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Environmental outcomes of climate migration and local governance: an empirical study of Ontario

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Abstract

Purpose – This study aims to examine the impact of migration growth on environmental outcomes and local governance and assess how well the existing local municipal governance has responded to the environmental impact of increased migration influx in Ontario, Canada using the annual data during 2012–2021.

Design/methodology/approach – This study used the grey relational analysis (GRA) to examine the correlation degree between migrant growth, environmental outcomes and local governance, used coupling coordination degree model (CCDM) to access to what extent the existing local governance systems have responded to the environmental impact of immigrant growth.

Findings – Results show that higher immigrant populations are associated with worse environmental outcomes and the need for more municipal environmental investment and service. The present local municipal environmental service in Ontario lags behind in response to the environmental impacts of increased migration. Good local governance practices and environmental services are required to improve the environmental adaptation capacity of host countries to migrant influx.

Originality/value – Climate change has been regarded as an important driver of internal and international human migration. The mass influxes of migrants will threaten cities' environmental quality and put considerable pressure on municipal services. This study provides empirical evidence for Ontario's municipal environmental governance and relevant authorities on how to deal with the environmental impact of

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increased migration and contributes to call the attention of other countries to the urban environmental pressure caused by migration influx due to the changing climate world wide.

Keywords Climate change, Migration, Environmental outcomes, Local governance, Municipal services, Coupling coordination degree model (CCDM)

Paper type Research paper

1. Introduction

Migration, as documented throughout human history, involves the mobility of people, usually *toward* a new location due to pull (e.g. work and livelihood) or push factors (e.g. drought, flood, political instability, poverty and violent conflicts) or a combination of both (Hansen, 2019). Climate migration refers to climate-induced migration. It implies that people are forced to migrate due to environmental degradation or people choose to move for a considerably better quality of life in response to environmental or climate pressures (Brown, 2008; Wilkinson *et al.*, 2016). It reflects how climate and the environment affect quality of life and emphasize the impact of climate change on population migration, so as to attract the attention of the public and policymakers and prevent potential risks (Piguet *et al.*, 2011).

A rapid growing field of study has focused on the impact of climatic factors on human migration, exploring the mechanisms underlying the climate migration relationship (Barrios *et al.*, 2006; Marchiori *et al.*, 2012; Millock, 2015; McLeman, 2017). The results demonstrate that climate change has been an important driver to provoke migrations and displacements of human populations. With climate change, sea level rise and increasing disasters and extreme drought, migration has become an adaptation strategy to cope with the risks of climate change (Siddiqui, 2010). According to the *World Migration Report* by International Organization for Migration (IOM) in 2020, most of the new displacements in Oceania are caused by natural disasters; human migration in the Pacific Island countries is directly related to climate change [1]. The United Nations High Commissioner for Refugees (UNHCR) also confirmed that the environmental impact of climate change is a key driver of an anticipated surge in human movement in the coming decades, and there will be at least 50 million people displaced by natural hazard related disasters by 2050 (UNHCR, 2016). In fact, Myers (2005) estimated that some 50–200 million people would be displaced by 2050 using a rudimentary methodology, and then he revised this figure as being closer to 250 million, which has been adopted in much of the literature (Ahmed, 2018; Berchin *et al.*, 2017). Stern (2007) later suggested that Myers' estimate of 250 million was "conservative" in his authoritative review (Stern, 2007). Kulp and Strauss (2019) showed that under a high emissions scenario up to 340 million people could be displaced by 2050 and 630 million by 2100. These are significantly higher estimates than predicted in a recent World Bank report (Kumari *et al.*, 2018). Climate-induced migration is an emerging global phenomenon (Siddiqui, 2010; Weber, 2015; McLeman, 2017; Ni, 2021). For most of the global population concerned about climate-induced migration, the fight no longer surrounds convincing nonbelievers of human-induced climate change, but forming policies to mitigate and adapt to its effects (Cutlip, 2019).

Rapid population growth results in additional use of natural resources and public resources, stressing the environment and challenging the sustainable management of the region (Berchin *et al.*, 2017). The interactions among human migration, climate change and environmental degradation are recognized as significant global concerns in the two important compacts on human movements: the Global Compact on Refugees and the Global Compact for Migration adopted by the United Nations General Assembly in 2018 (Morris, 2021). Similarly, IOM recognizes "the need to better integrate migration into global climate and environmental mechanisms, and for climate change mechanisms to incorporate human mobility aspects" (Oakes *et al.*, 2020).

Numerous authors have focused on the impacts of climate migration or refugees on the labor supply market (Ruiz and Silva, 2015; Fallah *et al.*, 2019), public health system (Cutlip, 2019; Palinkas, 2020), public infrastructure (Drolet *et al.*, 2018), land use (Maystadt *et al.*, 2020) and cultural integration (Mohamed and Bastug, 2021), assessing the sustainable livelihoods of migrants and limits of political and institutional frameworks to deal with such problems. Others also examined the effects of the greater population of migrants on environmental outcomes, such as effects on greenhouse emission (Morris, 2021), air pollution (Cramer, 1998), land use (Maystadt *et al.*, 2020) and water pollution (Rafiq *et al.*, 2017; Aliu *et al.*, 2021). However, few studies systematically investigate the relationship between climate migration, environmental outcomes and local municipal environmental governance. Aksoy and Tumen (2021) discussed the correlation between local governance and the environmental outcomes of large-scale refugee migration and found that the Syrian refugee influx has worsened environmental outcomes along several dimensions in Turkey, and the deterioration in environmental outcomes is almost entirely driven by provinces with poor-quality governance. They did not, however, empirically assess to what extent the local environmental governance has responded to the environmental impact of large-scale migration, properly quantified and incorporated into future planning decisions. We discuss our approach further in this paper.

Refugee and Migratory Movements Research Unit at University of Dhaka found that a major section of people moved from rural to urban areas due to environmental or climatic stresses (Siddiqui *et al.*, 2014). According to Muggah and Abdenur (2018), more than 60% of all refugees and 80% of all internally displaced people are living in urban areas. Only 30% of all refugees live in rural settings. These figures imply that many cities around the world are facing a mass influx of migrants. With increased migrant settlements, the demand for locally provided goods and services is increased, accessing to common resources becomes more limited (Squalli, 2010), public services are overburdened, energy consumption and greenhouse gas emissions are increased (Morris, 2021). Moreover, municipality level standards, such as the quality of waste management and environmental protection services, will be under pressure (Squalli, 2009). Under such circumstances, any delayed response by local municipalities in improving the infrastructure and waste management outcomes may aggravate the congestion in environmental services and reduce the environmental quality (Aksoy and Tumen, 2021).

