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CHANGES IN THE LOCATION OF COW HERDS IN POLAND IN LIGHT OF SINCLAIR'S LOCATION THEORIES

Key words: central city, cow numbers, livestock density, location

ABSTRACT. The purpose of this study was to determine the changes in the location of cow herds around 11 biggest Polish cities in 1960, 1973, 1996 and 2010. Membership of districts was determined based on the smallest distance between the district's capital and one of the 11 central cities. The area surrounding the cities was split into eight 25-kilometer rings; the last (eighth) ring constitutes territories located over 175 km away from the nearest central city. Calculations were based on cow numbers and area of agricultural land at a district level. This allowed to specify cow density per 100 hectares of agricultural land. The study found that changes occurred in the distribution of cow numbers in territories surrounding central cities. Semi-peripheral areas located around the biggest central cities witnessed a reduction in cow density. This suggests that these territories are anticipated to be used for urban development purposes. These processes gained momentum only after 1990. Conversely, this trend was not observed in agglomerations with a population of less than one million. Milk production was mainly relocated to peripheral areas (located 50 to 124 km away from central cities defined in this study). The intensification of environmental measures in Europe suggests that action be taken to slow down the territorial concentration of cow herds in Poland. This study also confirmed the theory by Sinclair who claimed that animal production should be located in remote areas.

INTRODUCTION

International literature includes many papers addressing the location of agricultural production in urban areas or around metropolitan areas [e.g. Berry 1979, Lawrence 1988, Henderson 2005]. This issue was also tackled by Polish researchers [Sroka 2015, Nalej 2016, Busko, Szafrańska 2018, Sroka et al. 2018]. However, to the author's knowledge, no research has been carried out focusing on the location of agricultural production on a countrywide basis, except for a paper by Benedykt Pepliński, who studied the location of pig and sow herds in relation to11 biggest Polish cities [Pepliński 2019].

Polish agriculture is experiencing rapid changes noticeable in many areas, including production industrialization processes driven by production concentration. This is especially true for production processes considered in two contexts: that of an average farm size and animal numbers [Sobczyński 2011, Olszańska 2012, Pepliński 2019], and that of territorial distribution [Kopiński 2014, Ziętara, Adamski 2014, Pepliński 2017, 2019]. Concentration processes accelerated considerably after 1990. However, the progress is

too slow compared to other EU countries, especially in the context of the rapidly growing minimum scale of farming operations to provide resources for development [Sadowski et al. 2019, Pepliński et al. 2019]. In the case of most European countries with a similar agricultural structure to that of Poland, the number of cows exceeds 100, while in Poland, those with 20-29 cows can still be considered development farms [Pepliński 2019]. However, a rapid increase in the minimum scale of this production type should be expected. This forces farmers to decide whether they want to commit themselves to a future in that very type of production activity, or look for other sources of income. In addition to the most important determinants of these decisions the following, among others, are included: farmer age, presence of a successor and financial capacity [Sroka et al. 2018]. There is also a location aspect (especially in relation to farms within impact range of large urban centers) which, however, is neglected in most cases. Sinclair indicated, as early as the middle of the 20th century, that urban expansion and the anticipation of urban use of agricultural areas close to large urban centers is leading to the extensification of agricultural production and that the level of intensity is increasing as the distance from central centers increases (Thünen›s inverted circles) [Sinclair 1967, Kupkova 2007, Siekierski 2008]. In view of the above, the purpose of this study was to determine the changes in the location of cow herds around 11 biggest Polish cities in 1960, 1973, 1996 and 2010.

MATERIAL AND METHODS

In the analysis of the location of plant production, Sinclair referred to Thünen›s theory of circles, but took into account three additional factors which, in his opinion, influenced land use in modern industrial areas. He included them [Kupkova 2007] as follows:

– modern production organization preferring large-scale production and the mass transport of agricultural products,
– the national or worldwide market,
– competitiveness between different agricultural land uses, taking increased competitiveness of non-agricultural land use into account.

