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Application of a statistical model to identify villages at risk of depopulation in Poland

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Abstract. Rural settlements are dynamic structures, and each historical period is characterised by certain directions of changes in the countryside, visible mainly in demographic processes. Based on an analysis of statistical data for the years 1950–2021, the authors determine those directions of future demographic changes in Polish villages that are causing changes in the rural settlement structure. The authors, using a statistical model, indicate the regions of the country that are at risk of village desertification and identify villages facing permanent population regression. This article presents the changes that took place in the rural settlement structure of Polish villages between 1950 and 2021 and forecasts future changes. The research aims to create a probabilistic projection of the population in Polish villages. Factors influencing the rural population are also discussed. The research is addressed to state and local administrations with the message that they should implement timely and responsible measures to revitalise the countryside and stop the demographic shrinkage leading to the emptying of villages in some regions of Poland.

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1. Introduction

Rural depopulation is a common phenomenon across Europe, with many areas experiencing population declines (Čipin et al., 2020). It is clear from research that various processes are currently behind population decline. Descriptions of these processes can be found in the report *European Shrinking Rural Areas: Challenges, Actions and Perspectives for Territorial Governance* (ESCAPE, 2020). In general, populations in rural areas are currently being depleted by out-migration (active shrinking), and by their age and demographic structure (legacy shrinking). Most rural shrinking regions are losing population due to "legacy" effects (due to their age structure, low fertility rates and high mortality rates). The cause of the variation in rural demographic shrinkage is also attributable to regional or national rural–urban processes, but its cause may also be related to pan-European or intercontinental (globalised) population flows. Undoubtedly, researchers agree that shrinkage, has an impact on rural economies and societies, often leading to "cumulative causality" and "vicious cycles" of decline.

According to the above-mentioned report, across Europe, almost 60% of regions (NUTS 3) with predominantly rural or intermediate regions meet the criteria for permanent (past or projected future) demographic decline, accounting for nearly one third of the population and covering an area of around 40% of the EU. They are mainly located in the east and south of Europe, with scattered regions in the north. Countries with advanced shrinkage processes include Bulgaria, Latvia and Lithuania, where the average annual shrinkage rate is greater than –1%. Moderate rates of shrinkage (rate: –1 to –0.5% p.a.) are found in Croatia, Estonia, Portugal and Romania, while small rates of decline (between –0.5 and 0) are characteristic of Austria, the Czech Republic, Finland, France, Hungary, Italy, Poland, Slovakia, Slovenia and Sweden (Copus et al., 2020).

This problem is very relevant to their future development. Essentially, two ways of dealing with this problem are indicated: aiming for growth – reversing the trend of population shrinkage and stimulating population growth; or dealing with decline – accepting population shrinkage and adapting to its economic and social consequences. From the analyses conducted for the ESCAPE report (Copus et al. 2020), governance from the national level plays a key role in regional and rural development, primarily as a channel for funding from both EU and national sources. The national level of governance is seen as a source of guidance and policy through strategies, spatial plans, territorial development concepts or even specific institutions, such as the General Directorate of Policies against Depopulation in Spain (Ortega-Reig et al., 2020). An example of a document guiding changes related to population shrinkage is the 2015 Demographic Strategy of the Federal Government in Germany (Machold et al. 2020) or the Dutch Intergovernmental Action Plan for Population Decline of 2009, which aimed to protect living conditions in regions experiencing depopulation and in regions that expected population decline in the future (Christiaanse, 2020). Some countries, including Germany, have been very active in setting up various expert groups to address the causes and consequences of demographic change in specific areas (Machold et al., 2020).

Complementing the activities from the national level is the local administrative level (municipality), which is seen as important as a provider of care services, an initiator of local development projects and an intermediary between the local community and policy-making, so development directions can and should be differentiated and chosen at the level of individual municipalities. According to Copus et al. (2020), there is a strong need to strengthen the position of the local level in policy-making, giving it a stronger voice in multi-level governance processes because currently the local level of governance is faced with few financial resources to devote to targeted activities, limited room for manoeuvre and limited opportunities for independent action. There is also a lack of cooperation between local and national administrations in combating population shrinkage. The lack of a clear vision or strategy to deal with rural shrinkage is highlighted and, in extreme cases, policymakers do not understand the seriousness of the problem of demographic decline (Copus et al., 2020). Support for creating equivalent policies for depopulating areas also comes from NGOs and academia.

The contemporary condition of villages in various parts and regions of Poland is a consequence of post-war development conditions. The face of rural settlements was also largely shaped by the size of their populations, which determines the basic needs of any human habitat. Three classes of villages were present in Poland: progressive villages (recording population growth), stagnant villages, and regressive villages (depopulating, characterised by population declines) (Wesołowska, 2018). However, most Polish villages have experienced population loss.

Demographic shrinkage is also termed "statistical depopulation", "population decline", or "demographic regression". The term was introduced into the literature in the 1980s by German researchers as a process affecting urban centres, interchangeably

referred to as "urban shrinkage", "urban decay", "urban decline", "urban blight", or "population loss" (Couch et al., 2012; Großmann et al., 2008; Pallagst, 2008). Demographic shrinkage is understood as the process associated with a spatial population decline occurring as a result of various factors and under various historical, social and economic conditions (Strauß, 2012; Stryjakiewicz et al., 2012). The interest in rural shrinkage is a key theme in the policy discussion on rural development in Europe (Dax & Copus, 2022). It refers to issues of area peripheralisation, marginalisation, domination and deprivation (Szarfenberg, 2006). They are characterised by less development and face many economic, social and cultural problems (Danson & De Souza, 2012; Jones et al., 2007; Kühn, 2015; Máliková, 2013). The existence of marginal regions is closely linked to socio-spatial polarisation. As Mahler (1993) notes, maldevelopment is the source of marginalisation of large population groups and their social exclusion. As a rule, the areas characterised by the greatest population decline are mainly located in peripheral areas at the border of regions (Lešková & Vaishar, 2019). A study by T. Inoue and N. Inoue (2019) in Japan shows that, with spatial marginalisation, there is a risk of certain areas becoming uninhabitable in the future, particularly when the population shows a high rate of aging.

In the Polish literature, peripherality is perceived as a characteristic of an area in which the economic structures formed do not provide decent sources of livelihood and lead to unfavourable phenomena such as unemployment and social marginalisation and ultimately manifest themselves in depopulation (Balińska, 2015; Hefner, 2011; Miszczuk, 2013; Stanny, 2012; Wójcik, 2011).

The article's basic aim is to determine the direction of demographic changes in villages in Poland causing changes in the rural settlement structure and to identify villages facing permanent population regression. The authors will use a statistical model to identify the regions of the country at risk of rural desertification. The research aims to create a probabilistic projection of the population in Polish villages.