Different methods, both quantitative and qualitative approaches (Marchiori *et al.*, 2012; Maurel and Tuccio, 2016; Evangelia, 2021), have been used in this field to analyze the environmental impacts of migration. However, less attention has been paid to assessing environmental outcomes and local governance indicators in particular area to address multiple systems analysis and coordinated development evaluation related to migration growth, environmental pollution and local governance. Thus, we use the grey relational analysis (GRA) and Coupling Coordination Degree Model (CCDM) to address this problem. GRA is a multiple factor statistical analysis method, which is used to measure the effect of the target item affected by other factors according to the degree of similarity or dissimilarity of development trends between factors (Deng, 1985). This method overcomes the shortcomings of traditional statistical sample demand and calculation and is widely used in social and natural science for multiple systems analysis and evaluation (Wang and Ge, 2007; Xia *et al.*, 2016; Chen, 2021). CCDM is an effective tool for evaluating the degree of coordinated development between multiple systems in a research region. The coupling degree reflects the interdependence and mutual restriction relationship between systems, and the coordination degree further reflects the coordination level and quality of this relationship (Wang *et al.*, 2021). The method is easy to calculate and the results are intuitive, so it is widely used in the empirical research on the coupling and coordination development level of multiple systems, such as the environment (Guan and Liu, 2012; Wang and Ge, 2007), the economy (Zhou and Chen, 2019), social development (Shen *et al.*, 2000), urbanization (Zhang and Wu, 2006; Maystadt, 2020), population (Liu *et al.*, 2018) and so on. Using these two methods can better meet the research objective of the paper and enrich the research methodology system in this research field.

Thus, the purpose of this paper is to address the impacts of migration on environmental outcomes and local environmental governance and assess to what extent the existing local municipal governance has responded to these challenges. Using the province of Ontario as a case study, an empirical analysis is conducted on the correlation between migrant growth, environmental outcomes and local environmental governance by using the GRA method. CCDM is used to evaluate the coordination level of environmental outcomes and local environmental governance in the context of migration growth, to reflect how well the local environmental governance mechanisms mitigate the environmental impact of increased migration influx. The findings are expected to not only serve as empirical evidence for Ontario's municipal environmental governance and relevant authorities on how to deal with the environmental impact of large-scale immigrants but also contribute to call the attention of other countries to the urban environmental pressure caused by migration influx and draw inspiration from Ontario. It also makes recommendations for further research for governmental policymakers and fellow researchers in academia.

2. Analytical framework: formation of index system

2.1 Environmental outcomes indicators

Studies revealed that per capita CO_2 emissions are nearly three times higher in countries with net immigration than in countries with net emigration (Morris, 2021), and the higher migrant settlements are associated with worse environmental outcomes, such as per capita waste, per capita distributed freshwater and wastewater (Aksoy and Tumen, 2021). The mass influx of population into cities will accelerate the process of urbanization, leading to urban greening reduction. Maystadt (2020) found that a 1% increase in the number of refugees amplifies the transition from dominant forested areas to cropland by 1.4 percentage points. Lantz *et al.* (2021) argued that urbanization processes such as densification and urban expansion can result in significant reductions in the quantity and quality of "green" areas as well as impervious surfaces, bare soil and low-density vegetation.

Referring to the above studies, we employ five variables to test the impact of immigration on environmental outcomes (Table 1), namely:

- per capita wastewater (from households and businesses, reflect daily average, net of wastewater recycling);
- per capita distributed freshwater (from natural resources, such as lake or groundwater reservoirs, reflect the per capita share of freshwater);
- average normalized difference vegetation index (NDVI) [2] (reflect the overall greenness of cities and towns);
- per capita solid waste -net of recycling (reflect per capital solid waste collected, net of recycling); and
- greenhouse gas emission intensity (reflect direct and indirect greenhouse gas emission intensity).

2.2 Local government and governance indicators

There is a consensus in the literature that improving the quality of local governance is an important driver of more efficient allocation/provision of public resources (McAdam, 2011; Krantzberg and Song, 2020). Climate migration and its impacts cannot be omitted when planning and implementing governance of the local environment.

	Variables	Variable explanation	Variable attribute	Weight coefficient
Environmental outcomes (A)	Per capita Wastewater (A1)	Wastewater from households and businesses, reflect daily average, net of wastewater recycling	−	0.046
	Per capita Solid waste (A2)	Reflect per capita solid waste collected	−	0.033
	Average normalized difference vegetation index (NDVI) (A3)	Reflect the overall greenness of cities and towns	+	0.065
	Per capita distributed freshwater (A4)	From natural resources, such as lake or groundwater reservoirs, reflect the per capita share of freshwater	+	0.066
	Greenhouse gas emission intensity (A5)	Reflect per unit of direct and indirect greenhouse gas emission	−	0.051
Local governance (B)	Waterworks infrastructure (B1)	Reflect per capita expenditures on municipal clean water supply works and services	+	0.11
	Sewage infrastructure (B2)	Reflect per capita expenditures on municipal wastewater management services	+	0.191
	Electric power infrastructure(B3)	Reflect government expenditure on electric power infrastructure	+	0.171
	Waste disposal facilities (B4)	Reflect per capita expenditures on municipal waste disposal facilities services	+	0.117
	Pollution abatement and control (B5)	Reflect government expenditure on pollution abatement and control	+	0.159

Table 1. Index system and weights of environmental outcome and local governance in Ontario

Local governments typically have primary responsibility for providing public services, such as waste collection, wastewater and water supply, and have some responsibility in the areas of housing and urban public transportation (Thomas and Benjamin, 2018). With the increasing immigrants, it is inevitable to increase consumption of natural resources (such as freshwater) and services (such as waste collection and recycling) (Becker and Ferrara, 2019). According to Aksoy and Tumen (2021), environmental degradation is almost entirely driven by cities with poor local municipal services.

Therefore, local municipal governorates and the governance systems play important roles in reducing the negative impact of large-scale migration influx on the environment. Well-governed municipalities were better at tackling the challenges from rapidly increasing population density and investing in infrastructure to keep pace with population growth. Thus, we developed five quantitative indicators to assess how well the existing local governance systems respond to the environmental impact of increased migration (Table 1): waterworks infrastructure service (include water filtration plants and other water infrastructure, reflect per capital expenditures on municipal clean water supply works and services); sewage infrastructure service (reflect per capita expenditures on municipal wastewater services); waste disposal facilities service (reflect per capita expenditures on municipal waste disposal facilities services); pollution abatement and control (reflect government expenditure on pollution abatement and control); electric power infrastructure (reflect government expenditure on electric power infrastructure).

