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# METHODOLOGY FOR THE DETERMINATION OF PERI-URBAN AREAS ON THE BASIS OF DATA OF LAND TYPE AND USE BY EXAMPLE OF THE TOWN OF TARTU

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**Abstract.** Development processes take place everywhere, but they are more observable in urban areas and peri-urban areas. Regulations for urban areas are usually well developed, but the situation is less clear for peri-urban areas. Peri-urban areas sometimes have land use conflicts, or competition for the land occurs. Meanwhile, it is quite problematic to determine where the peri-urban area ends and the rural area begins. The aim of the paper is to propose a method for the determination of the peri-urban areas around the town of Tartu according to data of land use types and land use. The study was carried out around the town of Tartu in Estonia. Ten buffer zones have been created; each buffer zone was two kilometres in width. Cluster analysis was used. It demonstrated that the first two zones differ from others and the width of the peri-urban areas around Tartu is about four kilometres.

**Key words:** peri-urban area; cluster analysis; Estonia.
**JEL code:** R11, Q15

## Introduction

Urbanization, urban sprawl and changes in peri-urban areas are topics that have frequently been covered by different authors. Polarization of territory between urban and rural areas is still an important question. Quite often the authors handle the urbanization as a negative phenomenon because it represents an unfavourable impact on natural resources, economic health and community character (Wilson et al., 2003). The conflicts between agricultural use and other usages have also been discussed (Heimlich & Anderson, 2001; Maasikamäe et al., 2011; Maasikamäe et al,. 2014).

The concept of peri-urban areas is nuanced. This area is neither urban nor purely rural in the traditional sense (OECD, 1979); it is a mixed area under urban influence but with a rural morphology (Caruso et al., 2001). Urbanization occurs when rural lifestyles are replaced by urban ones (Antrop, 2000). The parameters describing the peri-urban areas fall into different categories. It is possible to distinguish physical, social and economic aspects of variables that characterize the peri-urban areas (Budiyantini & Pratiwi, 2016).

The identification of the spatial context of peri-urban areas is complex and therefore it is problematic to determine where the urban settlement area ends and the peri-urban area starts. Peri-urban areas have been spatially defined by different authors. For instance, Dutta (2013) has presented transformation classes between rural and urban areas as natural, rural, transitional and urban. Rakodi (1999) said that peri-urban areas are the transition zone between fully urbanised land in cities and predominantly agricultural areas. This type of area is characterised by mixed land uses and indeterminate inner and outer boundaries, and typically is split between a number of administrative areas. Ravetz et al. (2013) defines peri-urban areas as a new kind of multifunctional territory which is determined by relatively low population density, scattered settlements, high dependence on transport for commuting, fragmented communities and lack of spatial governance. According to the PLUREL project, the peri-urban area is defined as the area between the urban settlement and the rural hinterland (Piorr et al., 2011).

The determination of peri-urban areas may depend on the usage of selected indicators. Several authors have used landscape metrics, socio-economic indicators or a combination of both (de Ferreiro et al., 2016; Budiyantini & Pratiwi, 2016).

Some previous studies exist on this topic for Estonia. For example, Roose et al. (2013) focused on land use policy directed at suburbanization on the basis of the spatial

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analysis of land use. The spatial extent of urban development follows the borders of the five adjoining municipalities of Tartu, which were defined as a peri-urban zone. They used cartographic and landscape metrics analysis for exploring land use processes and dynamics. Additionally, they used master plans and thus the processes in the peri-urban zone can be well tracked.

One of the features of the peri-urban areas is that different land use types compete for land. For example, agricultural producers are interested in the continuation of farming, while real estate developers want to convert the agricultural land into built-up land. The peri-urban area is also vulnerable to uncontrolled development, which can have a negative impact on the use of agricultural land (Maasikamäe et al., 2011). Furthermore, the need to protect valuable agricultural land against vulnerable activities, including in peri-urban areas, has been under discussion in Estonia (Maasikamäe et al., 2014).