2. Studies on rural depopulation

The phenomenon of depopulation in rural areas is not new. In Western Europe, the abandonment of rural areas in favour of cities was closely linked to the 19th-century industrial revolution and urbanisation. In addition, it coincided with the modernisation of agriculture. The wave of large rural–urban migrations has continued uninterrupted for several decades and has led to demographic deserts in many rural regions (Collantes & Pinilla, 2011). This process was particularly intense in the 1970s and 1980s in German, French, Spanish or Dutch villages and weakened the rural population, especially in mountainous regions (including the southern part of the Massif Central and the southern Alps). Due to the mass character of the phenomenon described, the problem of leaving rural settlements has been called a "rural exodus" in the English-language literature (Gonda-Soroczyńska, 2006; Pinilla et al., 2008).

As Lutz and Gailey (2020) noted in the UNDP report, "the striking contrast in demographic patterns currently observed in various parts of the world is essentially a consequence of different populations being at different stages of this universal process". Numerous studies suggest that the depopulation process depends on a combination of factors. In addition to demographic determinants, natural determinants are also indicated that show a significant relationship with the depopulation rate, but locally their impact is always modified by site-specific socio-economic factors closely related to the economic history of the locality (Latocha, 2018). Those most commonly cited include: geographical location (including the proximity of the locality to cities/urban and metropolitan areas and transport routes) (Lavesson, 2017; Serra et al., 2014); features of the local settlement system (including the size of the locality and position in the settlement hierarchy, the structure of the built-up area and compactness of development) (Vaishar et al., 2021); accessibility and availability of services (Rosner, 2012); the economic base of the area and related labour-market fluctuations (Wesołowska, 2011); political changes and resulting boundary changes (Eberhardt, 2010); or natural disasters (Driver, 2006).

The consequences of population shrinkage are manifold. In the literature, depopulation is very often analysed in the context of its environmental effects, including land use change and its ecological and economic consequences. Particular attention is given in this case to the abandonment of arable land and landscape changes, including the regeneration of forested areas, which is common in many European countries (Plieninger et al., 2016). In some rural areas, especially those located in peripheral areas, as a result of significant migration and advanced aging processes, vacancies increase or social infrastructure (schools, kindergartens, health centres) is dismantled. Problems in the labour market emerge that usually result in economic

regression (Weber, 2011, 2012; Wesołowska, 2018). The final stage of statistical depopulation may be the complete disappearance of a village. In addition, rural depopulation in the literature is seen as a social problem and as a cause of other problems affecting sustainable socio-economic development (Li, 2015). Therefore, rural depopulation should be shaped by relevant policies dedicated to rural areas. However, some researchers believe that demographic regression is the effect, not the cause, of many of the structural problems facing contemporary rural areas (Coulmas & Lützeler, 2011).

Despite the universality of the depopulation process in different regions of the world, its local determinants vary widely, and some are even specific to a particular place and time (Kerckhof et al., 2016; McLeman, 2011). As a result of the interaction between rural areas and the external environment, rural communities develop, decline or even disappear (Collantes & Pinilla, 2011; Li et al., 2019). Recaño (2017), based on a factor analysis of localities in Spain, distinguished three demographic types of rural spaces:

1. *demographically resilient spaces*: larger units with some demographic stability, located on the edge of the central plateau of Spain and far from the more depressed mountain areas. They are characterised by a higher population density than the average for rural areas of Spain and a lower emigration rate,
2. *rural spaces of emigration*: a small population and low population density, negative population growth, gender imbalance, relatively high levels of aging, and significantly affected by emigration,
3. *rural spaces at risk of irreversible depopulation*: very low population numbers, low population density, advanced aging processes.

According to Recaño (2017), the second and third types of rural spaces may not survive, due to the demographic processes observed. Similarly, a study was carried out by Rizzo (2016), who distinguished three groups due to this diversity of demographic phenomena taking place in Sicilian villages:

1. *slow growth*: these are villages characterised by slow demographic growth, linked to economic and cultural growth through investment in quality food markets, agriculture and agri-tourism,
2. *transition*: transitional villages, characterised by both the features of growing areas (advanced rural economy) and declining areas (depopulation),
3. *declining*: villages that have neither modernised their economies nor created employment opportunities and thus have not been able to retain their populations, which has manifested itself in depopulation.

Although the problem of depopulation has been well diagnosed in the literature as to causes and effects, relatively little attention has been paid to developing models/scenarios for the exit of these areas from demographic regression. It therefore seems important to show and evaluate some of the effects of the population changes taking place leading to significant spatial transformations. The study of rural shrinkage on European soil was to some extent popularised by Gerlind Weber (2008, 2009, 2011, 2012) with her research on rural depopulation in Austria. She presented rural shrinkage using a model referred to as the negative development spiral. A negative development spiral is a scenario of regression and subsequent degradation of settlements as a result of population decline and changes in age structure, leading to a loss of vitality and the loss of the "critical mass" necessary for functioning. The course of the process has the character of multiple negative feedbacks following the triggering factor, e.g. unsatisfactory living conditions, shortage of jobs and inability to meet high life expectations (Wilczyński, 2016: 213).

3. Polish rural demographic shrinkage after Second World War

According to many authors, rural depopulation in Poland started in mountain areas characterised by low-quality agricultural production space and difficult farming conditions (Ciok, 1988, 1995; Chachaj, 1978; Miszewska, 1989; Plewniak, 1978; Salwicka, 1978; Soja, 2001, 2008). Slightly different reasons for the desertification of areas were observed in north-western Poland in the post-war period. Warfare and the post-war shifting of borders revealed underpopulated areas – a kind of demographic void where the population density was fewer than ten persons per square kilometre. At that time, the average population density of the country was 77 persons per km^2, and in the former lands it was almost nine times higher (89 persons per km^2) (Gawryszewski, 2005). This issue can be found in studies by Maryański (1961, 1964), Piesowicz (1987) and Eberhardt (2010), among others. The first population census conducted after World War II (1946) showed a population of over

23.9 million in Poland, 68% of whom were rural inhabitants (Halamska, 2020). The aforementioned underpopulated areas have not rebuilt their population potential (being still characterised by low population density). Post-war population changes characterised by population loss (migration and low birth rates) resulted in these areas' population regression. Although Poland's population grew by an average of around 300,000 per year, in rural areas the population remained at a steady level of around 15 million inhabitants until modern times (2016), which means that its share of the total population was steadily declining. A process of deurbanisation was taking place (Halamska 2020). Two factors were mainly responsible for the decreasing share of the rural population in the country's population: internal migration, most of the time dominated by the rural-to-urban stream, and (to a lesser extent) changes in the administrative division (residence status) (Eberhardt, 1991; Gawryszewski, 2005).