3. Methodology and data

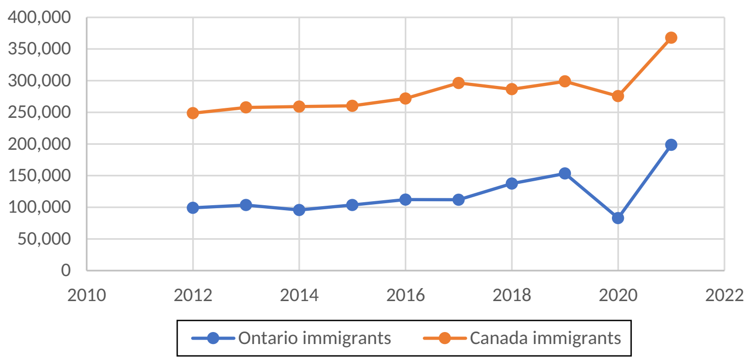
3.1 Study area and data collection

Ontario is the most populous of the 10 provinces in Canada, with an area of 1.068 million square kilometers and a population of 13.448 million (2016 census), accounting for approximately 38% of the total population in Canada. Ontario is regarded as one of the most multicultural provinces in the world, and it prides itself on being a tolerant and open society (Martin and Macklem, 2017). Immigrants play an important role in social- economic development of Ontario, as they are essential to increasing the labor force capacity. Ontario is located at 41°~57° N and 74°~95° W. The Great Lakes regulate the climate, so it is not too cold in winter and not too hot in summer; this favorable climactic environment makes Ontario a good destination for migrants (Martin and Macklem, 2017).

Ontario is also the province receiving the most immigrants per year in Canada. Especially after the COVID-19 pandemic, immigration is higher than ever and represents a substantial contributor to population growth in Ontario. According to Immigration, Refugees and Citizenship Canada by Citizenship and Immigration Canada News, Canada exceeded its 2021 immigration target by landing 405,303 new permanent residents, and Ontario received 198,085, accounting for 48.9% of the total immigration in Canada. As the immigration goal of Canada is to reach 431,645 in 2022, 447,055 in 2023 and 451,000 in 2024 [3], the immigrant population in Ontario will continue to increase. Therefore, Ontario is facing and will face more severe pressures and challenges to environmental outcomes through immigrant influx than other cities in Canada.

In addition, Ontario is located in the Laurentian Great Lakes region, where freshwater is abundant, but still at risk of ecological and economic damage due to climate migration. With climate change, the surging immigration from surrounding countries and regions may increase the economic, social and environmental burden of Ontario in the coming decades. As such, Ontario, as a case study, is representative of Canada (Figure 1).

The data to construct the index system was derived from the *Statistics Canada* [4], *Government of Ontario* [5] and *Environment and Climate Change Canada* [6]. To make sure we had adequate data availability, a 10 year data set from 2012–2021 was selected. As there are no specific climate migrant statistics available, the immigration statistics are used in lieu of climate migration statistics, but it can still achieve the purpose of this study. On the one hand, climate migration refers to persons or groups of persons who, for compelling reasons of sudden or progressive changes in the environment as a result of climate change that



Source: Statistics Canada

Figure 1.
Immigrants in Ontario and Canada between 2012 and 2021

adversely affect their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad (IOM, 2007). Some population displacement will come directly as a result of rising sea levels or extreme drought, while much of the migration will be caused indirectly, as a result of gradual environmental degradation leading to shortages in food, freshwater and energy. Although migration and climate change have a significant relationship, it is extremely difficult to disentangle and quantify (Becklumb, 2014; Wilkinson *et al.*, 2016). However, it is clear that the environmental impact of climate change has greatly affected the people's decision to relocate, and the impacts would follow similar trends of economic or other drivers for immigration (Wilkinson *et al.*, 2016; Ni, 2021; Martin, 2021).

On the other hand, Many studies regard the climate migrant as climate refugee (Berchin, 2017; Ahmed, 2018; Roman *et al.*, 2021). According to Martin and Macklem (2017), Ontario receives Canada's immigrants across three classes: economic, sponsored family members and refugee and humanitarian. Although economic immigration accounts for 41% of total immigration to Ontario, compared to the other provinces in Canada, Ontario receives proportionally less economic immigrants, more family, refugee and humanitarian class immigrants, respectively, accounting for 29%, 45% and 48% of the three classes of Canada's immigrants. Ontario accounts for almost half of Canada's refugee and humanitarian settlers (Martin and Macklem, 2017). The purpose of this study is to examine the impact of immigrant influx on environmental outcomes and access to what extent the local governance has responded to the environmental pressure caused by migration influx, especially in the context of increasing climate-induced migration, so as to provide an empirical basis for local governments to deal with the challenge of environmental pressure. Regardless of the reason for migration, the impacts on the receiving locations should be very similar (Naser *et al.*, 2019; Palinkas, 2020).

As the indicator of distributed freshwater is not reported on an annual basis by the Ontario, and the data of 2019–2021 for the greenhouse gas emission intensity are not available, interpolation is used to supplement the missing data (Squalli, 2010; Ji *et al.*, 2020; Roman, Barbora and Kira, 2021).

3.2 Weight determination method

As the indicators have different orders of magnitude and dimensions, combined with the nature of indicators, we divided them into positive indicators and negative indicators. Positive indicators are represented by "+" and negative indicators by "−" (Table 1). The evaluation index was normalized using the min-max standardization method to eliminate the dimension influence:

- Data standardization. For positive indicators, the formula is used:

$$y_{ij} = \frac{x_{ij-\min(x_{ij})}}{\max(x_{ij}) - \min(x_{ij})} \tag{1}$$

For negative indicators, the formula is used:

$$y_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})} \tag{2}$$

where x_{ij} is the original data matrix, and y_{ij} is the standardized data matrix, (x_{ij}) max and min (x_{ij}) respectively represent the maximum and minimum values of the j index:

- Weight determination (Table 1). The weight of each indicator (w_{ij}) is determined by the Entropy method. The Entropy is an objective weight method, and the information entropy of each index was calculated by following formula:

$$e_{j=-k}\sum_{i=1}^{n} p_{ij}\ln\left(p_{ij}\right) \tag{3}$$

where e_j represents the entropy of the j index, $0 \leq e_j \leq 1$; $k = \frac{1}{\ln n}$, n is the number of samples p_{ij} represents indicator proportion, $p_{ij} = y_{ij}/\sum_{i=1}^{n} y_{ij}$ the weight value of each index was calculated and determined by Formula (4):

$$w_{ij} = \left(1 - e_{ij}\right)\sum_{i=1}^{n}\left(1 - e_{ij}\right) \tag{4}$$

In Formula (4), w_j represents weight, e_{ij} represents the entropy, n is the number of samples.

