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CLIMATE CHANGE AND DEPOPULATION: INSIGHTS ON KEY FACTORS FOR REGIONAL DEVELOPMENT

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Climate change and depopulation challenge regional sustainability through their negative effects on socioeconomic conditions. Given regional peculiarities in terms of geographical, economic, social, cultural, demographic, and environmental aspects, regions differ. As a result, the intensity of the possible negative effects provided by climate change and depopulation also differs across regions. A timely understanding of possible risks that have to be addressed through sustainable regional development policies allows for effective risk management. The article aims to characterise depopulation and climate change risks for the regions of Latvia. Within the article, the authors, first, elaborate long-term forecasts for population change by application of system dynamic modelling; second, characterise the climatic and environmental peculiarities of the regions in Latvia. The research findings introduce a wider audience of scientists and practitioners to possible risks for sustainable regional development in terms of climate change and depopulation. According to the data analysed, at the moment, for sustainable regional development in Latvia, depopulation is a greater risk than climate change. However, both risks have to be addressed through effective management.

Keywords: *sustainable regional development, climate change, population forecasts, socioeconomic conditions, environmental conditions.*

INTRODUCTION

Climate change and depopulation challenge regional sustainability in both developed and developing countries. Climate change affects socio-economic conditions through ecosystems, health, production processes, and actions devoted to mitigation of climate change. Global warming is expected to provide negative effects on regional socioeconomic development in a long-term (Lu et al., 2019). Depopulation also threatens balanced regional development and has to be addressed through sustainable development policies. The process of depopulation depends on demographic, socioeconomic, environmental, and cultural factors that affect attractiveness of certain territories for living and working.

Given regional peculiarities in the terms of geographical, economic, social, cultural, demographic, and environmental aspects, regions differ. As a result, intensity of possible negative effects of climate change and depopulation across regions differ. Timely understanding of possible risks that have to be addressed through sustainable regional development policies allows for effective management. This article aims to characterise depopulation and climate change risks for the regions in Latvia. Within the article, the authors, first, elaborate long-term forecasts for population change, second, characterise climatic and environmental peculiarities of the regions in Latvia. The research findings introduce wider audience of scientists and practitioners to possible risks for sustainable regional development in the terms of climate change and depopulation in Latvia.

Intentions to solve negative effects that appear as a result of climate change result in elaboration of action plans. For example, according to the Colocci et al. (2023) regional action plans that address climate issues effectively support regional sustainability. Although, not only the presence of action plans but their relations with practical implementation (Colocci et al., 2023) and comprehensive policy formulation (Zhang et al., 2023) are required. In this context, holistic approach, monitoring, professionalism of policy makers (Ray Biswas & Rahman, 2023), horizontal coordination and collaboration between regions (Armstrong, 2023) are keys to success. Although, despite intentions towards effective

climate risks management at regional level, researchers found out that regional plans are insufficient for meeting the goals of the Paris Agreement, but national plans comparing them with transnational plans are insufficient for encouraging regional activities (Salvia et al., 2021). Overall, researchers highlight the role of quality of economic and political institutions for acting towards mitigating climate change (Song, Wang, & Wang, 2023).

Obviously, that climate change poses risks for social and economic development in regions. At the sectoral level, researchers point out primary sector, tourism, and nature-based activities (Goers et al., 2023; Gonçalves et al., 2022; Mayer et al., 2023; Pickson et al., 2023) as sectors with potential losses depending on regional economic structures and environmental characteristics (Song, Wang, & Wang, 2023). Effects may appear as decline in gross regional product and employment (Goers et al., 2023). According to the studies, climate change challenges social development at regional level (Lu et al. 2019) through, for example, increasing fiscal stress and regional inequalities (Yang & Tang, 2022). Timely and qualitatively developed action plans to mitigate climate change are required for addressing the possible socioeconomic risks. Researchers found out that effects from climate change mitigation activities may have negative effects on economic growth but positive on social and environmental development (Abid et al. 2023). Knowledge, technical and economic resources are necessary and their lack may hinder success, especially in small municipalities (Ricciardi et al., 2023). Overall, researchers indicate on heterogeneity across European countries in terms of effects of climate change mitigation (Abid et al., 2023).

Besides climate change, depopulation also threatens regional prosperity and requires attention within sustainable regional development policies. Sometimes, researchers consider the both issues as mutually linked with negative effects for socioeconomic conditions in regions (Szymanowski & Latocha, 2021). For explanation of the future socioeconomic changes, scientists predict population changes with accents on demographic and migration issues (Amcoff & Westholm, 2007). Within scientific studies, the main questions are – why territories depopulate and how it is possible to prevent this negative tendency.