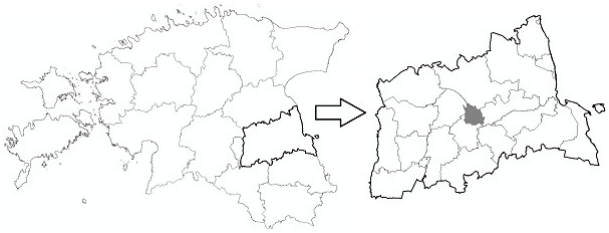
The geographical determination of peri-urban areas is challenging. For that reason, the focus of this study is on the physical aspect of the peri-urban areas. The data about land use types and land use have been analysed. The aim of the paper is to propose a method for the determination of the peri-urban area around the town of Tartu according to the data of land use types and land use. There are two research questions: *i*) is it possible to use cluster analysis for determination of the difference between peri-urban and rural areas around the town of Tartu, and *ii*) are there some differences between land use types and land use in peri-urban and rural areas around the town of Tartu?

The paper is structured as follows: first, the methodology of the study is introduced; second, the result and discussion are provided; third, the conclusion, proposals and recommendations are presented.

## Methodology

The study was carried out using the surroundings of the town of Tartu in Estonia. ArcGIS and Statistica (version 13) software were used for the study.

Tartu is situated in Southern Estonia. The location of the study area is presented in Figure 1. Tartu, with its population about 100,000 in an area of 38.9 square kilometres, is the second largest city in Estonia. The urban area of Tartu consists of the central city of Tartu and of five neighbouring parishes. The population of Tartu's urban area is 120,929 (2014), of which 81 % live in the town of Tartu. The population of the area has been growing particularly in suburban areas. According to the analysis of the demographic development in the past 20 years, Tartu has undergone a process of demographic decentralization and suburbanization (City of Tartu, 2015).



***Source: author's compilation based on the Estonian Topographic Database***

Fig. 1. **Location of the town of Tartu**

The implementation of cluster analysis for the determination of the differences between peri-urban and rural areas was the main idea of the methodology. It was assumed that the indicators that describe the land use types and land use in the peri-urban area differ from rural area. Furthermore, it was predicted that the cluster analysis would make separate clusters for peri-urban and rural areas.

For that purpose, the first 10 buffer zones were created around the town of Tartu. The width of the zones is two kilometres. The schematic location of the buffer zones around the town of Tartu is presented in Figure 2.

The following digital maps from the Estonian Land Board were the main data sources for

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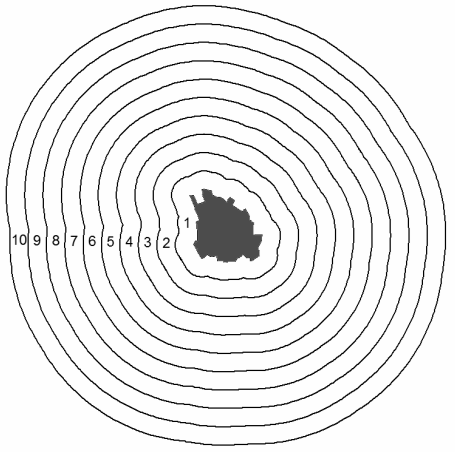
calculation of the indicators that described the data about land use types and land use characteristics in particular zones:

- the Estonian Topographic Database provided data about the land use types (on 01.01.2016);
- the map of cadastral boundaries provided data about location of boundaries and the intended purpose of the parcels (on 01.01.2016).




***Source: author's compilation based on the Estonian Topographic Database***

Fig. 2. **Buffer zones around the town of Tartu**

For the characterization of land use types and land use by zones, all land objects (for example, parcels) were related to a particular zone. However, it happened that some objects were locating simultaneously in two zones because the zone boundaries and object boundaries did not match exactly. The belonging of objects to a particular zone has been determined by the location of their centroids in the zones.

The competition for land between agricultural land use and non-agricultural land use is characteristic for the peri-urban areas. For that reason the main indicators that characterised the use of agricultural land (e.g. percentage of arable land) were selected on the one hand. The indicators that characterised the built-up land (e.g. percentage of residential land) and transportation land were used in the study on the other hand.

The indicators of the zones surrounding the town of Tartu can be divided into two groups. The first group of indicators has been used for cluster analysis and the following indicators for each zone were calculated:

- percentage of profit-yielding land (hereinafter AFL.rat);
- percentage of residential land (hereinafter REL.rat);
- percentage of transportation land (hereinafter TRL.rat);
- percentage of arable land (hereinafter ArL.rat);
- average size of the profit-yielding land parcels (hereinafter AFL.area);
- average size of the residential land parcels (hereinafter REL.area);
- average size of the arable land plots (hereinafter ArL.area);
- density of the road network (km/km$^2$) (hereinafter DeRN).