3.3 Relational degree analysis

GRA is used to explore the correlation degree between immigrant growth, environmental outcomes and local municipal governance. The analysis steps are as follows: establish the evaluation index system; raw data treatment (normalization and nondimensionalization); calculate the correlation coefficient (the solution coefficient ρ is set as 0.5); calculate grey correlation degree R, where the detail calculation step can refer to Chen (2021); the degree of impact immigrants have on environmental outcomes and local environmental governance could be determined by the correlation degree R, the greater correlation value is, the more significant impact it has and vice versa.

3.4 Coupling coordination degree analysis

CCDM is used to assess how well the local government and governance systems have responded to the environmental impact of immigrant growth in Ontario in the past 10 years. CCDM is evaluated by three index values, the coupling degree SC, and the coupling coordination degree ST, and SD.

First, the comprehensive development index of two systems is calculated to characterize its overall change dynamics. The formula is as follows:

$$f_1(t) = \sum_{j=1}^{n_1} a_j \times X_{ij} \tag{5}$$

$$f_2(t) = \sum_{j=1}^{n_1} b_j \times Y_{ij} \tag{6}$$

where $f_1(t)$ indicates the comprehensive index of environmental outcomes, $f_2(t)$ indicates the comprehensive index of local municipal governance a_j and b_j, respectively, represent the weight of the j index of environmental outcomes and municipal governance, X_{ij} and Y_{ij}, respectively, represents the standardized value of the j index of environmental outcomes and municipal governance.

SC is introduced to reflect the interdependence and restriction between environmental outcomes and local municipal governance. The formula is as follows:

$$SC = 2 * \sqrt{\frac{f_1(t) * f_2(t)}{[f_1(t) + f_2(t)]^2}} \tag{7}$$

where SC ∈ [0,1]. When $SC = 1$, the coupling degree between two systems is the largest, indicating that the two systems are well coupled or close dependency; When $SC = 0$, the coupling degree between the two systems is the smallest, indicating that the two systems are in disordered or independent condition. SC can be divided into four stages. $0 < SC \leq 0.3$ represents the low coupling stage; $0.3 < SC \leq 0.5$, represents the antagonism stage; $0.5 < SC \leq 0.8$ represents the adaptation stage; $0.8 < SC < 1$, represents the high coupling stage (Liao, 1999; Wang and Ge, 2007).

Subsequently, ST and SD are introduced to further evaluate the coordination levels and quality of the two systems. The formula is as follows:

$$\begin{cases} SD = \sqrt{SC * ST} \\ ST = a * f_1(t) + b * f_2(t) \end{cases} \tag{8}$$

The higher the *SD is*, the better coordinated the local government and governance system are. It indicates that the local government is responding well to the environmental impact of increasing immigrant influx. *ST* reflects the overall coordination effect of environmental outcomes and local governance, a and b represent the horizontal weight of the systems, the two systems generally have the same weight. In this study, we believe that migration is as important as local municipal governance (because we cannot ban immigration for its bad environmental outcomes), so $a = b = 0.5$ (Guan and Liu, 2012; Ji *et al.*, 2020). With reference to Ji *et al.* (2020), the evaluation standards of coordination level between two systems are as follow (Table 2).

4. Data analysis and results

4.1 Comprehensive development trend analysis

Figure 2 shows the tendencies of the comprehensive development of immigrant growth, environmental outcomes $f_1(t)$ and municipal governance $f_2(t)$ in Ontario from 2012 to 2021.

It indicates that immigration in Ontario, except from 2013–2014 and 2019–2020, is upward overall. Especially after the COVID-19 pandemic, the immigrant population increased rapidly in 2020–2021. Environmental outcomes $f_1(t)$ shows an overall upward

SD	Coordination level	SD	Coordination level
[0.0–0.1]	Extreme maladjustment	[0.5–0.6]	No coordination
[0.1–0.2]	Severe maladjustment	[0.6–0.7]	Basic coordination
[0.2–0.3]	Some maladjustment	[0.7–0.8]	Some coordination
[0.3–0.4]	Very little maladjustment	[0.8–0.9]	Good coordination
[0.4–0.5]	No maladjustment	[0.9–1.0]	Excellent coordination

Table 2. Criteria for coordination level between environmental outcomes and local governance

trend from 0.288 to 0.675 during the period 2012 – 2021. Compared to $f_1(t)$, the tendency of local municipal governance $f_2(t)$ changed a little as it shows a downward trend from 0.507 in 2015 to 0.484 in 2021. It indicates that the immigrant growth is related to worse environmental outcomes, while municipal investment in waste management on environmental services has not changed in a meaningful way.

4.2 Results of relational degree (impact effects)

Determining the reference value and the comparison value is the basis of the GRA. The reference value represents the characteristics of the target variables, and the comparison value represents the characteristics of the associated objects. The relational degree between two factors is judged by the relationship between the reference value and the comparison value (Wang and Ge, 2007). This study analyzes the impact of immigrant growth on environmental outcomes and local governance, so environmental outcomes and local governance are set as the reference value, and the amount of immigrants is set as the comparison value.

By setting 0.5 as the resolution coefficient (Wang and Ge, 2007), the correlation between immigrant growth and environmental outcomes is shown in Table 3 and Table A1 in Appendix. The results show that there is a significant correlation between immigrant growth and negative environmental outcomes with all the correlation coefficients over 0.7 (Table 3). It indicates that immigrant growth will increase the per capita solid waste (0.9), greenhouse gas emission intensity (0.866), wastewater generation (0.854); and reduce the per capita distributed water (0.835) and NDVI (0.774) in Ontario. Solid waste (A2) has the strongest correlation with immigration, and NDVI is relatively weakest. It supports previous findings that higher immigrant population is associated with worse environmental outcomes (Aksoy and Tumen, 2021).

Taking local governance as the reference value, the correlation between immigrant growth and local governance is shown in Table 4 and Table A2 in Appendix.

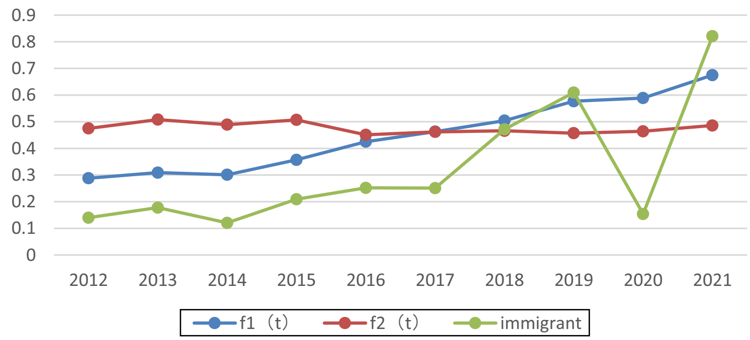


Figure 2. Comprehensive development tendencies of immigrant growth, environmental outcome $f_1(t)$ and municipal governance $f_2(t)$ in Ontario from 2012 to 2021

Table 3. Correlation degree of immigrant and environmental outcomes

Variables	Correlation coefficient	Effect attribute	Ranking
Per capita solid waste (A2)	0.9	+	1
Greenhouse gas emission intensity (A5)	0.866	+	2
Per capita wastewater (A1)	0.854	+	3
Per capita distributed freshwater (A4)	0.835	–	4
NDVI (A3)	0.774	–	5

There is a significant correlation between immigrant population and the quality of local governance with all the correlation coefficients over 0.5. It demonstrates that immigrant growth is significantly correlated with waste disposal facilities (0.714), sewage infrastructure (0.710), electric power infrastructure (0.708), waterworks infrastructure (0.702) and pollution abatement and control (0.573). It provides evidence that higher immigrant influx is associated with the need for higher municipal environmental investment and service.