Already in the 1960s, Polish researchers took up the subject of population problem areas on a large scale. Zagożdżon (1988) pointed to areas characterised by a large scale of depopulation, resulting mainly from the lack of an emotional connection to the farm, difficulties in adapting among immigrants (Sudetenland area), and areas with reduced farming efficiency (e.g., due to land fragmentation). The indicated factors led to the migration of the rural population, mainly towards cities (Gołata & Kuropka, 2015). Bański (2008) assumed the scale of depopulation of the area, population aging, and reproductive problems when distinguishing population problem areas. It can be noted that, after the Second World War, in the 1950s and 1960s, the motives for migration from rural areas were predominantly economic (difficulties in rebuilding farms and maintaining smallholdings, a large developmental distance between the countryside and the city, and fears of the authorities' agricultural policy and collectivisation). The greatest losses due to migration in rural Poland were recorded in the 1970s and 1980s, when the negative balance of internal migration exceeded the natural increase. Migration decisions were then taken for sociological and psychological reasons (the greater attractiveness of urban areas in terms of access to all kinds of services, e.g. education, culture, possibility of leisure activities, professional and social advancement).

For Poland as a whole, particularly intensive studies on depopulation were carried out in 1986–90 during the preparation of the Diagnosis of the State of Poland's Spatial Economy (Bański 2008). A research programme entitled "Depopulation of the Polish countryside" was then implemented. This programme was coordinated by the Institute of Geography and Spatial Planning of the Polish Academy of Sciences (PAN), where works covering the whole of Poland were mainly produced, as well as in some Polish academic centres: Białystok, Kraków, Koszalin, Lublin, Łódź, Olsztyn, Opole, Szczecin and Wrocław (Eberhard, 1989; Frenkel, 1989; Heffner, 1990; Jasiulewicz, 1989; Miazga, 1990; Stasiak, 1987, 1990). Since the 1990s, population changes in rural areas have been bi-directional. Nationally, there has been a change in the trend observed so far, manifested in a gradual increase in the proportion of the population living in rural areas. Although this change remains confined almost exclusively to municipalities located on the outskirts of urban centres, the trends are so strong that they have begun to outweigh the still-existing migration from rural areas to cities (Rakowska, 2011), resulting from the phenomenon of suburbanisation. Outside agglomerations, on the other hand, there is a further population decline. In most villages located far from cities or with difficult transport access, the migration balance tends to be negative, and the low birth rate further compounds the distorted population structure. The Rogers-Castro model (Rogers & Willekens, 1986) explains this process of degradation of age structures in rural areas. According to the cited studies, in more than two thirds of cases, migration involves young people aged between 20 and 34. This leads to a spatial polarisation of the age structures of the population. The described phenomena result in the progressive aging of the rural population of out-migration villages. This, in turn, determines further population decline in these villages. Based on the demographic forecast of the population until 2030 presented by Statistics Poland, further aging of the population is expected, as well as a decrease in the share of young people, especially women, in depopulation areas. This will contribute to further depopulation of many villages, especially those in eastern and central Poland.

As a result of the processes described above, the share of the rural population in Poland decreased after the Second World War. In 1950, Poland's rural areas were home to 15 million people, which accounted for 61% of the country's total population; today, a similar number of people live in rural areas, but their share of the total Polish population has decreased to 40%, which is evidence of the progressive demographic shrinkage of rural areas.

4. Research methodology and statistical methods used

The survey covered 41,269 localities in Poland. According to the definition of Statistics Poland, a locality is a settlement unit or other built-up area distinguished from other localities by a separate name and, in the case of an identical name, by a different designation of type (*Note* 1). The division of settlements was made based on data from population censuses. They were used because they are distinguished by their high level of detail and are considered a valuable source of information. From the point of view of the possibility of conducting demographic analyses, the population census, which presents the state and structure of the population at a single point in time throughout the country and shows the comprehensive relationships occurring between the types of characteristics analysed, is of the greatest importance among sources of statistical information (Holzer, 2003). The available census data allowed the research to be conducted at the level of the lowest administrative units, which are the statistical localities, distinguished by the clear specificity of the course of depopulation processes. In the dynamic approach, statistical and spatial data for the period 1950–2021 were taken into account. These data were organised into "dynamic time-territorial series".

The simplest linear trend function, $y_i = a_i t + b_i$, was used to analyse the population change trend, where i is the index assigned to the examined locality, t is the time variable, y_i is the projected population at time t. The directional coefficients a_i and b_i were estimated using the classical least squares method based on census observations. The directional coefficient a_i is interpreted as the expected change in population over the next period. As the village counts varied widely, the depopulation coefficient $DR_i = a_i / y_{i,2021}$ (where $y_{i,2021}$ is the population according to the last census) was used to analyse the projected depopulation. This ratio, expressed as a percentage, indicates the projected percentage change in population for the next period. This coefficient was recoded into an ordinal variable as follows:

- $DR_i \leq$ -50%: depopulation risk,
- – 50%< DR_i < – 10%: decrease in population,
- – 10% ≤ $DR_i \leq$ + 10%: no significant change,
- DR_i > + 10%: increase in population.

Subsequent indicators were calculated as at 2021 and recoded into ordinal variables according to standard rules.

1. Feminisation index (FEM_i), a feminisation scale proposed by Rosset (1975),
   - FEM_i < 100% – very young society,
   - 100% ≤ FEM_i ≤ 104% – norm,
   - 100% < FEM_i ≤ 108% – dislocated structure,
   - 108% < FEM_i ≤ 112% – severely dislocated structure,
   - FEM_i > 112% – anomalous structure.
2. Size of villages (SV_i), the distribution was made analogous to the Bański (2016),
   - $SV_i \geq$ 1000 – very large,
   - 500 ≤ SV_i <1000 – large,
   - 200 ≤ SV_i < 500 – medium,
   - 100 ≤ SV_i < 200 – small,
   - SV_i < 100 – very small.
3. Demographic old age index ($DOAI_i$) with reference to the degrees of demographic old age according to the scale proposed by Kowalewski and Majdzińska (2012), which is a modification of the scale of E. Rosset scale:
   - $DOAI_i$ < 12% – low,
   - 12% ≤ $DOAI_i$ < 16% – medium,
   - 16% ≤ $DOAI_i$ < 20% – high,
   - $DOAI_i \geq$ 20% – very high.
4. Distance from a large city (100,000 inhabitants) (DLC_i) was analysed with reference to the transport accessibility model (Rosik et al. 2012):
   - $DLC_i \leq$ 30 km – low,
   - $DLC_i \leq$ 30 km – medium,
   - $DLC_i \geq$ 60 km – large.
5. Index of agricultural production space valorisation ($APSV_i$) was expressed on the IUNG point scale:
   - up to 50,
   - 50–60,
   - 60–70,
   - 70–80,
   - 80–90,
   - more than 90.
6. The index determining the attractiveness of Poland's natural landscape for recreation, (RAI_i), developed by Richling (2010) was expressed in numbers: 1, 2, 3, 4, 5, 6.

In further proceedings, the depopulation rate was analysed according to the six factors described above. All of the above variables are expressed on an ordinal scale, so the primary tool for describing the direction and strength of the relationship is the rank correlation coefficient. All correlation coefficients are statistically significantly different

from zero (Table 1). A more detailed analysis of the dependency structure was based on count tables and the chi-square independence test, which in each case confirmed the existence of a relationship between the depopulation rate and the factors studied.