A decline in transport costs, the development of logistics and the extension of shelf life have resulted in almost all sales of agricultural products being taken over by the agri-food industry, which is located almost entirely outside central centers. Sinclair stated that, in the first circle, closest to the agglomeration, production should be typical of urban agriculture, with extensive production and increased set-aside. In the second circle, grazing land use and field tillage are to come first, while in the next circle, field tillage should be supplemented by milk production. In the farthest zone, intensive agricultural production requiring good and stable conditions and specialized animal production using fodder crops should be carried out [Peplinski 2019].

The time scope of the analysis was determined based on availability of data from the Central Statistical Office. Because of prolonged restocking of cows and numerous amendments to the government's agricultural policy in Poland, 1960 was set as the initial year. 1973 was the last year for which essential data was retrieved with respect to the 1957-1965 administrative division of Poland. In turn, 1996 and 2010 are the years of the first and last census including cow numbers at a district level in the current administrative

division. Central cities were defined as the top 10 Polish largest cities in 2010, the last year covered by the analysis. Because of the size of the Silesian agglomeration, following Wojciech Sroka et al. [2018], this study also included Katowice, Poland's 11th largest city and the largest one in the agglomeration of 14 cities.

Calculations were based on cow numbers and area of agricultural land at a district level. This allowed to specify cow density per 100 hectares of agricultural land. The distance between the district town and the center of the central city, determined based on Google Maps data, was used as the distance to the central city. Of the options proposed by Google Maps, the shortest route was selected; highways were excluded because most of them have only been built recently. Membership of districts was determined based on the smallest distance to one of the 11 central cities. Under this assumption, districts of the Wielkopolskie Voivodship found themselves located in impact areas of as many as four central cities (Bydgoszcz, Łódź, Poznań and Wrocław). Another simplifying assumption was that all cows and land in a district are located at a distance equal to that of the district capital from the central city.

Following Benedykt Pepliński [2019], this study defined eight 25-km rings, with the last one representing districts located 175.0 km (or more) away from the nearest central city. This allowed the whole country to be surveyed. Because of the uneven territorial distribution of central cities defined in this study, 8 rings were defined for only five of them; and only 5 rings were defined for Katowice and Bydgoszcz. Following Immanuel Wallerstein [1974], the rings were divided into three zones:

– semi-peripheral, i.e. located within 25 km from the center (ring 1);
– peripheral, i.e. located within 25-125 km from the center (rings 2 to 5);
– outer, i.e. located over 125 km away from the center (rings 6 to 8).

RESULTS OF THE STUDY

Data shown in Figures 1-4 suggest that the smallest differences in cow density within the impact range of most central cities were recorded in 1960, and grew in three ways in each of the years covered by the analysis.

Firstly, there were growing differences in average cow density across the impact range of particular cities; that trend accelerated in the market economy era, i.e. after 1990. In 1973, the difference in cow density between the impact range of Gdansk and Cracow was 89%, whereas in 2010, cow density varied by a factor of 7.8 between the impact range of Szczecin and Białystok.

Secondly, there were growing differences in territorial concentration within the impact range of most central cities. In 1960 and 1973, disparities were small but started to increase faster after 1990. The average difference between rings with the lowest and highest cow density, across all central cities covered by this study, went up from 55%–63% in 1960 and 1973 to 135% in 1996 and 335% in 2010.

Thirdly, the size of the central city proved to be significant. Over the years covered by this study, cities with a metropolitan area population of one million or more had an increasingly visible impact on cow density in the two rings located closest to the center; in the other four smallest cities (Białystok, Bydgoszcz, Lublin and Szczecin) that impact was much weaker.