4.3 Results of coordination level evaluation

Table 5 and Figure 3 show the results of the level of coordination between environmental outcomes and local governance in Ontario during 2012–2021. SC shows that the coupling degree between two systems are in an adaption stage with the value between 0.5 and 0.8, except in 2013 and 2015, where the coupling degree is high. It indicates that the two systems are well coupled and closely dependent on each other. SD and ST demonstrate that the

Variables	Correlation coefficient	Effect attribute	Ranking
Waste disposal facilities (B4)	0.714	+	1
Sewage infrastructure (B2)	0.710	+	2
Electric power infrastructure (B3)	0.708	+	3
Waterworks infrastructure (B1)	0.702	+	4
Pollution abatement and control (B5)	0.573	+	5

Table 4. Correlation degree of immigration and local governance

Year	f1 (t)	f2 (t)	SC	Coordination level	ST	SD	Evaluation results
2012	0.398	0.595	0.748	Basic coordination	0.718	0.683	Good in local governance
2013	0.401	0.568	0.854	Some coordination	0.692	0.715	Good in local governance
2014	0.403	0.517	0.709	Basic coordination	0.606	0.636	Good in local governance
2015	0.409	0.534	0.880	Basic coordination	0.587	0.680	Good in local governance
2016	0.497	0.483	0.719	Basic coordination	0.443	0.605	Good in local governance
2017	0.503	0.454	0.643	No coordinate	0.347	0.556	Barely satisfactory in local governance
2018	0.504	0.456	0.609	Very little maladjustment	0.241	0.368	Lag in local governance
2019	0.517	0.455	0.625	Very little maladjustment	0.206	0.312	Lag in local governance
2020	0.499	0.454	0.651	Some maladjustment	0.189	0.284	Lag in local governance
2021	0.663	0.486	0.572	Some maladjustment	0.167	0.209	Lag in local governance

Table 5. Coordination level between environmental outcomes and local governance in Ontario during 2012–2021

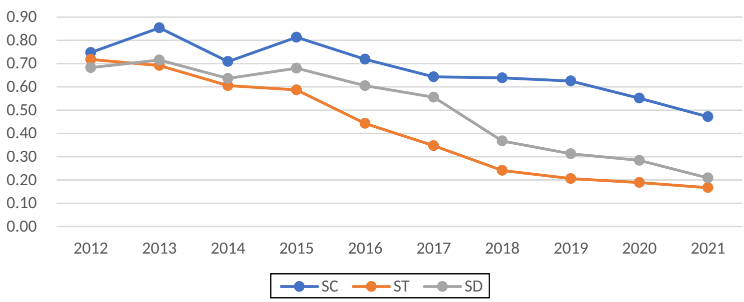


Figure 3. Dynamic trends tendencies of coordinated level between environmental outcomes and local governance in Ontario during 2012–2021

coordination level between environmental outcomes and local governance has changed from some coordination to some maladjustment (Table 5), showing an overall downward trend in the past 10 years. Before 2017, they were in a coordination level with SD above 0.5, which indicates that municipal investment and services were good in response to the environmental impacts of increasing migrants during 2012–2017. However, it changed into maladjustment after 2017 with SD declined from 0.556 in 2017 to 0.209 in 2021. This indicates that the local government lagged in responding to negative environmental effects related to immigrant growth. Significantly, the coordination level of two systems was in some maladjustment during 2019–2021, especially in 2021, which is very close to the edge of severe maladjustment.

5. Discussion and conclusion

Climate-induced environmental degradation has brought additional challenges to the human migration, and this migration may happen both internally and internationally (Myers, 2005; Weber, 2015; McLeman, 2017; Ni, 2021). Under these circumstances, many cities will face negative environmental effects and considerable pressure on municipal services with the influx of migrants (Aksoy and Tumen, 2021). Our study confirms this point and expands the much-needed dialogue on the relationship between immigrant growth, environmental outcomes and local governance systems. Taking Ontario as a case study, the findings can not only serve as empirical evidence for Ontario's municipal governments and governance systems to be better prepared for the environmental impact of large-scale immigration, but also to call other regions to attention of the urban environmental pressure caused by migration influx dur to the changing climate world wide. Several insightful results can be summarized as follows.

First, the study shows there is a significant correlation between immigrant growth, negative environmental outcomes and local governance deficits in Ontario. It is consistent with the findings reported by the large body of literature investigating the link between environmental deterioration and population growth (Ahmed, 2018; Maystadt, 2020). It provides evidence that a higher immigrant population is associated with worse environmental outcomes and the need for more municipal environmental investment and service. However, our findings show that compared to the upward trend of negative environmental outcomes, there is nearly no change on the municipal governance in waste management of environmental services in Ontario; it even shows a downward trend during 2015–2021. A higher migrant population should lead to a more spending on waste management services in well governed municipalities (Aksoy and Tumen, 2021). We suggest that sufficient investment in municipal environmental services is vital to mitigate the negative environmental effects of higher immigrant population density.

Second, more people mean more demand on resources and energy. Our results are also in line with this observation. We find that immigrant growth can increase greenhouse gas emission intensity and reduce the per capita distribution of freshwater (Table 3). Human population size not only correlates strongly with CO_2 emissions but also is a substantial threat to water quality (Shi, 2003; Chaudhry and Malik, 2017; Morris, 2021). It is evident that the stumbling block to combat environment pollution is not an absence of technical solutions but rather political and institutional factors. In addition to improvements and investments on waterworks and sewage infrastructure, local governments should provide leadership for residents to reduce household energy consumption and adverse environmental outcomes by carrying out environmental protection projects and providing public services, such as implementing municipal renewable energy projects (Malav *et al.*, 2020), urban forestation programs (Garcia-Lamarca *et al.*, 2021) and improving green vegetation coverage (Maystadt, 2020).