Table 1. Correlation coefficients between the depopulation rate and the factors described

variable	Depopulation Rate DR)	Feminisation index (FEM)	Size of village (SV)	Demographic ageing index (DOAI)	Distance from city (DLC)	Quality of agricultural production space (APCV)	Recreational attractiveness index (RAI)
Depopulation Rate (DR)	1,000000	0,010347	0,528545	-0,231546	-0,129495	0,060850	0,042780
Feminisation index (FEM)	0,010347	1,000000	0,017713	0,090692	-0,056068	0,035483	-0,014778
Size of village (SV)	0,528545	0,017713	1,000000	-0,151239	-0,194039	0,096118	0,095343
Demographic ageing index (DOAI)	-0,231546	0,090692	-0,151239	1,000000	0,064114	0,049033	-0,051613
Distance from city (DLC)	-0,129495	-0,056068	-0,194039	0,064114	1,000000	-0,162499	-0,059572
Quality of agricultural production space (APCV)	0,060850	0,035483	0,096118	0,049033	-0,162499	1,000000	0,123845
Recreational attractiveness index (RAI)	0,042780	-0,014778	0,095343	-0,051613	-0,059572	0,123845	1,000000

Source: Own elaboration

5. Results. Forecast of changes in the rural settlement network of Poland

Nowadays, the distribution of villages of different sizes in Poland is not uniform. Central Poland is characterised by a very fragmented settlement structure, which is strongly linked to its lowland character with an absence of barriers, which did not favour the clustering of settlements. Historically low settlement levels and a small settlement structure (up to 50 houses) are characteristic of wetland areas, such as the Włodawa marshes, the area between Międzyrzecz and Biała Podlaska, the area near the Biebrza River, the Warta and Noteć riverside or the Suwałki region. A different settlement structure was formed in the south of Poland, especially in southern Małopolska. In these areas, the distribution of settlements was uneven due to the existence of large tracts of anecumene (mountainous areas, relief unfavourable to settlement), due to which rural settlements were rarer, but larger, and showed tendencies to group population, e.g., in Podhale, which was a densely populated area, settlements numbered 100–300 houses (Deszczka, 1931).

After the Second World War, there was a process of population concentration, with an increase in the number of the largest villages of over 1,000 people. Studies show that the number of medium-sized villages (200–500) was decreasing in favour of large (500–1000) and very large (above 1000) ones (Wesołowska, 2016, 2018). On the other hand, the number of small villages with up to 200 people was also increasing. The smallest villages of up to 50 people were the most depopulated, their share more than tripling between 1950 and 2021 (Table 2). The cited data testify to a strongly marked process leading to the polarisation of village size in Poland. Today (2021), the distribution of villages by size is uneven in the country (Fig. 1). Large villages are located near cities and in mountainous areas. In contrast, small villages are characteristic of eastern and central areas. Comparing this state with 1950, it is noticeable that the share of small villages increased in the centre of the country (in the Warmińsko-Mazurskie and Podlaskie Voivodeships) and decreased in the Podkarpackie Voivodeship (Fig. 1), which is a reflection of the real movement of the population, both the natural growth (higher in Podkarpackie than in the north of Poland, in Podlaskie – a high number of deaths resulting from the old population structure) and migration behaviour (strong, long-lasting migration from rural areas in Warmińsko-Mazurskie (*Note* 2) and Podlaskie). This is confirmed by the research of the authors of the MROW report (2023), who noted that human resources are currently being "sucked out" from the peripheral parts of the regions by the central ones, thus creating an intra-regional polarisation of development. This is particularly visible in the voivodeships of Central Poland.

In general, among mountain villages, small villages occur sporadically. One in three villagers is resident in one of the largest villages (of more than 1,000 inhabitants). Their concentration near cities is characteristic, which is undoubtedly related to the attractiveness of a given city as a central centre and the size of that city. In suburban villages, a classic process of suburbanisation is taking place; if this trend continues, the largest villages will soon strengthen their position in the local settlement network. The largest villages are grouped in the suburban zones of cities and in the southern part of the country – primarily in the Małopolskie and Podkarpackie voivodeships (Fig. 1), where rural settlements have adapted to the difficult orographic conditions and distribution of industrial raw materials. The concentration of the largest settlement units in this area strongly relates

Table 2. Number of the rural settlements according to size of the village (1950–2031)

Size of the village	1950	%	2021	%	2031	%
<50	1033	2,5	3354	8,1	5094	12,4
50-100	4352	10,6	6668	16,2	6643	16,1
100-200	11719	28,4	10759	26,1	9818	23,8
200-500	17361	42,1	12670	30,7	11735	28,5
500-1000	5163	12,5	4689	11,4	4698	11,4
>1000	1578	3,8	3066	7,4	3218	7,8

