	289.2	711	180	13.7	22.6
Jõhvi	187	14.4	0.21	221.8	132	55	8.6	28.2
Kanepi	994	7.0	0.20	100.6	604	390	4.6	10.6
Kernu	444	9.1	0.21	108.2	303	141	9.9	8.7
Kohila	555	11.1	0.20	114.2	293	262	13.6	8.9
Koonga	497	15.7	0.20	193.1	376	121	12.8	24.9
Käina	449	10.8	0.20	112.8	331	118	11.5	10.5
Martna	436	13.3	0.20	102.5	363	73	14.0	13.2
Muhu	653	7.3	0.20	127.5	306	347	10.4	3.7
Puka	742	6.9	0.20	140.7	341	401	3.9	9.5
Rannu	259	23.7	0.21	193.8	197	62	28.4	22.2
Türi	1147	17.9	0.20	226.1	841	306	18.0	17.9
Võru	1043	5.4	0.20	143.3	501	542	7.2	3.5
Väike-Maarja	664	24.3	0.20	424.3	494	170	22.0	30.8
All investigated municipalities	9575	12.4	0.20	424.3	6169	3406	11.4	14.2

Table 2

The impact of the percentage of arable land in surrounding of plots and compactness coefficient of arable land plots on the likelihood of brushwood occurrence on the arable land

Municipality	Number of plots by groups		Average percentage of arable land in surrounding of plots			Average compactness coefficient of arable land plots by groups		
	plots without brush-wood	plots with brush-wood	plots without brush-wood	plots with brush-wood	p-value	plots without brush-wood	plots with brush-wood	p-value
Abja	376	238	42.5	42.3	0.918	1.26	1.41	0.000*
Jõgeva	711	180	51.6	43.0	0.000*	1.34	1.46	0.000*
Jõhvi	132	55	57.3	53.5	0.463	1.29	1.50	0.000*
Kanepi	604	390	43.1	39.6	0.000*	1.27	1.49	0.000*
Kernu	303	141	34.1	38.6	0.017*	1.25	1.32	0.001*
Kohila	293	262	40.5	45.4	0.001*	1.21	1.35	0.000*
Koonga	376	121	48.7	44.4	0.034*	1.49	1.63	0.000*
Käina	331	118	38.6	45.1	0.002*	1.24	1.40	0.000*
Martna	363	73	44.1	50.6	0.010*	1.36	1.45	0.017*
Muhu	306	347	35.6	35.4	0.613	1.20	1.44	0.000*
Puka	341	401	39.0	36.6	0.086	1.24	1.45	0.000*
Rannu	197	62	57.7	63.6	0.061	1.35	1.50	0.002*
Türi	841	306	45.0	53.7	0.000*	1.33	1.46	0.000*
Võru	501	542	34.2	40.3	0.000*	1.26	1.53	0.000*
Väike-Maarja	494	170	56.3	50.1	0.002*	1.32	1.44	0.000*
All investigated municipalities	6169	3406	47.4	40.0	0.000*	1.30	1.46	0.000*

* - the difference between groups of plots without brushwood and with brushwood is significant at a confidence level of 95% ($p < 0.05$)

between the two compared groups (plots with and without brushwood) is statistically significant. In five municipalities (Kernu, Kohila, Käina, Türi and Võru) the ratio of arable land in surroundings of plot centroids was higher for the plots with brushwood compared with plots without brushwood. The result could be explained with the local differences, but this result needs deeper investigations. The similar difference that is not easy to explain was observed in the study of impact of distance of plots from the roads on the conversion arable land into brushwood (Mandel and Maasikamäe, 2013).

There is a clear impact of the plots' shape on the likelihood of brushwood occurrence on the arable land plots. The uncompact arable land plots tend to have brushwood more likely than compact plots. The difference between average coefficients of compactness for plots without brushwood and with brushwood is statistically significant for investigated municipalities and in general.