The percentage of profit-yielding land (AFL.rat), the percentage of residential land (REL.rat) and the percentage of transportation land (TRL.rat) were calculated by dividing the total area of parcels of particular type of intended purpose of land in the zone by the total area of that zone and multiplying by 100. Formula 1 describes the general procedure for those calculations.

$$X.rat = S.cad / S.zone \times 100 \quad (1)$$

Where:

$X.rat$ is the percentage of land of intended purpose in the zone (AFL.rat, REL.rat or TRL.rat);

$S.cad$ is the total area of parcels of a particular type of intended purpose of land in the zone and

$S.zone$ is the total area of a particular zone.

A similar procedure has been implemented for calculation of the percentage of arable land in the zones (ArL.rat). The only difference is that the total area of arable land in the zones has been used instead of the total area of parcels of a particular type of intended purpose of the land. Data from the Estonian Topographic Database have been used for determination of the area of arable land in the zones.

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The arithmetic means of the average size of the profit-yielding land parcels (AFL.area) and the average size of the residential land parcels (REL.area) has been calculated by zone and by the type of intended purpose. The data were obtained from the digital map of cadastral boundaries.

Estonian Topographic Database data have been used for the determination of an average area of the arable land plots (ArL.area). The arable land plot is an area of arable land that is delimited by other types of land (e.g. forest), by roads, ditches, or other linear objects. The average areas of arable land plots have been calculated by zone as the simple arithmetic means.

Estonian Topographic Database data have also been used for the determination of the density of the road network (DeRN). The total length of state and local roads in zones was divided by the total area of those zones.

The second group of indicators have been used only for the comparison of the cluster analysis results. This group of indicators consists of the following indicators:

- percentage of the business and production land in the zones (hereinafter BPL.rat);
- average size of the business and production land parcels (hereinafter BPL.area);
- the average compactness of profit-yielding land parcels (hereinafter comp.AFL);
- the average compactness of the residential land parcels (hereinafter comp.ReL);
- the average compactness of the business and production land parcels (hereinafter comp.BPL).

The percentage of the business and production land in the zones (BPL.rat) has been calculated using the same rule as the percentage of the profit-yielding land (AFL.rat), the residential land (REL.rat) and the transportation land (TRL.rat), according to Formula 1. The average size of the business and production land parcels (BPL.area) has been calculated by zone as the arithmetic means of areas of parcels of that type of intended purpose of the land.

The coefficient of compactness describes the shape of plots. Formula 2 has been used for the calculation of the compactness of each parcel.

$$K = P / \sqrt{4 \times S} \qquad (2)$$

Where:

$K$ is the coefficient of compactness of the parcel;

$P$ is the actual perimeter of the parcel and

$S$ is the area of the parcel.

The necessary data for determination of the coefficients of compactness have been obtained from the map of cadastral parcels boundaries.

The average indicators of compactness (comp.AFL, comp.ReL and comp.BPL) have been calculated by zone as a simple arithmetic means of coefficient of compactness of the parcels of particular type.

The K-mean clustering technique has been used for detection of (for distinguishing) the peri-urban and rural areas. The final number of clusters was set to two. All data for the cluster analysis have been standardized because of the different scales of different indicators.

The cluster analysis has been carried out in two variants. All eight indicators were included for the first variant of the cluster analysis. Five indicators have been used for the second variant of cluster analysis. Percentage of arable land in the region (ArL.rat) and the average area of the arable land plot (ArL.area) were excluded from analysis because of the relatively small differences in the means of those clusters. The graphical plot of the means of clusters (one of the outcomes of the cluster analysis in the Statistica software) has been used for the evaluation of the differences of the mentioned means. The density of the road network in the region (DeRN) was excluded from the analysis because this indicator described the transportation and traffic conditions as the percentage of transportation land in the region (TRL.rat).

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Finally, the values of different indicators have been calculated for peri-urban and rural areas. Those values of indicators allowed the land-related characteristics of peri-urban and rural areas to be compared. The calculated indicators for the comparison of peri-urban and rural areas can be divided into two types. The first type of indicators was computed by dividing the total area of a particular land use type (for example, total area of arable land in the region) with the total area of that region. The percentage of profit-yielding land in the region is an example of that type of indicator. It is not possible to use the tests for evaluation of the statistical significance of the differences between such indicators calculated for different regions.