Source: own study

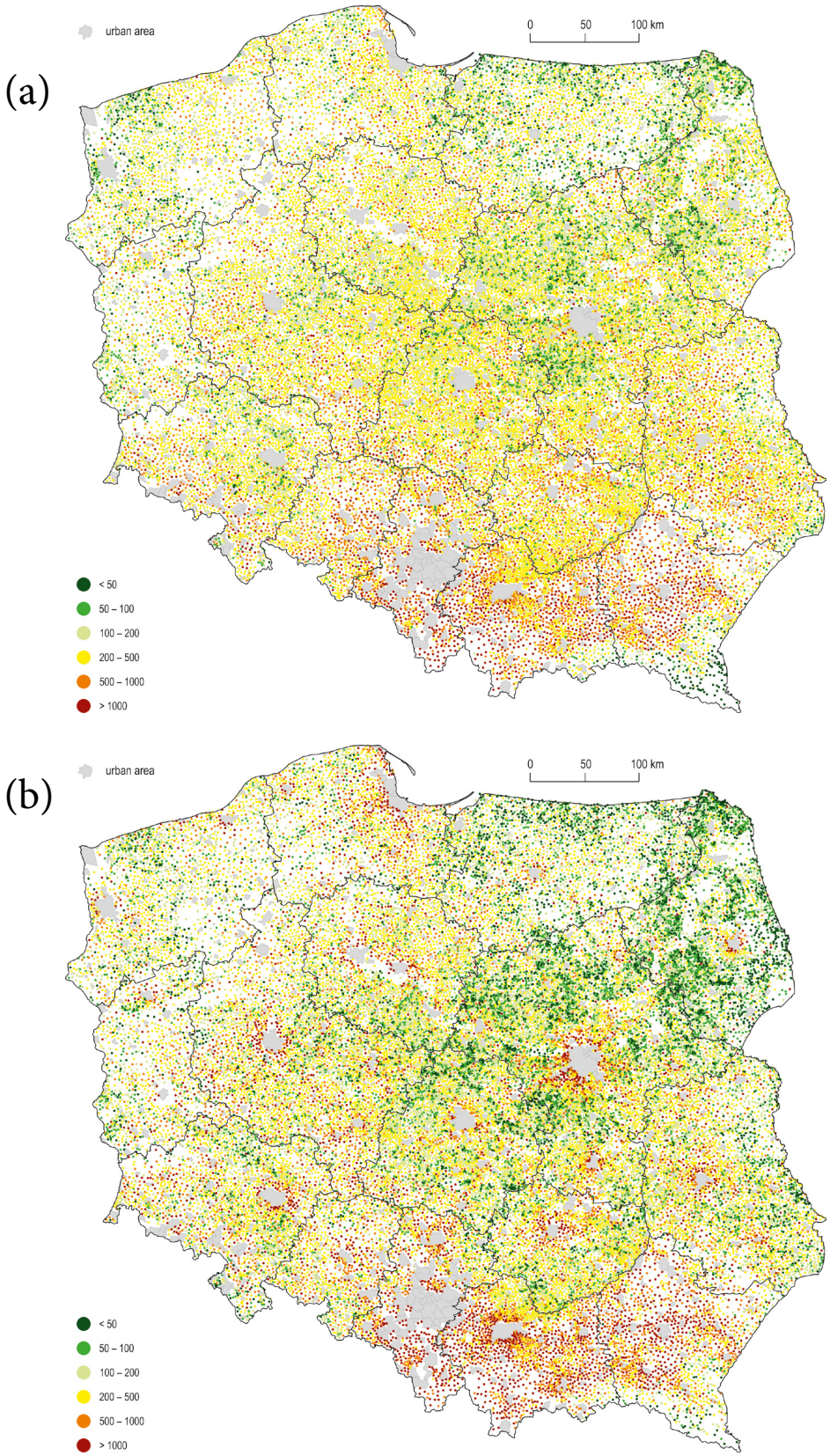

Fig. 1. Structure of the rural settlement network in 1950 (a) and 2021 (b)
Source: Wesołowska M., 2023

Table 3. Village numbers by demographic process (baseline data)

Class*	Number of villages	%
(1) Threatened by depopulation	930	2.25
(2) Population decline	10,371	25.13
(3) No significant changes	28,927	70.10
(4) Population growth	1,041	2.52

*see Fig. 2; Source: own elaboration

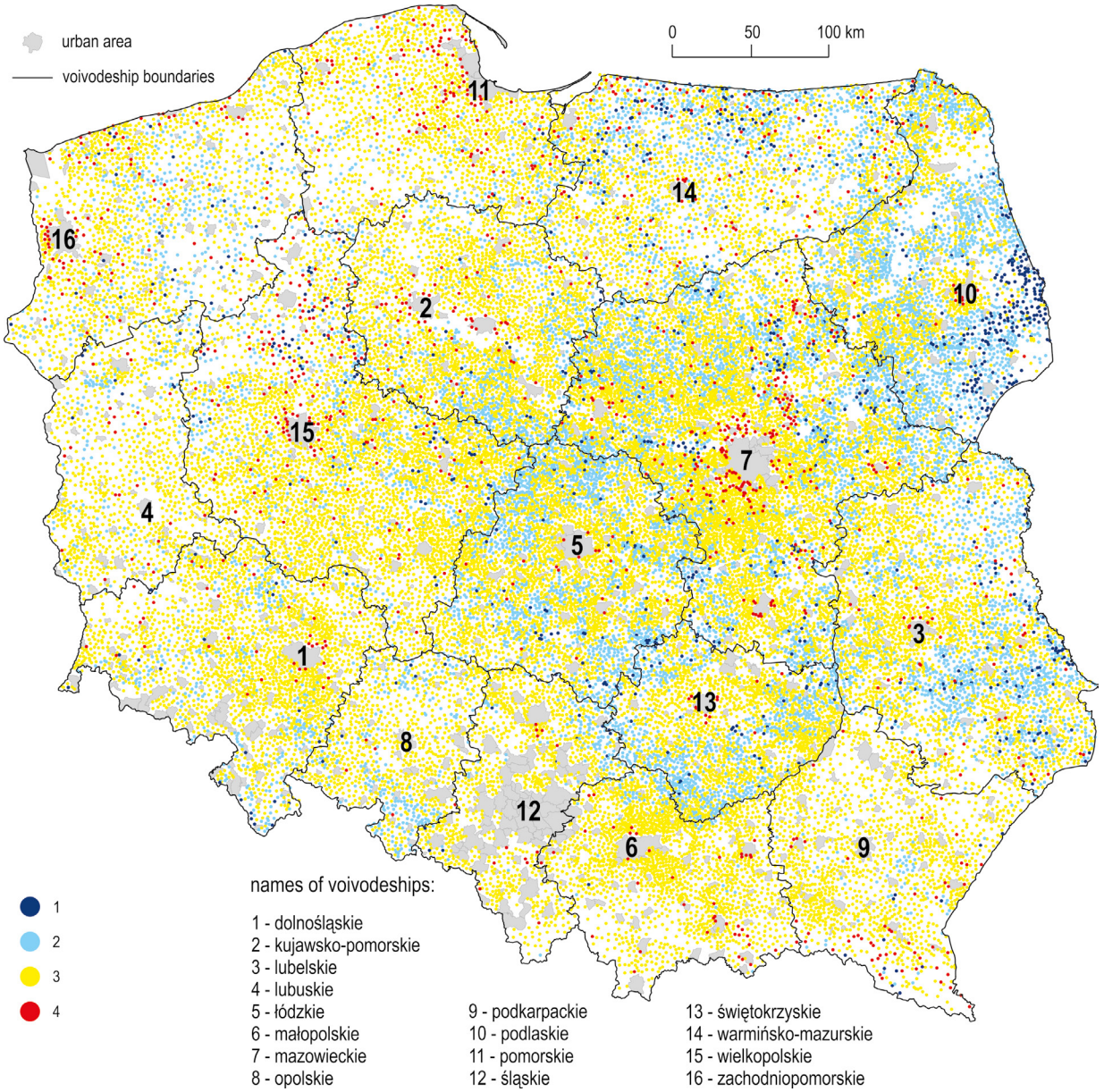

Fig. 2. Village types distinguished by depopulation rate
Source: own elaboration based on CSO data

to the natural conditions – above all the relief (the population was concentrated along river valleys).

To determine probable future population changes and related changes in the size of villages, the authors attempted a probabilistic projection in the structure of the rural settlement network of Poland in a short-term perspective of ten years. The result of the research procedure is the identification of villages in terms of the observed population processes, specifying villages at risk of depopulation (Table 3; Fig. 2). Among all the analysed villages, they account for slightly more than 2%. They are located mainly in eastern and central Poland. Their highest concentration is in Podlaskie Voivodeship (Fig. 2).

