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Population Aging and Environmental Degradation: A systematic review and future research avenue

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Abstract
This paper systematically reviews the relationship between population aging and environmental degradation, a complex and interdisciplinary topic. Focusing on existing studies and identifying gaps in the literature, the paper underscores the crucial need to understand the environmental implications of aging populations in developed and developing countries. The review highlights the research trend, emphasizing the interconnectedness of population aging and environmental issues across various disciplines. The paper proposes future research avenues to explore the complex interactions between aging demographics and environmental degradation.

Keywords: population aging; environmental degradation; developed and developing countries; demography; systematic review

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1.0 Introduction

Population aging, a significant demographic shift with profound global implications, refers to the increasing proportion of elderly individuals within a population. A sustained decline in fertility rates, healthcare system advancements, and overall longevity improvements primarily drive this phenomenon. It represents the simultaneous growth in the number of people aged 65 and above, coupled with a significant fall in the proportion of people aged 15 and younger (Ismail et al., 2021). The ongoing demographic transition has become a defining feature of the 21st century, posing various challenges and opportunities for nations worldwide. Based on the United Nations World Social Report (2023), it is expected that the world population of individuals aged 65 years and older to increase to more than double by 2050, increasing from 761 million in 2021 to an estimated 1.6 billion. Importantly, this phenomenon is not confined to industrialized nations; it is also rapidly manifesting in developing countries, further complicating efforts to ensure social, economic, and environmental sustainability (Meng et al., 2023).

Environmental degradation, on the other hand, encompasses the progressive decline in the natural environment's quality, primarily resulting from human activities. This deterioration often manifests the depletion of natural resources, a reduction in biodiversity, and the contamination of critical ecosystems such as air, water, and soil (Maurya et al., 2020). The interplay between population aging and environmental degradation is both multifaceted and complex. While older populations may adopt consumption patterns that exert

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relatively lower environmental pressure, the growing demand for healthcare services, energy, and resources associated with aging can inadvertently exacerbate environmental stressors.

This research paper employs a systematic review methodology to explore the intricate relationship between population aging and environmental degradation. The study ensures a comprehensive and unbiased examination of this intersection by meticulously identifying, screening, and synthesizing existing research findings (Petticrew & Roberts, 2006). Quality assessments are conducted on relevant studies to maintain the rigor and reliability of the findings (Kraus et al., 2020). By integrating insights from diverse disciplines, this study seeks to illuminate how population aging influences environmental outcomes while identifying associated challenges and potential opportunities.

The findings presented in this study aim to address the pressing need for further research, particularly in countries on the brink of becoming aged societies. By offering nuanced insights, this research aspires to guide policymakers in crafting adaptive strategies and policies that mitigate the adverse environmental impacts of aging populations. At the same time, it underscores the potential advantages of leveraging demographic shifts to promote environmental sustainability. Finally, this study is believed to contribute to the broader perspective on sustainable development, bridging the gap between aging demographics and environmental conservation.

2.0 Literature Review

The environmental implications arising from the growing number of elderly individuals within a population are intricately tied to observable changes in consumption behaviors and resource utilization patterns. A substantial body of research has consistently demonstrated that older adults tend to consume fewer natural resources and utilize less energy, contributing to a measurable reduction in carbon dioxide (CO_2) emissions. This phenomenon can be attributed to lifestyle changes commonly associated with aging, including a decline in physically demanding activities and a reduced frequency of travel.

For instance, a study by Kim et al. (2020) provides compelling evidence that carbon emissions tend to decrease as populations age. This reduction is primarily driven by the fact that older individuals typically engage in fewer daily activities requiring significant energy expenditure and have lower transportation needs than younger, more active age groups. These findings underscore the potential for aging populations to moderate overall environmental pressures, albeit within a complex matrix of factors that vary by region and socioeconomic context.