Third, immigration growth has a significant effect on NDVI. This result supports previous findings that urbanization population density results in significant reductions in the quantity and quality of "green" areas (Lantz *et al.*, 2021). Although the level of urban greenness also depends on natural environmental conditions and differences in local land use (Nowak *et al.*, 1996), population factor should not be ignored. Green spaces are essential to building the resilience and livability of cities through the ecosystem goods and services they provide (Heris *et al.*, 2021). Cities around the world are increasingly "going green", a process that entails programmers to reduce urban waste and air pollution, promote clean energy and mobility policies or increase the quantity and quality of urban green spaces (Garcia-Lamarca *et al.*, 2021). Thus, we argue that more efforts and programs should be carried out on improving green spaces for local municipal governments in the future.

Fourth, our study also shows that the present local governance in Ontario is not doing enough to prevent negative environmental outcomes of migrant growth, especially in 2021, where it was very close to the edge of severe maladjustment. It is mainly because of the substantial increase of immigrants after COVID-19. A sudden increase in population results in more environmental pressure, if the municipal governance fails to respond in a meaningful way. Typically, municipal-level water, sewage and energy infrastructure development is long term and, lags behind the demand. According to our results on municipal governance, municipal investment in waste management on environmental services has shown nearly no change. Hence, the key reason for the deterioration in environmental outcomes in response to immigrant influx is the lack of adequate attention to infrastructure upgrades by local governments (Tossutti and Esses, 2012). Although municipal governments in Ontario spend billions of dollars each year to provide the public services that meet these important needs of Ontario residents, some municipalities have been able to advance environmental protection significantly even with limited powers and limited access to funding, while others simply met the minimum required by senior levels of government (Valiante, 2007; Tovilla and Webb, 2017). Future governance at the municipal level needs to be adaptive so as to meet the challenges that migration due to the changing climate world-wide is posing. Local government should improve the governance quality to strengthen the environmental adaptation ability and migrant accommodation capacity at a municipality level, and improve citizens' awareness of environmental protection. Meanwhile, governance arrangements and management practices should be flexible and adaptable, participatory governance and public engagement are necessary. Migrants, however, sometimes cannot be expected to put environmental considerations ahead of their own safety and welfare (UNHCR, 2001), so it is necessary to make policies to restrict their behavior of environmental pollution.

The contribution of this paper can be summarized in three points. First, we examine the impact of migration growth on environmental outcomes and local governance, which has not received much attention in the migration literature. Second, we use the CCDM method to assess how well the existing local governance systems have responded to the environmental impact of immigrant growth in Ontario in the past 10 years, which is an extension of the previous quantitative research in this field. Third, we use immigration data to simulate the increase in pressure on the region due to enhance migration due to the changing climate world-wide and seek to address the importance of good local governance in the challenges faced by municipalities related to increased migrant concentration. The Ontario case study was used to obtain the first evidence on these issues, to the best of our knowledge, there has been no systematic attempt in current literatures.

This study also has some limitations. First, the selection of samples and the national context of this study potentially limit the generalizability of the findings, as this study only considers Ontario. Further research on a wider range of countries is needed to develop a greater understanding of the issues. Second, general immigration statistics were used to simulate the increase in pressure on the region due to enhance migration due to the changing climate, since no specific climate migration statistics exist, more investigations and interviews should be conducted in future climate migrant studies. Third, the assessing index system and time period selection in the paper may be limited by the availability of data, and future studies should focus on conducting extensive empirical research to collect both qualitative and quantitative data, to yield broader findings. Fourth, as there are "hot spots" for migration in each region, that is, regions where people are more willing to leave or move to, further research is needed to examine each case from a different theoretical perspective, both empirically and normatively.

Notes

1. "World Migration Report," *International Organization for Migration*, 2020, p. 119.
2. NDVI captured by remote sensors is an indicator of vegetation presence and quantity – it provides a relative measure of photosynthetic activity. The results of NDVI calculation range from −1 to +1, and these values vary depending on the type of satellite images, season, study area, atmospheric effects, soil type, humidity, etc. Generally, high NDVI values correspond to healthier vegetation while low NDVI values indicate less or no vegetation. NDVI values close to +1 should represent dense green leaves, whereas very low values (0.1 and below) correspond to barren rock, sand, snow, water or impervious surfaces (e.g., roads and buildings).
3. Statistics Canada: www.canada.ca/en/immigration-refugees-citizenship/news/notices/supplementary-immigration-levels-2022-2024.html
4. Statistics Canada: www150.statcan.gc.ca/n1/en/type/data?MM=1
5. Government of Ontario: www.ontario.ca/page/government-ontario
6. Environment and Climate Change Canada: www.canada.ca/en/environment-climate-change.html

References

Ahmed, B. (2018), "Who takes responsibility for the climate refugees?", *International Journal of Climate Change Strategies and Management*, Vol. 10 No. 1, pp. 5-26, doi: 10.1108/IJCCSM-10-2016-0149.

Aksoy, C.G. and Tumen, S. (2021), "Local governance quality and the environmental cost of forced migration", *Journal of Development Economics*, Vol. 149, p. 102603, pp. 1-21, doi: 10.1016/j.jdeveco.2020.102603.

Aliu, I.R., Akoteyon, I.S. and Soladoye, O. (2021), "Living on the margins: socio-spatial characterization of residential and water deprivations in Lagos informal settlements, Nigeria", *Habitat International*, Vol. 107, p. 102293, doi: 10.1016/j.habitatint.2020.102293.

Barrios, S., Bertinelli, L. and Strobl, E. (2006), "Climatic change and rural-urban migration: the case of Sub-Saharan Africa", *Journal of Urban Economics*, Vol. 60 No. 3, pp. 357-371, doi: 10.1016/j.jue.2006.04.005.

Becker, S.O. and Ferrara, A. (2019), "Consequences of forced migration: a survey of recent findings", *Labour Economics*, Vol. 59, pp. 1-16, doi: 10.1016/j.labeco.2019.02.007.

Becklumb, P. (2014), *Climate Change and Forced Migration: Canada's Role*, Canadian Electronic Library, Beaconsfield, Quebec.

Berchin, I.I., Valduga, I.B., Garcia, J., Salgueirinho, J.B. and Guerra, O.A. (2017), "Climate change and forced migrations: an effort towards recognizing climate refugees", *Geoforum*, Vol. 84, pp. 147-150, doi: 10.1016/j.geoforum.2017.06.022.

Brown, O. (2008), “Migration and climate change”, IOM Migration Research Series, No. 31, doi: 10.18356/26de4416-en.

Chaudhry, F.N. and Malik, M.F. (2017), “Factors affecting water pollution: a review”, *Journal of Ecosystem and Echography*, Vol. 7 No. 1, p. 1000225, doi: 10.4172/2157-7625.1000225.