Statistical calculations have shown that the highest correlation is between the depopulation rate and the size of the village (Table 4), the demographic aging index (Table 5), and the distance from the city (Table 6). In general, small villages are often inhabited by an older population, which contributes to a faster rate of depopulation. They have been abandoned by younger residents due to their peripherality, marginalisation and lack of basic services and employment opportunities for residents. "In many rural zones, the presence of various types of disadvantages of location (national, regional, or even local periphery, difficult environmental, communication or infrastructure conditions, etc.) has an impact on population decline and the gradual disappearance of settlements" (Heffner, 2015). In villages characterised by population loss, small and economically weak, there is a need for social, economic and spatial restructuring. However, such villages are unable to initiate development based on their strengths as they are characterised by too little human and economic capital and are located far from growth centres and so can also not benefit from development impulses coming from those centres. As a result, in the coming years, peripheral rural areas may experience the consolidation or increase in scale of negative phenomena, e.g. poverty, and social exclusion, which in the long term will lead to the weakening of key pro-development factors, i.e. human capital, cultural heritage and the state of infrastructure will deteriorate. Wesołowska (2018) estimates that nearly 40% of Polish villages with permanent population regression lack endogenous potential for development, condemning these villages to probable disappearance.

In opposition are the large villages, which attract population, resulting in an observed increase in their population. As Heffner rightly pointed out, "only a fraction of villages in rural areas are susceptible to socio-economic development, this is especially true for settlements with a concentrated and compact character […] with a larger population […] of at least 300 people, i.e. around 100 households or residential buildings, which makes economic sense to sustain the primary service sector and create public spaces with a central character" (Heffner 2015, 2016). According to the synthesis of *Monitoring of rural development* (Stanny et al., 2023), the "relatively most favorable demographic

Table 4. Relationship of villages at risk of depopulation with their size. Summary of observed frequencies

Depopulation	Very small villages	Small villages	Medium villages	Large villages	Very large villages	Total
Threatened by depopulation	**882**	**38**	**10**	**0**	**0**	**930**
% column	8.78	0.35	0.08	0.00	0.00	
% of row	94.84	4.09	1.08	0.00	0.00	
Decrease in population	**5,551**	**3,398**	**1,337**	**81**	**4**	**10,371**
% column	55.23	31.54	10.54	1.73	0.13	
% of row	53.52	32.76	12.89	0.78	0.04	
No significant changes	**3,584**	**7,257**	**11,112**	**4,340**	**2,634**	**28,927**
% column	35.66	67.36	87.59	92.48	85.91	
% of row	12.39	25.09	38.41	15.00	9.11	
Population growth	**33**	**81**	**227**	**272**	**428**	**1,041**
% column	0.33	0.75	1.79	5.80	13.96	
% of row	3.17	7.78	21.81	26.13	41.11	
Total	**10,050**	**10,774**	**12,686**	**4,693**	**3,066**	**41,269**

Source: own elaboration

Table 5. Dependence of villages at risk of depopulation on the demographic aging index. Summary of observed frequencies

Depopulation	Low	Medium	High	Very High	Total
(1) Threatened by depopulation	**88**	**57**	**68**	**717**	**930**
% column	5,90	0,99	0,54	3,35	
% of row	9,46	6,13	7,31	77,10	
(2) Decrease in population	**304**	**790**	**1,833**	**7,444**	**10,371**
% column	20,38	13,72	14,53	34,78	
% of row	2,93	7,62	17,67	71,78	
(3) No significant changes	**1,036**	**4,668**	**10,356**	**12,867**	**28,927**
% column	69,44	81,08	82,07	60,12	
% of row	3,58	16,14	35,80	44,48	
(4) Population growth	**64**	**242**	**361**	**374**	**1,041**
% column	4,29	4,20	2,86	1,75	
% of row	6,15	23,25	34,68	35,93	
Total	**1,492**	**5,757**	**12,618**	**21,402**	**41,269**

Source: own elaboration

Table 6. Dependence of villages at risk of depopulation on distance from the city. Summary of observed frequencies

Depopulation	Low	Medium	High	Total
(1) Threatened by depopulation	**43**	**361**	**526**	**930**
% column	0.75	2.31	2.64	
% of row	4.62	38.82	56.56	
(2) Decrease in population	**611**	**3,965**	**5795**	**10,371**
% column	10.61	25.42	29.11	
% of row	5.89	38.23	55.88	
(3) No significant changes	**4,782**	**11,002**	**13,143**	**28,927**
% column	83.05	70.52	66.01	
% of row	16.53	38.03	45.44	
(4) Population growth	**322**	**273**	**446**	**1,041**
% column	5.59	1.75	2.24	
% of row	30.93	26.22	42.84	
Total	**5,758**	**15,601**	**19,910**	**41,269**

Source: own elaboration

structures are found around larger urban centers, especially the seats of provincial governments", while the opposite phenomena in most areas located "along the borders of provinces, away from large and medium-sized cities located peripherally to urban centers" are characterised by worse demographic conditions. This confirms the observations of other authors, described above, that rural development is most influenced by location advantage (Serra et al., 2014; Lavesson, 2017), demographic structure (Bański, 2008) and village size (Vaishar et al., 2021).

In light of the presented data, further changes can therefore be expected in the size structure of rural settlements in Poland. The demographic

forecast carried out for this study for 2030 predicts a further increase in the largest villages, which will account for nearly 8% of the rural settlement structure, and an increase in the number of the smallest villages (up to 200 people) to 52.3% (Table 1). In 619 villages, the population is projected to fall below 0, which means that about 1.5% of Poland's rural settlements may soon disappear. In space, this will manifest itself in the form of huge disparities between different size categories of villages. The smallest villages (of fewer than 50 inhabitants) will dominate in the Podlaskie Voivodeship. They will also comprise a significant share in the Warmińsko-Mazurskie, Mazowieckie, Łódzkie, Świętokrzyskie and Lubelskie Voivodeships (Fig. 3).

6. Conclusions

In the post-war period, depopulation processes covered the vast majority of rural areas in Poland. A phenomenon accompanying this process was an increase in the rate of aging of the rural population, resulting from selective migration and low natural growth. A direct effect of the demographic shrinkage of rural areas is the transformation of the settlement network.