Notwithstanding, the relationship between aging populations and environmental effects is complex. The interrelation between social, economic, and environmental sustainability is essential in dealing with the quality of life of the elderly (Toyong & Yahaya, 2022). Regarding the environmental aspects, Liu et al. (2020) reported a universal decline in energy usage and carbon emissions with the advancing age of populations. However, it is crucial to acknowledge that the changing lifestyles of older people may also lead to increased resource use in certain areas. With advancing age, people tend to spend more time in their homes, resulting in increased household energy consumption and, consequently, a surge in carbon emissions. Furthermore, there is a correlation between people's increasing longevity and the escalating use of domestic energy, particularly in increased electricity consumption (Zhu & Lin, 2022; Yu et al., 2023).

Furthermore, the travel patterns of older individuals worsen the environmental impacts linked to a growing geriatric population. A study by Rahman et al. (2020) found that older people engage in fewer trips, travel shorter distances, and are more likely to rely on privately owned automobiles. Based on the findings of Cao and Liau (2023), reliance on private mobility can result in increased combustion of fossil fuels and subsequent emissions. Given the restricted mobility of older people, their pronounced preference for personal vehicles underscores the need to implement targeted strategies to mitigate the environmental impacts associated with this demographic. As such, without equitable access to efficient, well-connected, and user-friendly public transportation systems to cater to the needs of the elderly population, it will reduce the usage of the amenities and make it more likely to opt for personal vehicles (Zakaria et al., 2024).

Research indicates that population growth substantially enhances carbon emissions, ultimately resulting in environmental damage (Pham et al., 2020; Chaurasia, 2020; Zakaria et al., 2021). As the population increased, carbon emissions also rose due to heightened demand and consumption patterns. Nevertheless, insufficient attention was given to the impact of demographic change on carbon emissions. One of the current concerns is the aging population. The global population is aging, affecting economic growth and environmental factors. Research has indicated that the aging population will reduce carbon emissions due to altered consumption patterns among older individuals (Yang et al., 2021; Li et al., 2024). On the contrary, studies have identified a positive nexus between the aging population and carbon emissions (Kusumawardani & Dewi, 2020; Fan et al., 2020; Yu et al., 2023). This signifies that no synonymous outcomes were obtained from these studies, thereby allowing for more exploration of this problem, particularly in addressing emerging challenges related to the aging population in the future.

3.0 Methodology

3.1 Formulation of Research Questions

The research question is an essential aspect of SLR. This will lead to selecting relevant articles and data and the reporting process (Xiao & Watson, 2019). According to Lockwood et al. (2015), specific mnemonics formulate a research question based on three keywords: population, interest, and context (PICo). This study fulfills these three keywords, which are population aging (Population), the

impact on environmental degradation (Interest), and worldwide context (Context). Therefore, the research question for this study is, "How does population aging contribute to environmental degradation?"

3.2 Systematic Searching Strategies

The systematic searching strategies have three main phases: identification, screening, and eligibility. The Scopus database was used to identify and trace relevant research articles thoroughly. The first step is searching for the appropriate keywords. The following keywords were used: "Population aging" OR "aging population" AND "carbon emission" OR "CO2" OR "ecological footprint" OR "environmental degradation" OR "environmental sustainability" OR "greenhouse gas" OR "GHG" to identify relevant papers with substantial effects on the research. An aggregate of 280 scholarly publications was obtained using the search query. The screening procedure was conducted to precisely choose the articles directly related to population aging and environmental degradation, as the first results included articles irrelevant to the sought-after topic. Following a thorough screening process, 131 research works were found to be pertinent. The eligibility phase is carried out to examine the articles' relevance to the study's needs. The process occurs by manually monitoring the retrieved articles to ensure all the articles after the screening process align with the criteria. This process was conducted by reading the titles and abstracts of the articles, which resulted in excluding 40 unrelated articles. Therefore, only 91 articles are identified as relevant, focusing on population aging and environmental research in developed and developing countries, which suit the question and objective of this study. Figure 1 illustrates a methodical approach to conducting a systematic search:

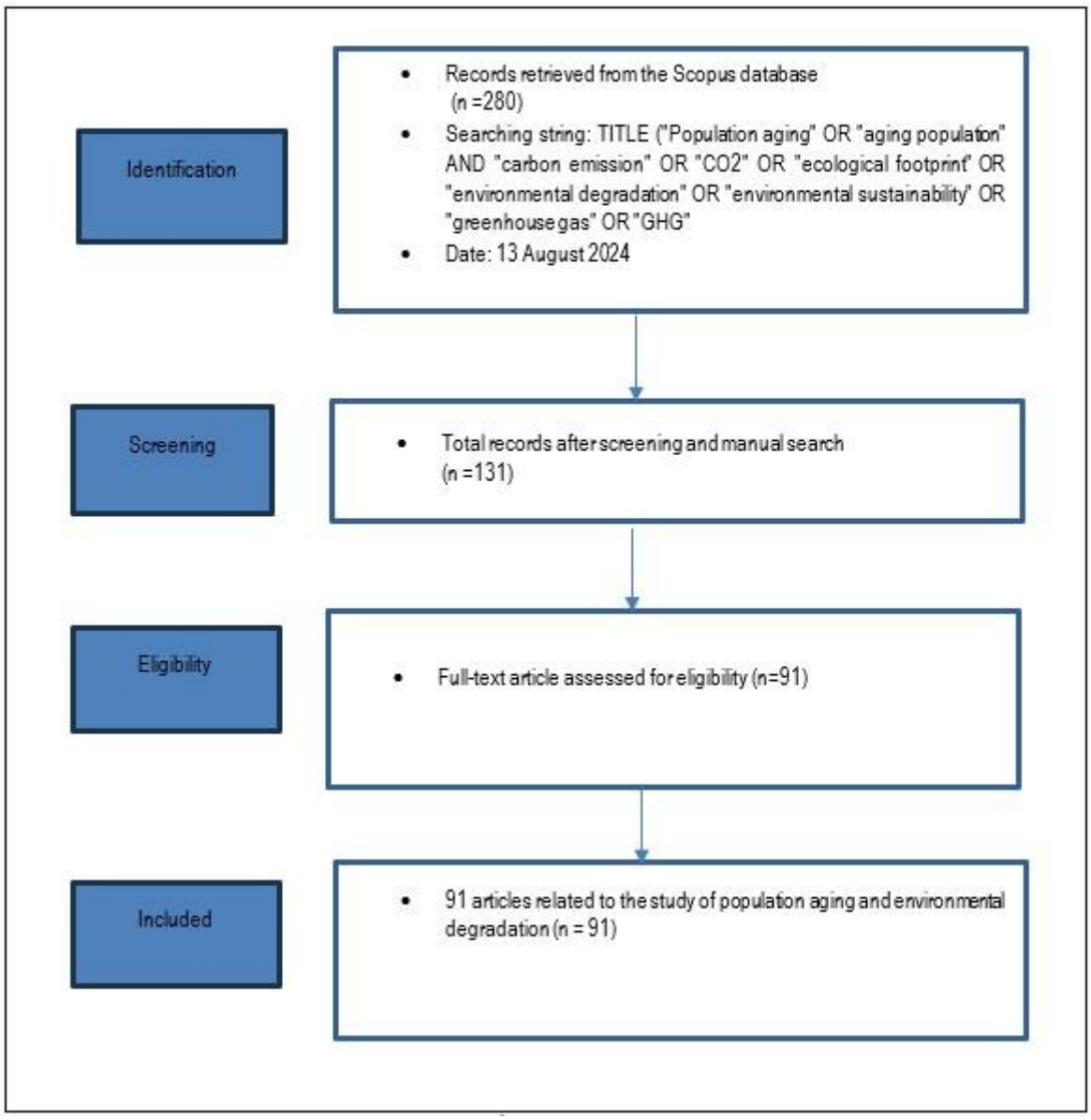

Fig. 1: Systematic Searching Strategy

Source: Articles retrieved from the Scopus Database by the author

Inclusion and exclusion criteria will ensure the selected studies' relevance and accessibility to the current study. This is a pivotal part of the systematic review, determining the most accurate literature accessed in the study (Amin et al., 2022). As summarized in Table 1, the criterion of the literature types selected is research articles only, and other literature types are excluded. The investigation was conducted in the English language only, and other languages have been removed from this study. The articles were published after the year 2000 because this year, attention has been drawn to the topic related to population aging and environmental degradation. This study also focuses only on social sciences research and excludes all non-social sciences articles.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Literature type	Research articles	Chapter in books, book series, books, conference proceedings, theses, reports
Language	English	Non-English
Timeline	Between 2000-2024	< 2000
Subject Area	Social sciences	Non-social sciences

Source: Scopus Database and author's manual search

4.0 Findings

This study examines 91 selected research papers and has discovered two crucial aspects discussed in the study related to population aging and environmental degradation. The two main aspects are the impacts and types of emissions used in the studies. Examination of the articles showed that all research used quantitative methods, and 14 articles employed the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model, the most popular model to analyse the demographic impact on environmental degradation. Most of the articles were conducted in China, with 47 articles. Additionally, 12 articles carried out research of many countries, followed by nine articles in OECD countries and five articles in Asian, South Asia, and East Asian countries. Four articles focus on Japan and G7, G11, and EU-5 countries; meanwhile, only two were conducted in the United States and developed and emerging countries, respectively. New Zealand, the Mediterranean, and Malaysia are the countries with the researcher's least focus, representing only one article, respectively. Lastly, the two articles do not mention the countries' names.

4.1 Impact of Population Aging on Environmental Degradation

A comprehensive study of the papers has revealed several effects of population aging on environmental deterioration. Existing research consistently indicates a negative correlation between population aging and environmental degradation. Indications from 45 publications suggest that the environmental impact will decrease with the aging population. In contrast, 17 papers emphasized that aging exacerbates environmental deterioration, implying that a larger senior population will increase emissions and adversely affect the environment. Ten papers proposed an inverted U-shaped correlation between population aging and environmental deterioration, whereas seven studies identified a nonlinear correlation consistent with the Environmental Kuznets Curve (EKC) theory.