Chen, L.L. (2021), “Research of the safety path of colleges and universities laboratory basing on the analysis of grey correlation degree”, *Journal of Intelligent and Fuzzy Systems*, Vol. 40 No. 4, pp. 7755-7762, doi: 10.3233/JIFS-189596.

Cramer, J.C. (2021), “Population growth and air quality in California”, *Demography 35*, pp. 45-56.

Cutlip, L. (2019), “Maintaining stability in a changing climate: a comparative analysis of public health systems and migration policies in the US and Canada”, *Climate and Society*, Vol. 1 No. 1, available at: https://digitalcommons.carleton.edu/climateandsociety/vol1/iss1/2

Deng, J.L. (1985), “The correlation space of grey system theory”, *Fuzzy Mathematics*, Vol. 5, pp. 59-66.

Drolet, J., Enns, R., Kreitzer, L., Shankar, J. and McLaughlin, A. (2018), “Supporting the resettlement of a Syrian family in Canada: the social work resettlement practice experience of social”, *International Social Work*, Vol. 61 No. 5, pp. 627-633, doi: 10.1177/0020872817725143.

Evangelia, T. (2021), “Twenty-First century ‘new’ Greek transnational migration to Canada”, *Journal of Immigrant and Refugee Studies*, Vol. 20 No. 1, pp. 65-78, doi: 10.1080/15562948.2021.1900481.

Fallah, B., Krafftand, C. and Wahba, J. (2019), “The impact of refugees on employment and wages in Jordan”, *Journal of Development Economics*, Vol. 139 No. 7, pp. 203-216, doi: 10.1016/j.jdeveco.2019.03.009.

Garcia-Lamarca, M., Anguelovski, I., Cole, H., Connolly, J.J. and Shokry, G. (2021), “Urban green boosterism and city affordability: for whom is the ‘branded’ green city?”, *Urban Studies*, Vol. 58 No. 1, pp. 90-112, doi: 10.1177/0042098019885330.

Guan, W. and Liu, Y.F. (2012), “Analysis on spatiotemporal evolution of economic and environmental coordination development degree in Liaoning coastal economic belt”, *Geographical Research*, Vol. 31 No. 11, pp. 2044-2054.

Hansen, O.-S.A. (2019), *Involuntary Migration and Resettlement: The Problems and Responses of Dislocated People*, Routledge, London.

Heris, M., Bagstad, K.J., Rhodes, C., Troy, A., Middel, A., Hopkins, K.G. and Matuszak, J. (2021), “Piloting urban ecosystem accounting for the United States”, *Ecosystem Services*, Vol. 48, p. 101226, doi: 10.1016/j.ecoser.2020.101226.

IOM (2007), “Discussion note: Migration and the environment”, *94th session, International Organization for Migration (IOM)*, (revision 3.5).

Ji, R.T., Chen, M.and. and Chen, G.H. (2020), “Assessment of economic and environmental coordination development degree in the ‘two mountains’ base: a case study of ninghai in Zhejiang province”, *Journal of Environmental Engineering*, Vol. 10 No. 5, pp. 798-805.

Krantzberg, G. and Song, Z. (2020), “How does adaptive governance help restore and protect shared waters?”, *OALib*, Vol. 07 No. 10, pp. 1-19, doi: 10.4236/oalib.1106833.

Kulp, S.A. and Strauss, B.H. (2019), “New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding”, *Nature Communications*, Vol. 10 No. 1, pp. 1-12, doi: 10.1038/s41467-019-12808-z.

Kumari, R.K., de Sherbinin, A., Jones, B., Bergmann, J., Clement, V., Ober, K. and Schewe, J. (2018), “Groundswell: preparing for internal climate migration”, World Bank, available at: https://openknowledge.worldbank.org/handle/10986/29461

Lantz, N., Grenier, M. and Wang, J. (2021), “Urban greenness, 2001, 2011 and 2019”, Published by authority of the Minister responsible for Statistics Canada, available at: www150.statcan.gc.ca/n1/pub/16-002-x/2021001/article/00002-eng.pdf

Liao, Z.B. (1999), “Quantitative evaluation and classification system of coordinated development of environment and economy – a case study of urban agglomeration in the pearl river delta”, *Tropical Geography*, Vol. 2, pp. 3-5.

Liu, J.L., Liu, Y.S. and Li, Y.R. (2018), “Coupling analysis of rural residential land and rural population in China during 2007-2015”, *Journal of Natural Resources*, Vol. 33 No. 11, pp. 1861-1871.

McAdam, J. (2011), “Environmental migration governance”, in Betts, A. (Ed.), *Global Migration Governance*, Oxford University Press, Oxford, Chapter 7, available at: https://papers.ssrn.com/sol3/Papers.cfm?abstract_id=1412002

McLeman, R. (2017), “Thresholds in climate migration”, *Population and Environment*, Vol. 39 No. 4, pp. 319-338, doi: 10.1007/S11111-017-0290-2.

Malav, L.C., Yadav, K.K., Gupta, N., Kumar, S. and Bach, Q.V. (2020), “A review on municipal solid waste as a renewable source for waste-to energy project in India: current practices, challenges, and future opportunities”, *Journal of Cleaner Production*, Vol. 277, p. 123227, doi: 10.1016/j.jclepro.2020.123227.

Marchiori, L., Maystadt, J.F. and Schumacher, I. (2012), “The impact of weather anomalies on migration in Sub-Saharan Africa”, *Journal of Environmental Economics and Management*, Vol. 63 No. 3, pp. 355-374, doi: 10.1016/j.jeem.2012.02.001.

Martin, S.F., Bergmann, J., Rigaud, K.K. and Yameogo, N.D. (2021), “Climate change, human mobility, and development”, *Migration Studies*, Vol. 9 No. 1, pp. 142-149, doi: 10.1093/migration/mnaa030.

Martin, R.L. and Macklem, T. (2017), *Immigration in Ontario: Achieving Best Outcomes for Newcomers and the Economy*, Institute for Competitiveness and Prosperity, Toronto, ON, CA.

Maurel, M. and Tuccio, M. (2016), “Climate instability, urbanization and international migration”, *The Journal of Development Studies*, Vol. 52 No. 5, pp. 735-752, doi: 10.1080/00220388.2015.1121240.

Maystadt, J.F., Mueller, V., Hoek, J. and Weezel, S. (2020), “Vegetation changes attributable to refugees in Africa coincide with agricultural deforestation”, *Environmental Research Letters*, Vol. 15 No. 4, p. 44008, doi: 10.1088/1748-9326/ab6d7c.

Millock, K. (2015), “Migration and environment”, *Annual Review of Resource Economics*, Vol. 7 No. 1, pp. 35-60, doi: 10.1146/annurev-resource-100814-125031.