In 1960, cow density in areas located within 25 km of the center of 11 cities, covered by this study, was 3.9% above the countrywide average figure; higher numbers were recorded only in areas located within 50-99 km (ring 3 and 4) of central cities (Figure 1). The first ring was the one with the highest cow density in the case of three cities (Białystok, Gdańsk and Lublin) and the one with the lowest cow density only in the case of two cities (Katowice and Warsaw). On average, the lowest concentration of cows was recorded in outer areas, especially in those located over 175 km away from central cities; this is where cow density was over 25% lower, on average. However, in the last rings surrounding Białystok and Lublin, cow concentration was above the average level for the entire range of impact of these cities. The smallest and largest disparities in cattle concentration were found in the range of impact of Łódź and Cracow, respectively.

1973 saw a narrowing of the gap in average animal density between rings. Indeed, the difference between levels recorded in the first 7 rings was not in excess of 5%; in areas located over 175 km away from central cities, it was only 14% below the countrywide average figure (Figure 2). Compared to 1960, no considerable changes were experienced in central cities, except for a significant increase in cow density in the first ring surrounding Szczecin and Wrocław. This was primarily due to the location of state-run milk farms close to those cities.

As mentioned above, the shift to a market economy triggered growing differences in cow numbers across the territory. Pig and sow farming was also affected by that process [Pepliński 2019], which could suggest that these trends prevailed in most agricultural sectors in Poland. An above-average decrease in cow density was recorded in western voivodeships, while eastern voivodeships strengthened their importance (Figure 3). Also, a decreasing cow density was noticeable in the first, second and seventh ring. The greatest decline was experienced in the outer ring (with cow numbers being nearly 25% below the national average level). Note also that in the case of Wrocław and Bydgoszcz, it was ca. 44% less than in their entire area of impact; and it was 55-63% less in the case of Katowice and Szczecin, and as much as 70% less in the case of Warsaw. The latter

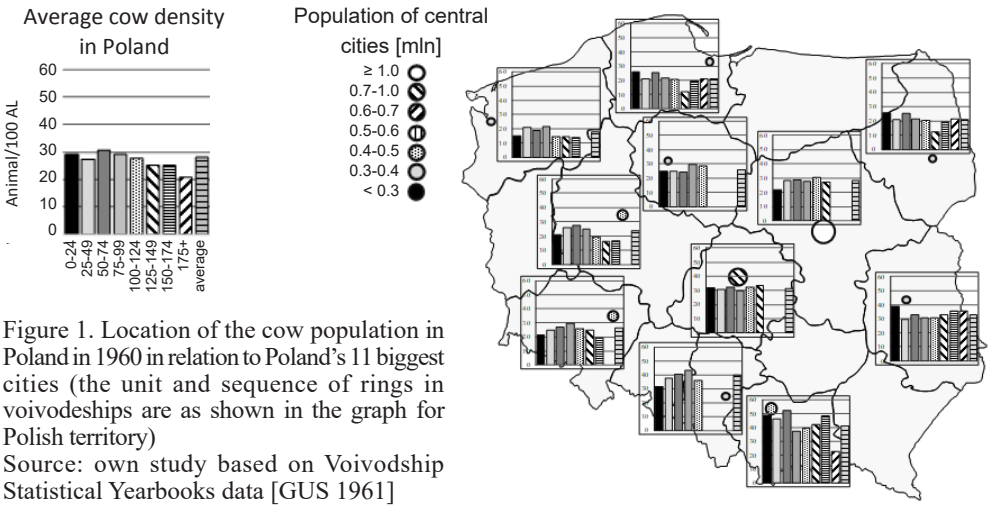

Figure 1. Location of the cow population in Poland in 1960 in relation to Poland's 11 biggest cities (the unit and sequence of rings in voivodeships are as shown in the graph for Polish territory)
Source: own study based on Voivodship Statistical Yearbooks data [GUS 1961]