Distinct variations in the impact of population aging on environmental degradation have been seen across different countries and income categories. For instance, certain studies suggest that emissions will increase with the aging population in industrialized or high-income countries, while others imply that emissions will be reduced compared to underdeveloped nations. Seven papers investigated the correlation between population aging and environmental deterioration in various geographical areas and specific socioeconomic categories. One publication provides an intriguing analysis of the relationship between population aging and environmental deterioration, focusing on gender disparities. The data suggest that women 65 and older will display higher emissions levels than males. Lastly, one research investigates how aging enhances pro-environmental behavior, benefiting the ecosphere.

4.2 Environmental Degradation Variables

Various variables are used to measure and analyze environmental degradation. The most common variable is carbon emissions (CO2), for which 56 research articles are utilized. This suggests that CO_2 is suitable for explaining the linkage between environmental degradation and population aging. Furthermore, nine articles employed ecological and carbon footprints, representing a narrow scope compared to CO_2. Eight articles study household or residents' CO_2, emphasizing the impact of population aging on residential and household consumption, which leads to emissions. Greenhouse gas emissions and per capita CO_2 are also used as environmental degradation indicators, representing five articles. Only two studies have analyzed the correlation between population aging and transportation CO_2. Other variables used are energy consumption, agriculture, and pollution emissions, representing one article for each. Finally, one research study deals with the pro-environmental behavior of the aging population to explore their behavior towards the environment, which, in turn, leads to an impact on the environment.

Studies of population aging on environmental degradation show a multifaceted exploration in the literature. Though the objective of the studies is to examine environmental degradation, numerous variables have been utilized as a proxy to measure the environmental aspects. Most studies used CO_2, but limited studies have explored other variables, such as residential and transportation emissions,

because several emissions are also essential to be analyzed. Different emissions will have distinct impacts, which are helpful to include in the literature.