The observed demographic processes affect both the number and size of settlement units. Research has shown that population loss processes lead to the polarisation of settlement structures, their concentration in more developed areas, and their

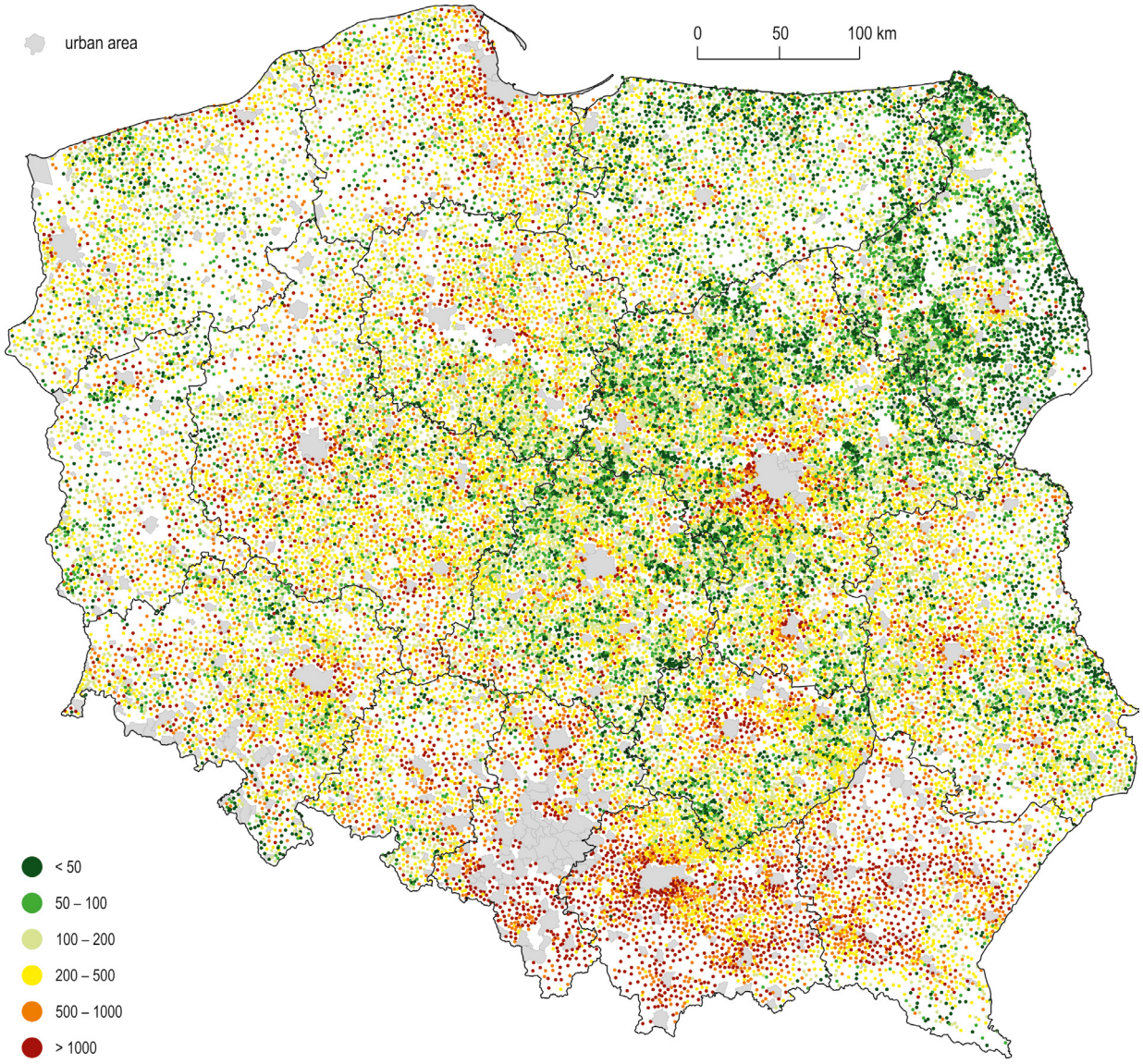

Fig. 3. Size of villages according to the forecast developed for 2031
Source: own elaboration based on CSO data

disappearance in marginal areas. The research shows that, in the period 1950–2021, the number of medium-sized villages decreased (decline of more than 11 percentage points) in favour of large and very large villages (increase of 2.5 percentage points), and the number of small villages of up to 200 people increased (by 9 percentage points). The smallest villages (of up to 50 people) depopulated the most, their share more than tripling in the period under review. The projection for 2031 showed that, in eastern and central Poland (especially in Podlaskie Voivodeship), there are 930 villages at risk of depopulation (about 2% of all analysed villages). Generally speaking, the smallest villages are currently located in central voivodeships and the east of the country (the effect of real movement, population aging, regional peripheralisation), the largest in the south and close to cities (the effect of suburbanisation). Similar processes are observed, for example, in the Czech Republic, where the villages with the highest population growth are mainly located near major cities, with the highest concentration around the capital Prague. In contrast, the greatest population decline is mainly in peripheral areas and on regional borders. The smallest municipalities, with a population of less than 50, have a much higher rate of population aging than other municipalities with more than 200 inhabitants and are therefore at risk of extinction from this point of view (Lešková & Vaishar, 2019).

The presented contemporary and projected differentiation in the structure of the rural settlement network strongly influences the development conditions of individual villages. The observed trends lead to a reconstruction of the settlement network, and a polarisation of space is taking place. Whereas large villages, usually subject to strong urbanisation pressure, have a chance for socio-economic and population development, the smallest villages are subject to degradation processes, and the effect may be the appearance of demographically empty villages.

Researchers note that there is a growing need to propose specific policies to counteract the ongoing population decline in Europe's vast rural areas (Alamá-Sabater et al., 2021). Rural depopulation should be shaped by relevant policies dedicated to rural areas, but taxonomic studies are needed to avoid rural areas becoming homogenised due to various rural development paths. These studies should focus on intra-rural divisions to capture different rural realities (assessing the spatial, economic, and structural conditions that explain why a village is experiencing depopulation). Researchers emphasise that there are no one-size-fits-all solutions in policies dedicated to overcoming regional disparities (Giannakis & Bruggeman, 2020; Heffner & Twardzik, 2022).

According to Fokt (2016), such analyses can provide "a pretext for considering topics of universal relevance, such as survival strategies for rural settlements in particularly adverse conditions". This finding is in line with the policy on shrinking rural areas in Europe and with the insights of the authors of the *Rural Development Monitoring* (2023) developed at the municipal level for Poland. The report *Shrinking Rural Regions in Europe* (ESPON 2020) states that the depopulation of certain areas should be accepted. Acceptance will enable a reorientation of rural policies and investment decisions to re-develop greener, modernised governance and public services through more holistic, proactive and place-based strategies in line with the realities of the 21st century. MROW (2023) research shows that it will be crucial to implement territorially sensitive policies through public policy interventions in rural areas affected by demographic pressures. It is important to provide local governments with financial stability, to establish a minimum allocation threshold for rural development, to support infrastructure projects, and to ensure minimum standards for the function of public services (health, social care and public transport systems).