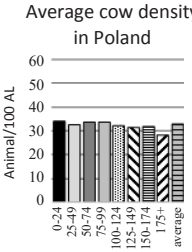

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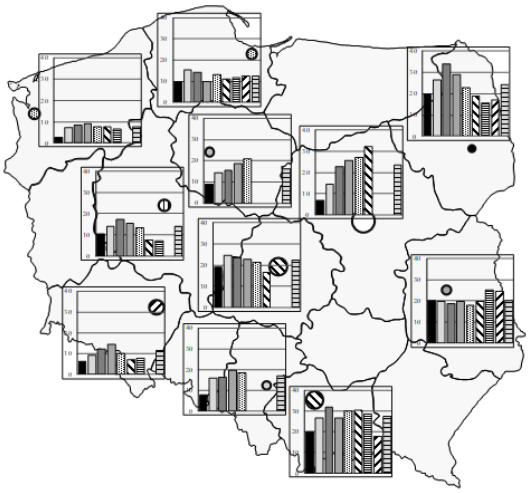
Figure 2. Location of the cow population in Poland in 1973 in relation to Poland's 11 biggest cities (the unit and sequence of rings in voivodeships are as shown in the graph for Polish territory)
Source: own study based on Voivodship Statistical Yearbooks data [GUS 1974]

city also saw a decline in cow numbers in areas located 25-49 km away from its center. In most central cities, the highest cow density was found in peripheral areas, except for Lublin and Warsaw, where the highest cow density was observed in inner areas.

The greatest transformation in the distribution of cow herds over the territory took place in 1996-2010. First of all, a concentration of cows was observed in the impact range of Białystok, i.e. in the Podlaskie Voivodship, the western part of the Warmińsko-Mazurskie Voivodship and in the impact range of Warsaw, mostly in the northern and north-eastern part (Fig. 4). Conversely, cow density in impact ranges of Katowice, Lublin, Szczecin and Wrocław declined by at least one quarter. The decrease was particularly noticeable in the impact area of Cracow (by 44%); considering the decline in average cow density in Poland (by 7.3%) and the above-average reduction in agricultural land, especially in foothills [Musiał 2019], it means that this region considerably lost its importance as a milk producer.



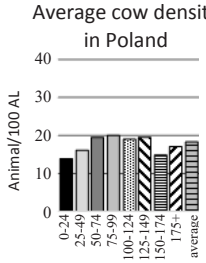


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Figure 3. Location of the cow population in Poland in 1996 in relation to Poland's 11 biggest cities (the unit and sequence of rings in voivodeships are as shown in the graph for Polish territory)
Source: own work based on the Local Data Bank of Central Statistical Office (CSO) data

Also, cow concentration followed a downward trend in semi-peripheral areas where average cow numbers in 2010 were 34% below the Polish countrywide level. The second and sixth rings were affected by depopulation to a lesser extent. On a countrywide basis, cows were mostly kept in areas located 50-125 km away from the country's main urban centers. A reduction in cow herds in the first ring (in relation to the average level for the entire area of the central city concerned) was most severe in Wrocław and Warsaw (with a density at a level of 13-15% of the average figure) and in Gdańsk (27% of the average figure). Bydgoszcz, Katowice, Cracow and Poznań were affected by this process to a lesser degree (48-59% of the national average figure). The cities were also found to differ significantly in the distribution of the cow population among the rings. An outstanding example is Warsaw, where the density consistently increased with the increment in the distance from the center, and cow density varied by a factor of over 9 between the first and sixth ring. On a countrywide basis, the highest concentration was found at a distance of 50-75 km away from Białystok, reaching 59.2 cows per 100 ha of agricultural land, while the national average was 17.0 and the average level for the entire impact area of Białystok was 37.4. The greatest homogeneity in cow density was recorded in the impact areas of Szczecin (41%), Katowice (77%) and Lublin (89%).