For some indicators, for example, the average area of a residential land parcel, it is possible to use the tests for the evaluation of the statistical significance of the differences between peri-urban and rural areas. The results of the comparison of the peri-urban and rural areas are presented in separate tables. If applicable (Table 2), the statistical significance level has been set to $\alpha=0.05$.

## Research results and discussion

The main result of the cluster analysis is the division of the zones around the town of Tartu into two clusters. Zones one and two formed the first cluster and the remaining zones (3-10) constituted the second cluster. The results were the same in both variants of clustering. However, the results of the clustering show only that zones one and two around the town of Tartu differ from the other zones (3-10) according to the clustering indicators. The comparison of different indicators that describe the land use type and use in the peri-urban and rural areas gives more information about the clustering results. Table 1 and Table 2 present indicators which describe land use type and use in the peri-urban and rural areas. Beside the indicators that have been used for clustering, Table 1 and Table 2 contain some indicators that have not been used for clustering. The comparison of indicators that have not been used for clustering shows that the peri-urban and rural areas can differ by more indicators than those that have been used for clustering. It is additional evidence that the land use type and use in peri-urban and rural areas is different.

Table 1 presents the indicators for which it is not possible to implement tests for the evaluation of the statistical significance of differences between comparable indicators.

Table 1

**General indicators describing land use type and use in peri-urban and rural areas**

| No | Indicator | Peri-urban area (zones 1 and 2) | Rural area (zones 3 to 10) |
|---|---|---|---|
| 1 | Percentage of profit-yielding land | 65.45 | 88.25 |
| 2 | Percentage of residential land | 10.34 | 2.21 |
| 3 | Percentage of transportation land | 4.85 | 1.31 |
| 4 | Percentage of arable land | 45.17 | 38.42 |
| 5 | Density of road network (km/km2) | 2.85 | 2.04 |
| 6 | Percentage of business and production land | 3.91 | 0.64 |

***Source: author's calculations based on Estonian Land Board data***

The comparison of indicators in Table 1 shows that the land use type pattern in the peri-urban area is less agriculture oriented than in the rural area. The percentage of profit-yielding land in the peri-urban area is less than in the rural area. Profit-yielding land consists of agricultural and forest land. In contrast, the values of other indicators in Table 1 (rows 2-6) are higher for the peri-urban area than for the rural area. This means that in the peri-urban area there is more residential, business and production land and there is a denser road network than in the rural area. Moreover, it is necessary to notice that the percentage of arable land in the peri-urban area is higher than in the rural area. The possible explanation of that phenomenon is that the ratio of forestland is higher and the ratio of arable land is lower in rural areas.

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The differences in five out of seven indicators for the peri-urban area and for the rural area are statistically significant. The average size of the profit-yielding land parcels, the average size of the residential land parcels and the average size of the business and production land parcels (rows 1, 2 and 4 in Table 2) are less in the peri-urban area than in the rural areas. It means that the land use pattern in peri-urban areas is more fragmented – the parcels are smaller. However, the difference between the average area of arable land plots in the peri-urban areas and in the rural areas (row 3 in Table 2) is not statistically significant.

Table 2

**The average indicators describing land use type and use in the peri-urban and rural areas**

| No | Indicator | Peri-urban area (zones 1 and 2) | | Rural area (zones 3 to 10) | | t- stat | p-value |
|---|---|---|---|---|---|---|---|
| | | Avg. | No. of obser. | Avg. | No. of obser. | | |
| **The indicators included in the cluster analysis** | | | | | | | |
| 1 | Average size of the profit-yielding land parcel (ha) | 7.72 | 1375 | 11.23 | 12739 | 2.56 | 0.011 |
| 2 | Average size of the residential land parcel (ha) | 0.26 | 6217 | 0.52 | 6861 | 31.85 | 0.000 |
| 3 | Average area of the arable land plot | 11.90 | 608 | 12.17 | 5122 | 0.27 | 0.786 |
| **The indicators not included in the cluster analysis** | | | | | | | |
| 4 | Average size of the business and production land parcel (ha) | 0.69 | 900 | 0.91 | 1138 | 2.97 | 0.003 |
| 5 | The average compactness of profit-yielding land parcels | 1.23 | 1375 | 1.24 | 12739 | 1.94 | 0.052 |
| 6 | The average compactness of the residential land parcels | 1.06 | 6217 | 1.11 | 6861 | 16.41 | 0.000 |
| 7 | The average compactness of the business and production land parcels | 1.08 | 900 | 1.21 | 1138 | 5.77 | 0.000 |