The proposed statistical model for identifying villages at risk of depopulation confirmed the high correlation between the depopulation process (demographic shrinkage) and the peripheralisation of areas. This peripheralisation is due to their great distance from the centres of social and economic life offered by urban agglomerations. In addition, this process occurs more quickly in small towns with weak endogenous economic potential that are inhabited by an old population. This has also been recognised by researchers monitoring rural areas in Poland (MROW, 2023), who revealed that in recent years there has been a very worrying trend of some rural municipalities turning back from the path of multifunctional development; this intensifies population migration and, as a consequence, there is a demographic shrinkage that sets in motion a process of rural dislocation. Municipalities that were already multifunctional began to lose their non-agricultural functions and turned back on the development path. This process was particularly evident in the Opolskie and Świętokrzyskie voivodeships, in the northern communes of the Mazowieckie and Warmińsko-Mazurskie voivodeships, and in the eastern part of the Kujawsko-Pomorskie and Zachodniopomorskie

voivodeships. The biggest challenge facing the government, local governments and the local community will be to face the intensive process of aging and selective migration, as the accumulation of these factors sets in motion a spiral of negative development – rural areas "desertify". Johnson and Lichter (2019) have demonstrated with an American example that "depopulation today is rooted in the past. Chronic out-migration eventuates over time in natural decrease, which in turn compounds ongoing rural decline […] future nonmetropolitan population change will vary across geographic space. […] some rural areas will be unable to avoid a continuing downward population spiral."

Of course, rural shrinkage is an inevitable process. It occurs when society transforms from an agrarian economy to an urban-industrial economy and then to a knowledge-based economy. As noted by Hrynkiewicz (2022), knowledge of areas that are "vulnerable" for reasons of state security and areas undergoing depopulation is not only of scientific or academic importance: it can also have important strategic significance. "Recognition of demographic processes is the basis for any assessment of the economic situation, as well as one of the most important reasons for regional policy decisions" (Jakubowski & Bronisz, 2019). In many cases, the future development or decline of rural areas depends largely on whether their inhabitants are willing to accept greater population diversity, e.g. as a result of migration. This has important implications for the design of policies towards derelict areas, which can help to foster social contact between the native population and newcomers (Čipin et al., 2020; ESCAPE, 2020). In addition, new development approaches need to be "smart", in the sense of both adapting to the place and responding to changing technologies and spatial behaviour patterns, especially in terms of mobility, information and communication. Research has shown that there is a need for rural areas to have similar access to technology as urban areas so that they can gain traction as places where well-paid employment can be combined with living closer to nature. However, as numerous studies indicate, policy goals to change demographic trends in shrinking rural regions are not easy to achieve, and it is not even clear whether they are needed (Barakat, 2014; Christiaanse, 2020; Copus et al., 2021; Heffner, Twardzik, 2022; Rigby, 2022; Wojewódzka-Wiewiórska, 2019). A paradigm shift requires a sustained, long-term commitment on the part of those in power.

Actions at national and local levels alike can help to solve the problems resulting from the shrinking of rural areas. NGOs can play an important role. An example is Bulgaria, where NGOs play an important role in facilitating and developing municipal cooperation, business opportunities and social services and are often directly involved in tackling rural shrinkage (Foryś & Nowak, 2020; Slavova et al., 2020). Another positive example of this is in Croatia, where programmes on rural shrinkage adaptation as well as rural shrinkage mitigation are carried out in cooperation with NGOs (Lukić et al., 2020). The main problem, however, is their funding and the perception of the activities of these organisations through the prism of small scale (Foryś & Nowak, 2020; Koós et al., 2020).

The scientific community has also become involved in the process of counteracting or reducing the effects of rural demographic shrinkage. Research has resulted in the search for new ways to develop areas where population potential is being lost. Scientific concepts emerged in the English-language literature that in time led to the launch of government programmes aimed at repopulating depopulated areas (Damyanovic & Reinwald, 2014; Halliday & Coombes, 1995; Rodríguez et al., 2002). Thanks to "village renewal" programmes, people are noticeably returning to areas of the countryside inhabited years ago (before migration to the city), and pensioners are frequently returning "to their roots". Displacement from remote locations and scattered buildings with high infrastructure maintenance costs, purchase and demolition of decapitalised vacant buildings by municipalities, and creation of new building plots and housing for young families in a central location (committing to a certain period of residence) are organised. The programmes are often preceded by social campaigns, such as: "*Modern housing in an old entourage*", and promotion of themed housing e.g.: "*Living and working under one roof*", "*Living and gardening in the centre*" (Weber, 2011; Wilczyński, 2012). In contrast, for some areas of Spain, the use of farmland has been advocated as an effective way to alleviate depopulation, and some strategies based on land management for sustainable agriculture have been developed, including for the province of Castellón (Jato-Espino & Mayor-Vitoria, 2023).

Paradoxically, in some areas where there has been large-scale depopulation due to, for example, spatial isolation, there are now factors stimulating their development, such as tourism. Through the creation of tourist routes in many Italian regions, and thanks to local government programmes (buying a house for €1), development is taking place, and new residents and holiday homes are appearing (Di Figlia, 2014). Similar observations apply to Georgia, where in some regions with

certain assets (e.g., mineral waters, hot springs, healthy climate and diverse mountain landscapes), investments in localities related to their recreational potential are taking place (Kohler et al., 2017). In Bulgaria, infrastructure development activities are proposed to attract and retain residents, exploit the natural and cultural-historical heritage, and stimulate economic activity and the development of different types of tourism (Mladenov & Ilieva, 2012).

Such examples can also be found in Poland. In villages depopulating but with high tourism and recreation potential, new inhabitants are appearing (Heffner & Latocha, 2021; Wesołowska, 2018), though usually only seasonally, which is related to the phenomenon of second homes (Czarnecki & Heffner, 2015). Some researchers predict that depopulated villages with high tourism and recreational potential "may regain their investment attractiveness by exploiting the advantages of location and landscape (tidying up, revitalization, renewal), natural environment (areas unencumbered by high population density and significant resource intensity), and economic competitiveness (low prices of land for development)" (Heffner & Latocha, 2021).

The presented study monitors the current demographic situation in rural localities in Poland and indicates a probabilistic projection of the population in Polish villages. Therefore, it can be used as an instrument of territorial policy. The diagnosed areas of depopulating villages can be assigned, through recommendations, an appropriate set of policy instruments to counteract the negative effects of this process. Moreover, the data presented for a large period (1950–2021 with a projection to 2031), can be used for evaluation and comparison in various national studies. The applied value of the study results may be in improving the effectiveness of public interventions within the spatial development policy of individual Polish regions. Information on the future development of the population in particular localities is essential for planning processes in politics and economic administration. As the analysis is limited to the rural areas of Poland, it is necessary to continue the proposed research in other European countries to compare the changes taking place and determine whether the authors' observations are universal or specific to the analysed country.

Notes

1. Independent settlements are referred to as "basic settlements" in the TERYT register. Belonging to a basic settlement is determined primarily based on the property serial numbering system. A "statistical locality" is a group of several localities separated for statistical purposes, usually including a village and its adjacent hamlets and other smaller localities, for which statistical data are collected and processed together. It is defined by a common name, usually that of a larger locality (https://bdl.stat.gov.pl/ BDL/metadata/territory/ locality).
2. Warminsko-Mazurskie has a multi-generational migration tradition as confirmed by research by Źróbek-Różalska and Zysk 2015: 127.

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