The analysis of central cities on a case-by-case basis makes it difficult to discover prevailing trends. Therefore, central cities with a metropolitan population of one million or more formed one group, whereas those with a metropolitan population of less than one million (Białystok, Bydgoszcz, Lublin, Szczecin) formed another. As shown in Table 1, in 1960 and 1973, cow density in the five first rings was similar to the average level recorded in the biggest and smallest centers. In the group composed of smaller centers, cow density recorded in the first ring was the highest of all rings. Conversely, large differences existed between outer areas (located over 125 km away from respective city centers) of the 7 biggest central cities. However, they decreased considerably between 1960 and 1973. That process regained its intensity after 1996. However, due to a faster decline in importance of milk production in outer areas of smaller central cities, the gap narrowed again in

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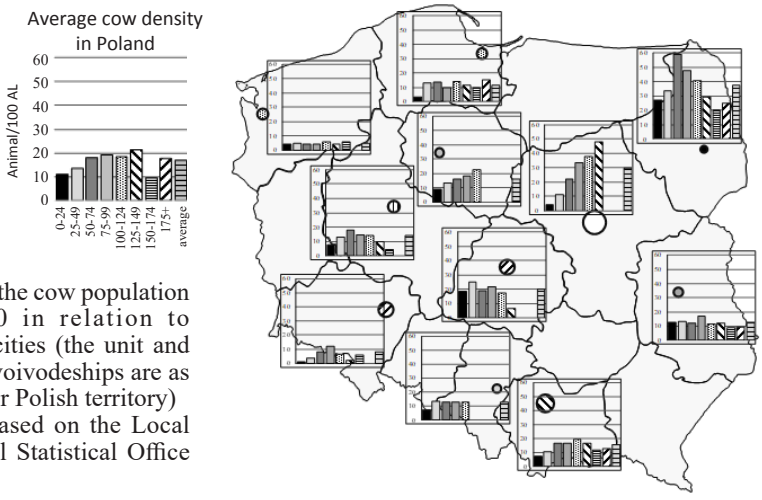

Figure 4. Location of the cow population in Poland in 2010 in relation to Poland's 11 biggest cities (the unit and sequence of rings in voivodeships are as shown in the graph for Polish territory)
Source: own work based on the Local Data Bank of Central Statistical Office (CSO) data

Table 1. Relative cow density in different rings located across Polish territory: 7 biggest and 4 smallest central cities in relation to average levels recorded in groups of central cities in 1960, 1973, 1996 and 2010

Distance from the central city	1960			1973			1996			2010		
	total	7 biggest	4 smallest	total	7 biggest	4 smallest	total	7 biggest	4 smallest	total	7 biggest	4 smallest
0-24, ring 1	103.93	96.97	116.17	103.91	97.13	112.90	75.64	67.06	88.60	65.58	45.39	92.31
25-49, ring 2	98.36	104.09	88.78	99.77	104.95	91.63	88.04	87.21	89.39	80.35	73.11	86.94
50-74, ring 3	109.54	107.80	111.75	102.58	103.87	98.91	107.38	106.17	109.83	105.87	102.34	114.79
75-99, ring 4	104.66	104.36	101.68	103.08	101.92	103.74	109.11	107.80	112.02	114.15	109.46	127.87
100-124, ring 5	99.42	101.53	97.63	98.46	99.93	97.05	104.86	110.82	96.24	109.74	115.29	101.47
125-149, ring 6	89.34	93.47	82.10	95.67	97.74	92.44	107.44	116.74	91.61	125.65	160.08	78.16
150-174, ring 7	90.01	80.15	107.71	97.05	84.67	117.80	81.80	68.33	101.59	56.10	55.79	56.10
175+, ring 8	74.25	54.78	99.70	86.13	73.40	99.68	93.41	80.16	105.62	105.40	88.96	113.79

Source: own study based on Central Statistical Office data

2010 (except for ring 6 which had the highest concentration of cows). Conversely, there was a consistent increase in disparities between semi-peripheral areas of the biggest and smallest central cities: from 15.8 percentage points (p.p.) in 1973 to 21.5 p.p. in 1996 and 46.9 p.p. in 2010.