One of the problematic aspects of this study is the selection of the radius for circles surrounding the plot centres in order to calculate arable land ratio inside those circles. The problem can be divided into two parts (or questions). The first question is: should the radius be the same for all plots? If so then what is the right radius? The example on Figure 4 clearly illustrates that the ratio of arable land in the circle surrounding the plot centroid will change in some cases if the radius of the circle will change (see Picture A on the figure 4). In some cases (see Picture C and Picture D on figure 4) the change of the radius of the

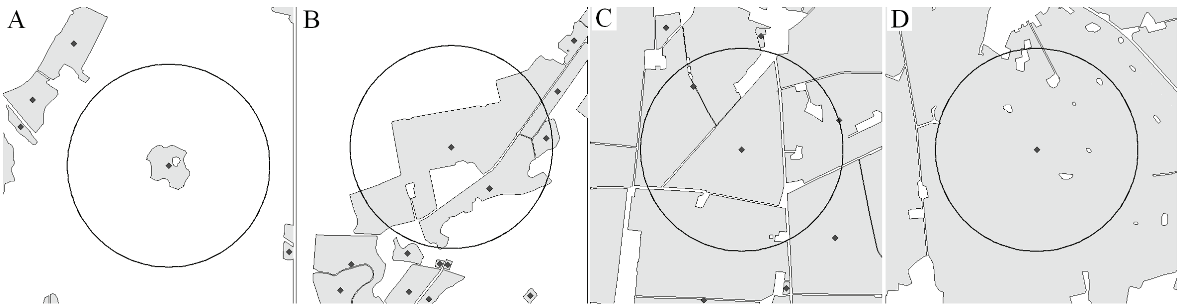


Figure 4. Examples of arable land plots inside the circle surrounding the centroid of plots.

circle surrounding the centroid of the plot will not have an impact on the ratio of arable land in this circle. The arable land ratio in such cases will be close to 100 percent anyway. However, if the radius of the circles will increase, there will be a situation that the ratio of arable land inside the circles is definitely less than 100 percent.

The second question arises if selection is in favour of the different radiuses of the circles surrounding the plot centroids. The question in this case will be: what is an argument for determination of varying radiuses? Should one keep in mind the spatial properties of the particular plot or is it necessary to consider a wider area? The average ratio of arable land in different regions varies. For example, the arable land ratio in Rannu municipality is about 40 percent while in Koonga municipality that figure is only 20 percent. The average area of arable land plots is also varying: in Rannu municipality that figure is almost 24 hectares while in Võru municipality only 5.4 hectares. The implementation of different radiuses for the circles surrounding the plot centroids allows taking into consideration the local conditions. At the same time it will be difficult, if not impossible, to compare the figures of different regions.

It is necessary to note that the result of the study does not mean that plots with the poor spatial properties will definitely be abandoned and converted to brushwood. The results of the study show that if the land abandonment and conversion of arable land into brushwood occur, it will more likely happen on the plots with poor spatial properties. It is somehow controversial that land abandonment occurred simultaneously with the situation when the area of arable land per capita in the world is decreasing. On the other hand, it shows that the land abandonment and conversion of arable land into brushwood is a complicated phenomenon.

The treatment of all plots in the same manner is the limit of the study. The problem is that small arable land plot, for example five hectares, is likely a part of one parcel and it is managed by one owner. The large arable land plot, for example 150 hectares, is probably divided among many owners and if one of them does not use his/her land then the whole plot was classified as arable land with brushwood. In this respect, the methodology of the study on the conversion of arable land into brushwood needs elaboration.

In this study, the study area of arable land plots was not considered. Small plots, for example less than five hectares, were treated in the same way as large plots, for example more than 100 hectares. Also, the area or the ratio of brushwood on the plot was not considered. The treatment of all plots in the same way can be considered as a limitation of the study. This aspect needs special attention in further studies.

Conclusions

1. The results of the study show that spatial properties of arable land plots can have the impact on the conversion of arable land into brushwood. There are clear indications that uncompact arable land plots tend to have more likely brushwood on them than the uncompact plots.
2. The impact of the ratio of arable land in surroundings of the plots centroids is different among investigated regions. In general, the ratio of arable land plots in surroundings of the plots without brushwood is higher (47.4 percent) than in surroundings of the plots with brushwood (40.0 percent).
3. There are no clear relations between the plot area and the likelihood of brushwood occurrence on arable land. The results of the study are contradicting in this respect.
4. The contradicting results of the present study indicated that local conditions (spatial properties land) of the regions must be investigated more deeply.

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