***Source: author's calculations based on Estonian Land Board data***

The shape of the parcels is one of the indicators that also characterises land use patterns. The residential land parcels and the business and production land parcels (rows 6 and 7 in Table 2) are more compact in peri-urban areas than in rural areas. The possible explanation for that phenomenon is that the residential land parcels and the business and production parcels in peri-urban areas are more frequently the results of planning activities. The boundaries of residential land parcels in rural areas are not generally determined by planning activities.

It is necessary to notice that the difference between the compactness of profit-yielding land parcels in peri-urban areas and in rural areas is not statistically significant (row 5 in Table 2). The average area of an arable land plot in the peri-urban area is 11.90 hectares and 12.17 hectares in rural areas. It can be supposed that the area of the agricultural land plots can be bigger 20 kilometres or more from the town of the Tartu.

The results of the study showed that cluster analysis as a method could be used for delimitation of the areas around town (peri-urban areas) and rural areas. However, this study has some limitations and there are questions that need further researching.

The width of buffer zones around Tartu was set at two kilometres. This was done on the basis of an expert opinion. It is possible to increase or to decrease the width of buffer zones. Both options are technically possible and both options have their advantages and disadvantages.

The decrease of the width of buffer zones gives (at least theoretically) the possibility to determine more precisely the boundary between the peri-urban area and the rural area. In the

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present study, this precision was two kilometres. In theory, it was possible to get the width of peri-urban areas with increments of two kilometres (2, 4, 6 kilometres and so on). The decrease of the width of buffer zones, for example, to one kilometre would improve the precision of the determination of the boundary between peri-urban areas and rural areas.

The decreasing of the width of buffer zones has two consequences that should be kept in mind. First, the amount of necessary calculations will increase. The second issue is about the determination of the belonging of different land objects, for example, parcels to the particular zone. The problem is that some objects can be located simultaneously in two or more zones as has been explained in the methodology part of the paper. The number of objects that will be located in neighbouring zones simultaneously will increase if the width of zones decreases.

The question of the precision of the detection of the boundaries between peri-urban and rural areas is an important issue for future studies. It is clear that there is no distinct line on the field that is separating peri-urban and rural areas. However, such kind of imaginary separation will be needed for some purposes. Knowing this line can be important, for example, for researching real estate development processes or for planning purposes.

The maximal width of the study area around towns is also an issue for discussion. In this study, the total width of all zones was 20 kilometres, in order to avoid the impact of other towns. The question can be asked: will it improve the quality of the results if the study area is extended? This can also be an issue for future studies.

In this study, the determination of the peri-urban areas was based on the indicators that described different land use types and use characteristics. It is possible to use different indicators, which can be physical, social and economic (Budiyantini & Pratiwi, 2016). However, it is not so easy to use some data, for example, population density or number of enterprises, by buffer zone if the width of the zone decreases. For example, Statistics Estonia (https://estat.stat.ee/StatistikaKaart/VKR) provides digital maps of population density by squares of one kilometre by one kilometre. There can be problems with the precision of the determination of the population density for the whole buffer zone if both the unit on the population density map and the width of buffer zones are equal.

The investigation of the surroundings of other towns of Estonia is also an important topic for future studies. The result of this study can be the basis for the subsequent studies. The scope of such studies is wide sand diverse.

## Conclusions, proposals, recommendations

1) The results of the study showed that cluster analysis could be used for the determination of differences between the peri-urban and rural areas.
2) According to this method, the width of peri-urban areas around Tartu is about four kilometres.
3) The comparison of the indicators in peri-urban and rural areas around the town of Tartu verified that indicators of land use type and use in peri-urban and rural areas are different.
4) This method is quite simple. It is feasible to implement it around the other towns in Estonia (and in Europe). It can also be used as a tool to monitor changes. It is possible to compare data for the peri-urban area and rural area in different years.
5) It is possible to improve methodology and extend the spectrum of parameters for comparing the study results.

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