In the terms of the reasons, researchers usually consider a set of factors, which characterise geographic, social, economic, cultural, demographic, and environmental aspects. Usually, results differ depending on the case studies and regional peculiarities. For example, Alamá-Sabater et al. (2021) link population changes with accessibility, economic conditions, public facilities and services, natural amenities, and degree of urbanization. Danko et al. (2023) studied regional attractiveness and found importance of economic, lifestyle, and social indicators. Szymanowski and Latocha (2021) mention political, institutional, social, cultural, economic, and environmental factors as possible drivers of depopulation.

Measures that may be realised for maintaining regional attractiveness for living and working are of high importance. Researchers indicate significance of rural entrepreneurship (del Olmo-García et al., 2023). In this context, del Olmo-García et al. (2023) conclude that investments in R&D and availability of credits ensure higher interest in rural entrepreneurship. Although, the same study indicate that interest differ depending on education level (del Olmo-García et al., 2023). García Fernández and Peek (2023) highlight the role of smart connectivity between rural and urban territories in the terms of infrastructure and digital competencies. For depopulated areas, Makkonen and Inkinen (2023) offer approach to "shrink smart" what means to adapt for population loss and maintain vitality of territories. Streimikiene, Baležentis and Kriščiukaitiene (2012) pay attention to interconnectedness between existing local development policies with climate change mitigating policies and sectoral-specific policies. Special attention to particular sectors Jato-Espino and Mayor-Vitoria (2023) pay by indicating that increase of land suitable for agriculture may reduce depopulation. Another specific focus Rodríguez-Lora, Rosado, and Navas-Carrillo (2022) make when consider cultural heritage as resource for economic and social development of a territory.

The above-mentioned issues on climate change and depopulation have widespread effects on regional development and attract deep attention from researchers. For effective management of possible risks, first, it is necessary to understand regional peculiarities in the terms of the mentioned issues. The present article contributes to the understanding of the risks for regional development in terms of climate change and depopulation in Latvia. The research results are intended to join debates on sustainability of regional development.

The article consists of four sections. In the second section, the authors provide research methods. In the third section, the authors present research results – first, forecasts for population change at regional level in Latvia by application of system dynamics modelling, second, climatic and environmental characteristics of regions in Latvia. In the fourth section, the authors offer conclusions.

RESEARCH METHODS

Given significance of depopulation and climate change for regional development in general and, particularly, for the regional development in Latvia, the authors, first, elaborate long-term population forecasts at regional level, second, analyse appropriate environmental statistical data. Analysis results allow for demonstrating possible regional development risks in Latvia.

For the elaboration of population forecasts until 2076, the authors use system dynamics simulation model. Initially introduced by Jay Forrester in the 1960s, this methodology has proven to be an effective tool for modelling complex, multifactorial, and interconnected systems (Forrester, 1986). This method offers substantial flexibility in adapting to different conditions and scenarios, allowing the creation of models that consider numerous parameters, including demographic structure, birth and death rates, migration rates, and other socio-economic indicators.

Mathematically, the fundamental architecture of a formal system dynamics simulation model is a network of interconnected, nonlinear, first-order differential (or integral) equations. (1),

$$\frac{d}{dt}x(t) = f(x,p)\frac{d}{dt}x(t) = f(x,p)$$

In this model, 'x' represents a vector of levels (also referred to as stocks or state variables), 'p' denotes a set of parameters, and 'f' is a nonlinear vector-valued function (Richardson, 1991). The simulation of these systems is conducted by dividing the simulated time into discrete intervals of length 'dt' and progressing through the system one 'dt' step at a time. Each state variable's computation is based on its preceding value and its net rate of change x(t):

$$x(t) = x(t-dt) + dt * x(t-dt).$$ (Richardson, 1996)

The behaviour exhibited by a system is a direct outcome of its inherent structure. This structure is composed of feedback loops, stocks and flows, and non-linear dynamics, all of which are formed through the interaction between the system's physical and institutional structure and the decision-making processes employed by the individuals operating within it (Sterman, 2000).

In the framework of this study, using system dynamics modelling, a scheme was developed consisting of basic demographic variables: age and gender, followed by the establishment of functional relationships between them. As a result, a model was formed in which changes in one variable could affect others, mimicking real demographic processes (Bossel, 2007).