Changes in the territorial distribution of cow numbers, expressed by the reduced concentration of cows around central cities, corroborate the assumptions formulated by Robert Sinclair [1967], especially when it comes to central cities with a population of one million or more. The development of suburban housing, which gained momentum after 1990, can be expected to extend territories where animal production is not accepted by residents who moved out of town. In Poland, a highly fragmented milk production base [Pepliński 2019], growing wage pressures, absence of successors, a decline in agricultural profitability and several other factors result in a situation whereby due to increasing conflicts between neighbors concerning the nuisance arising from agricultural production, farmers relatively often decide to discontinue their production activity. Also, development farms usually do not decide to build new cowsheds, fearing mainly future neighborly conflicts about nuisances in milk production (noise, smells, etc.) with the increasing number of city dwellers moving to suburban areas. Long-term investments in milk production are also threatened by growing pressures on the adoption of what is referred to as the ‘odor act’ which, according to ecologists, could help effectively suppress unpleasant odors.

Note also that the urban use of agricultural areas was not found to be anticipated in the case of central cities forming an agglomeration with a population below one million. However, it does not mean the urban use of rural areas is not anticipated at all. Data presented in this paper, necessary to calculate animal density, suggests that, at the outer perimeter of the smallest central cities, the decline in agricultural land was faster than in other rings and, therefore, there was a decrease in cow numbers while cow density remained the same. Changes in the numbers and density of pigs and sows were found to follow a similar trend [Pepliński 2019]. Hence, these areas need to be examined in greater detail.

SUMMARY

The study found that changes occurred in the distribution of cow numbers in territories surrounding central cities. Semi-peripheral areas located around the biggest central cities witnessed a reduction in cow density. This suggests that these territories are anticipated to be used for urban development purposes. These processes gained momentum only after 1990. Conversely, this trend was not observed in agglomerations with a population of less than one million. Milk production was relocated mainly to peripheral areas (located 50 to 124 km away from central cities defined in this study). The intensification of environmental measures in Europe suggests that action be taken to slow down the territorial concentration of cow herds in Poland.

This study also confirmed the theory by Sinclair, who claimed that animal production should be located in remote areas. However, the concentration of cows in remote areas of two central cities carries the risk of an excessive environmental burden, mainly in the context of the excessively intensive use of organic fertilizers and the related release of nitrogen compounds to groundwater and the atmosphere.

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ZMIANY LOKALIZACJI POGŁOWIA KRÓW W POLSCE W ŚWIETLE TEORII LOKALIZACJI SINCLAIRA

Słowa kluczowe: ośrodek centralny, pogłowie krów, obsada, lokalizacja

ABSTRAKT

Celem badań było określenie zmian w lokalizacji pogłowia krów w Polsce wokół 11 największych miast w Polsce w latach 1960, 1973, 1996 i 2010. Przynależność danego powiatu określono na podstawie najbliższej odległości miasta powiatowego do jednego z 11 ośrodków centralnych. Obszar wokół miast podzielono na osiem 25-kilometrowych okręgów, z tym że ostatni ósmy krąg oznaczał tereny położone ponad 175 km od najbliższego ośrodka centralnego. Podstawą do obliczeń było pogłowie krów oraz wielkość użytków rolnych w poszczególnych powiatach, które pozwalały określić obsadę krów w przeliczeniu na 100 ha UR. Przeprowadzone badania wykazały zmiany w przestrzennym rozmieszczeniu pogłowia krów wokół ośrodków centralnych. W przypadku największych ośrodków centralnych na terenach półperyferyjnych następowała redukcja obsady krów, co wskazuje na występowanie procesu antycypacji miejskiego wykorzystania terenu. Procesy te nasiliły się dopiero po 1990 roku. Natomiast nie zaobserwowano tego procesu w przypadku aglomeracji liczących mniej niż milion mieszkańców. Produkcja mleka przenoszona była głównie na tereny peryferyjne, tj. położone w odległości 50-124 km od wyznaczonych ośrodków centralnych. Nasilenie działań prośrodowiskowych w Europie sugeruje podjęcie działań zmierzających do spowolnienia przestrzennej koncentracji pogłowia krów w Polsce. Potwierdzona została także teoria Sinclaira, według której produkcja zwierzęca powinna być ulokowana na terenach peryferyjnych.

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