4.3 Future Research Avenues

Given the continuous interest in studying population aging and environmental degradation, it is crucial to investigate numerous pathways for future research. Further investigation into population aging and environmental deterioration should transcend the conventional emphasis on carbon emissions or CO_2, which, although crucial, only reflects a single facet of the wider environmental consequences. The increasing age of the global population necessitates a thorough investigation of the impact of various pollutants, including those from home sources like heating, cooling, household waste, and transportation emissions, on environmental deterioration. The levels of these pollutants differ based on consumption patterns and lifestyle choices and have specific environmental consequences (Balezentis, 2020). Residential emissions tend to rise when older populations spend more time at home, which may necessitate more energy for heating and cooling purposes (Yu et al., 2020). The escalating utilization of healthcare services and the mobility requirements of an aging population can lead to a corresponding increase in transportation emissions (Lin & Cui, 2021). Comprehending these many origins of emissions is essential for formulating focused policies that respond to the environmental issues presented by population aging. Policymakers should adopt specialized control mechanisms that consider the distinct features of these emissions, guaranteeing that strategies are not only concentrated on CO_2 but also on mitigating the environmental impact of other primary emission sources. Adopting this broader viewpoint will be crucial in developing sustainable solutions that effectively address environmental deterioration within the framework of a worldwide aging population.

Moreover, it is imperative to conduct further studies on the correlation between population aging and environmental deterioration in Malaysia, especially considering the nation's elevated CO_2 emissions (ourworldindata.org/co2-emissions) and the imminent transition towards an aging population by 2030 (United Nations, 2023). Notwithstanding the evident importance of this matter, a scarcity of studies has been undertaken within the Malaysian setting, resulting in a notable deficiency in comprehending the obstacles and prospects that await. In Malaysia's shift towards an aging society, it is vital to explore the possible impact of an aging population on environmental aspects such as energy consumption, waste generation, and transportation patterns. Such effects have the potential to worsen environmental deterioration. Investigating these patterns will offer policymakers vital insights, allowing them to develop well-informed and efficient measures to tackle the environmental consequences of an aging population. By directing attention toward Malaysia's distinct socioeconomic and demographic circumstances, such a study has the potential to provide customized remedies that harmonize the requirements of an aging population with the urgent need to mitigate environmental deterioration, gradually leading the nation towards a more sustainable future.

5.0 Conclusion

In conclusion, there is a pressing need to address issues in a world that is becoming more interconnected, as seen by the growing scholarly interest in the connection between population growth and environmental degradation. The substantial surge in studies, as demonstrated by examining the selected research papers, emphasizes the acknowledgment that comprehending these dynamics is essential for attaining a sustainable future. Amidst the predominant emphasis on CO_2 emissions, the growing recognition of other substantial emissions, such as those from residential and transportation sectors, exposes a deficiency in the current body of knowledge. However, this study does not account for more specific aspects that do not include the spatial differences, such as rural and urban areas, and it only focuses on the demographic factors alone. This study identifies that most past studies of population aging and environmental degradation have focused on China alone, leaving a gap for future research in other countries. Insufficient attention has been given to other fast-aging countries, such as Malaysia, which shows that studies on this issue are still scarce and not comprehensive. Due to Malaysia's significant CO_2 emissions and its imminent transition to an aging population by 2030, there is an urgent requirement for more focused research in this area. The investigation of the impact of these additional emissions on environmental deterioration will yield a more thorough comprehension of the matter and provide beneficial direction for policymakers in formulating approaches to tackle the difficulties and possibilities presented by an older population. This research will be crucial in preparing Malaysia to effectively manage its population transition in a manner that promotes both ecological sustainability and social welfare.

Paper Contribution to Related Field of Study

This paper provides insightful information and knowledge on the systematic research pattern on population aging and environmental degradation, especially to researchers, policymakers, and the government. It contributes to literature by exploring the impact of population aging on the environment. It directs potential researchers to explore the world's environmental challenges and issues related to the aging population more in-depth.

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