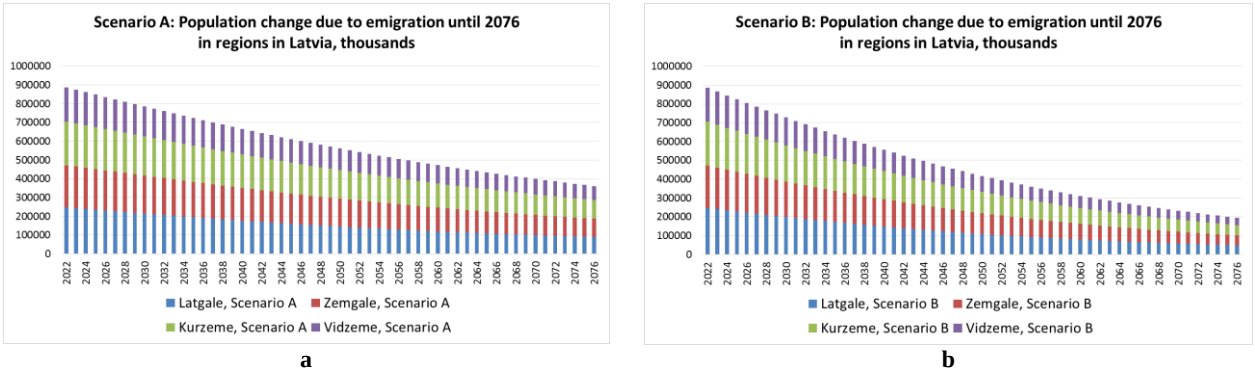
For demonstrating environmental peculiarities at regional level, the authors apply statistical analysis for the environmental indicators and dimensions of quality of life from the "Atlas for the Territorial Agenda 2030" (Federal Institute for Research on Building, Urban Affairs and Spatial Development et al., 2020). The indicators used are as follow: change of temperature 2081-2100 in summers and winters, change of precipitation in percent in summers and winters in 2081-2100, vulnerability to climate change, impact of climate change, adaptation to climate change, land change into urban use, green infrastructure, employment in Circular Business Models. Additionally, the authors characterise regions according to the data of Life Maintenance Index (personal, societal and ecological health sub-domains: personal health, personal safety, healthy economy, healthy society, healthy environment, climate change), Life Flourishing Index (personal, societal and ecological flourishing sub-domains: self-esteem, self-actualization, interpersonal trust/societal belonging, institutional trust/good governance, biodiversity wealth), and Good Life Enablers Index (personal, socio-economic ecological spheres: housing and basic utilities, health, education, transport, digital connectivity, work, consumption, public spaces, cultural assets, green infrastructure, protected areas), which include environmental and climate aspects among others.

RESEARCH RESULTS AND DISCUSSION

Characteristics of long-term population change at regional level in Latvia. Depopulation is one of the key issues, which negatively affect regional socioeconomic development. Emigration and low birth rates are the reasons for decline of number of population, especially in economically less developed regions. In Latvia, in 2022, birth rates were the lowest during the last hundred years (Official statistics portal. Official statistics of Latvia, n/d b). In turn, emigration is one of the key issues that stimulates depopulation at regional level during long time (Rajevska & Romanovska, 2016). Mainly, socioeconomic conditions are the reasons for emigration, especially in the case of rural and peripheral territories. Figures 1 and 2 demonstrate changes in number of population in regions in Latvia until 2076.

Differentiated scenarios for population change at regional level provide a basis for elaboration of sustainable regional development policies that target specific regional peculiarities. The "Scenario A" and "Scenario B" elaborated for population change at regional level in Latvia given emigration trends, demonstrate decline in number of population for both cases only with different speed. In 2022, Latgale, Zemgale, and Kurzeme regions had relatively similar number of population that is more than 220 thousand but does not reach 250 thousands. In 2022, Vidzeme region had number of population that is lower than 200 thousands but near to this mark. Riga region is the capital-city region, where 1/3 of country's population live. According to the "Scenario A", which is based on current emigration trends, number of population is expected to decrease in average by 60% until 2076 in Latgale, Zemgale, Vidzeme, and Kurzeme regions (see Figure 1a). In Riga region, decrease is expected to reach about 54% until 2076 (see Figure 2). According to the "Scenario B", which is based on historically the highest emigration trends, number of population is expected to decrease faster in all regions. The data calculated indicate on 77% and even 80% decrease in number of population at regional level until 2076 (see Figure 1b). Within the "Scenario B" even capital-city region may experience decline by 75% in number of population (see Figure 2).

According to the "Scenario A", in absolute values, decline of number of population until 2076 is expected in amount of 106126 persons in Vidzeme region, 128014 persons in Zemgale region, 133526 in Kurzeme region, and 157111 persons in Latgale region. In Riga region, where the biggest share of population live, decline in absolute values is expected to reach 534182 persons until 2076. Decrease in number of population in absolute values according to the "Scenario B" demonstrates bright depopulation risks – 140451 persons in Vidzeme region, 172513 in Zemgale region, 179212 in Kurzeme region, and 198724 in Latgale region, and 740085 in Riga region until 2076.



a **b**

Figure 1. Scenarios for changes in the number of population in regions in Latvia.

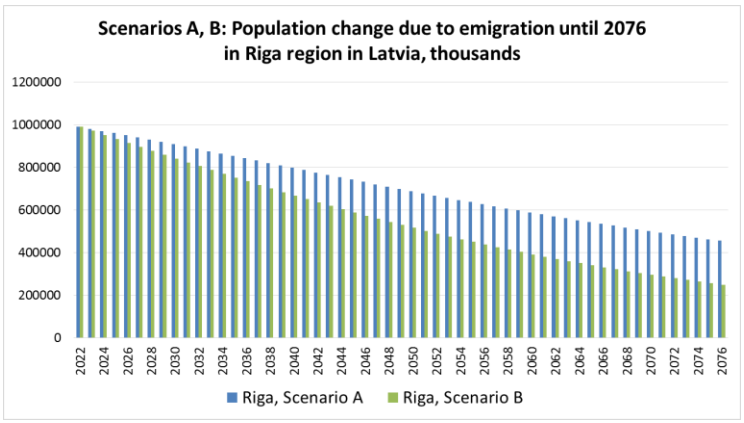


Figure 2. Scenarios for changes in the number of population in Riga region in Latvia.

In conclusion, it is possible to highlight decline in number of population in regions despite of the level of socioeconomic development (for example, Riga region (with Pieriga region) demonstrates the highest GDP per capita and Latgale region demonstrates the lowest GDP per capita (Official statistics portal. Official statistics of Latvia, n/d a)). These findings indicate on necessity to include focus on demographic issues and emigration in sustainable regional development policies.

Characteristics of environmental quality at regional level in Latvia. Climate change is considered as possible threat to social and economic development (Lu et al., 2019). Additionally, studies reveal that environment and its quality is significant for regional development (López-Penabad, Iglesias-Casal, & Rey-Ares, 2022). Healthy environment and ecological flourishing are among factors affecting territorial quality of life (Federal Institute for Research on Building, Urban Affairs and Spatial Development et al., 2020). According to the data of the "Atlas for the Territorial Agenda 2030" (Federal Institute for Research on Building, Urban Affairs and Spatial Development et al., 2020, pp. 36, 37), Life Maintenance Index and Life Flourishing Index describe territorial quality of life including also environmental factors, biodiversity, and climate change among others. The mentioned indexes indicate on diversity of the Latvian regions. Overall, the characteristics of flourishing of life is lower in regions with weaker socioeconomic conditions. Good Life Enablers Index also includes environmental factors in its composition (green infrastructure, protected areas). This index demonstrates the brightest differences across regions.

Climate change. Particularly, changes in temperatures and precipitation are considered as possible risks for socioeconomic development at regional level (Gonçalves et al., 2022; Lu et al., 2019; Yang & Tang, 2022). For the characteristics of climate change peculiarities in regions in Latvia, the authors use the data on temperature changes and precipitation (see, Federal Institute for Research on Building, Urban Affairs and Spatial Development et al., 2020, pp. 54, 57). According to the data of temperature in climate change, Latvia may experience increase in maximum temperature in 2081-2100 comparing with 1971-2000 for both summers and winters. In this case, the change in maximum temperature seems to be higher for summers than for winters in 2081-2100. At regional level, change of temperature 2081-2100 in summers looks similar for all regions. For the same time in winters, slight differences may be observed between Eastern and Western regions with lower temperature change for coastal territories. Change of precipitation in percent in 2081-2100 in Latvia comparing to the time 1971-2000 is expected to increase in winters similarly in all regions. Slight differences may be observed for precipitation change in 2081-2100 in summers between coastal and inner territories. Scientists indicate that fluctuations in temperatures and precipitations can provide negative effects on economic activities in primary sector and tourism (Gonçalves et al., 2022). For the knowledge, Gonçalves et al. (2022) indicate that assessment of possible vulnerability to climate change has to be addressed.

Potential vulnerability, impact, and adaptation to climate change in Latvia given geographical, physical, environmental, social, cultural, and economic characteristics may be understood through the data elaborated by the Federal Institute for Research on Building, Urban Affairs and Spatial Development et al. (2020, pp. 58, 59). According

to the data, potential vulnerability to climate change is evaluated as 'no/marginal vulnerability' for all regions and aggregate potential impact of climate change as 'no/marginal impact' for all regions. Overall, climate influences for the Baltic Sea Region are expected to be positive, for example, with increased crop yields and tourism potential. Adaptation to climate change in Latvia is evaluated with medium capacity for all regions.

Change of agricultural areas, forests and semi-natural areas marshland, water areas, mining areas and dumps into urban areas, industrial, commercial, and transport areas and urban green areas characterizes trends for population living in cities and economic growth (for the regional data see Federal Institute for Research on Building, Urban Affairs and Spatial Development et al., 2020, p. 61). Land change into urban use indicates differences between regions in Latvia, where the capital-city region is the leader.

Green infrastructure indicators discover how spatial planning integrate environmental issues in territorial development (for the regional data see Federal Institute for Research on Building, Urban Affairs and Spatial Development et al., 2020, p. 65). Regional coverage of potential green infrastructure network discovers difference between coastal and inner territories as well as progress in northeast territories.

Protected areas contribute to preservation of biodiversity and require balancing economic activities with nature protection (for the regional data see Federal Institute for Research on Building, Urban Affairs and Spatial Development et al., 2020, p. 73). According to the data of 'Proportion of protected areas defined by European and national legislation', Latvia has the highest share of protected areas in capital-city region and in northeast territories. Other regions demonstrate lower share although still significant.

Economic activities that minimize negative effects on environment quality present circular economy principles. These principles have to be realized in all regions regardless of their economic capacity what is possible through application of different Business Models (for the regional data see Federal Institute for Research on Building, Urban Affairs and Spatial Development et al., 2020, p. 75). In Latvia, share of people employed in Circular Business Models is similar for all regions. This indicator is relatively low, but similar to the most of regions in the European Union.

In general, researchers conclude that climate change and environmental risks have to be managed (Sumby et al., 2021; Swart et al., 2021; Pietrapertosa et al., 2023). Although, at the moment, stakeholders mostly act in the terms of collecting information and elaborating action plans rather than incorporating real actions in daily activities (Sumby et al., 2021; Pietrapertosa et al., 2023). Systematic understanding, technological solutions, collaboration at different governance levels, and elaboration of legal obligations may contribute to effective risks management in terms of climate change, environmental protection, and sustainable regional socioeconomic development (Kim et al., 2023; Swart et al., 2021; Pietrapertosa et al., 2023). In conclusion, the data analysis allow for highlighting favourable environmental conditions in the terms of climate change and need to enhance green economic capacity in Latvia at regional level.

CONCLUSIONS

Climate change and depopulation provide risks for sustainable regional development through worsening of socioeconomic conditions. Regions differ by geographical, economic, social, cultural, demographic, and environmental characteristics. As a result, effects of climate change and depopulation may differ across regions given their peculiarities. Timely understanding of possible risks that have to be addressed through sustainable regional development policies allows for effective management. Within the article, the authors, first, elaborate long-term forecasts for population change by application of system dynamic modelling; second, characterise climatic and environmental peculiarities of the regions in Latvia.

First, the authors elaborated two scenarios for changes in the number of population due to migration until 2076. The data analysed allow for concluding that all regions will experience significant decline in number of population despite of the level of socioeconomic prosperity. Given data on forecasts, it is noteworthy to indicate demographic and emigration issues that have to be addressed within sustainable regional development policies. Second, the data on climate change and environmental quality were analysed. According to these data, regions in Latvia is expected to experience changes in temperature and precipitation in both summers and winters, although, potential vulnerability to climate change and potential impact are not detected as significant at the moment. Relatively good environmental quality, but insufficient green economic capacity was identified.

The data analysed on long-term population change and climate change effects allow for indicating that at the moment depopulation is the greater risk for sustainable regional development in Latvia than climate change. Scientific literature provides wide knowledge on how climate change and depopulation affect regional development and how these risks have to be managed. It is necessary to include both risks, i.e., depopulation caused by emigration and climate change effects, in sustainable regional development policies.

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