Mohamed, E. and Bastug, M. (2021), “Syrian refugees in Canada and Trans culturalism: relationship between media, integration and identity”, *Journal of Refugee Studies*, Vol. 34 No. 1, pp. 219-240, doi: 10.1093/jrs/feaa009.

Morris, D.W. (2021), “On the effect of international human migration on nations’ abilities to attain CO_2 emission-reduction targets”, *Plos One*, Vol. 16 No. 10, p. e0258087, doi: 10.1371/journal.pone.0258087.

Muggah, R. and Abdenur, A.E. (2018), “Refugees and the city: the twenty-first-century front line”, World Refugee Center Research Paper. No. 2, pp. 1-28, available at: www.cigionline.org/sites/default/files/documents/WRC%20Research%20Paper%20no.2.pdf

Myers, N. (2005), “Environmental refugees: an emergent security issue”, *13th Economic Forum*, *Prague*, 23-27 May 2005.

Naser, M.M., Swapan, M.S.H., Ahsan, R., Afroz, T. and Ahmed, S. (2019), “Climate change, migration and human rights in Bangladesh: perspectives on governance”, *Asia Pacific Viewpoint*, Vol. 60 No. 2, pp. 175-190, doi: 10.1111/apv.12236.

NI, P. (2021), “Analysis on immigration activities and governance in pacific island countries”, *World Ethno-National Studies*, Vol. 4, pp. 76-87.

Nowak, D.J., Rowntree, R.A., McPherson, E.G., Sisinni, S., Kerkmann, E.R. and Stevens, J.C. (1996), “Measuring and analyzing urban tree cover”, *Landscape and Urban Planning*, Vol. 36 No. 1, doi: 10.1016/S0169-2046(96)00324-6.

Oakes, R., Banerjee, S. and Warner, K. (2020), “Human mobility and adaptation to environmental change”, World Migration Report, International Organization for Migration, pp. 253-269, doi: 10.18356/2a8d511f-en.

Palinkas, L.A. (2020), *Global Climate Change, Population Displacement, and Public Health: The Next Wave of Migration*, Springer International Publishing, Cham.

Piguet, E., Pecoud, A. and Guchteneire, P. (2011), "Migration and climate change: an overview", *Refugee Survey Quarterly*, Vol. 30 No. 3, pp. 1-23, doi: 10.1093/rsq/hdr006.

Rafiq, S., Nielsen, I. and Smyth, R. (2017), "Effect of internal migration on the environment in China", *Energy Economics*, Vol. 64, pp. 31-44, doi: 10.1016/j.eneco.2017.03.009.

Roman, H., Barbora, S. and Kira, V. (2021), "Improving the evidence base: a methodological review of the quantitative climate migration literature", *Global Environmental Change*, Vol. 71 No. 102367, doi: 10.1016/j.gloenvcha.2021.102367.

Ruiz, I. and Silva, C.V. (2015), "The labor market impacts of forced migration", *American Economic Review*, Vol. 105 No. 5, pp. 581-586, doi: 10.1257/aer.p20151110.

Shen, J.S., Song, J.M. and Guan, K. (2000), "Quantitative evaluation method and its application for infrastructure and social economy coordinated development", *Urban Environment and Urban Ecology*, Vol. 13 No. 5, pp. 10-12.

Shi, A. (2003), "The impact of population pressure on global carbon dioxide emissions, 1975–1996: evidence from pooled cross-country data", *Ecological Economics*, Vol. 44 No. 1, pp. 29-42, doi: 10.1016/S0921-8009(02)00223-9.

Siddiqui, T. (2010), "Impact of climate change: migration as one of the adaptation strategies", Working paper series no. 18, Refugee and Migratory Movements Research Unit (RMMRU), Dhaka.

Siddiqui, T., Bhuiyan, M., Sikder, M. and Islam, M. (2014), "Adaptation strategies of poor urban migrants in the context of climate change: a case study of informal settlements in natore, Sirjaganj and Rajshahi", Working Paper Series no. 46, Refugee and Migratory Movements Research Unit (RMMRU), Dhaka.

Squalli, J. (2009), "Immigration and environmental emissions: a US county-level analysis", *Population and Environment*, Vol. 30 No. 6, pp. 247-260, doi: 10.1007/s11111-009-0089-x.

Squalli, J. (2010), "An empirical assessment of US state-level immigration and environmental emissions", *Ecological Economics*, Vol. 69 No. 5, pp. 1170-1175, doi: 10.1016/j.ecolecon.2010.01.001.

Stern, N. (2007), "The economics of climate change: the stern review", Cambridge University Press, available at: https://doi-org.libaccess.lib.mcmaster.ca/10.1017/CBO9780511817434

Thomas, A. and Benjamin, L. (2018), "Policies and mechanisms to address climate-induced migration and displacement in Pacific and Caribbean small island developing states", *International Journal of Climate Change Strategies and Management*, Vol. 10 No. 1, pp. 86-104, doi: 10.1108/IJCCSM-03-2017-0055.

Tossutti, L. and Esses, V. (2012), "Local perspectives on immigration and diversity in 15 Ontario municipalities", London, Ont: Welcoming Communities Initiative, available at: www.cpsa-acsp.ca/papers-2011/Tossutti.pdf

Tovilla, E. and Webb, K. (2017), "Examining the emerging environmental protection policy convergence in the Ontario municipal drinking water, wastewater and stormwater sectors", *Water Quality Research Journal*, Vol. 52 No. 3, pp. 209-228, doi: 10.2166/wqrj.2017.043.

United Nations High Commissioner for Refugees (UNHCR) (206), available at: www.unhcr.org/en-us/ (accessed 26 September 2016).

UNHCR (2001), "Refugees and the environment", Engineering and Environmental Services Section, the UN Refugee Agency, available at: www.unhcr.org/protection/environment/3b039f3c4/refugees-environment.html

Valiante, M. (2007), "The role of local governments in great lakes environmental governance: a Canadian perspective", *University of Michigan Journal of Law Reform*, Vol. 40 No. 4, pp. 1055-1086, available at: https://repository.law.umich.edu/mjlr/vol40/iss4/9

Wang, L.Gand. and Ge, Y.S. (2007), "Evaluation of coordinated development degree between economy and environment in Nanjing", *Journal of Anhui Normal University (Natural Science)*, Vol. 4, pp. 500-503.

Wang, S.J., Kong, W., Ren, L., Zhi, D.D. and Dai, B.T. (2021), "Research on misuses and modification of coupling coordination degree model in China", *Journal of Natural Resources*, Vol. 36 No. 3, pp. 793-810, doi: 10.31497/zrzyxb.20210319.

Weber, E. (2015), "Envisioning South-South relations in the fields of environmental change and migration in the pacific islands: past, present and futures", *Bandung: Journal of the Global South*, Vol. 2 No. 1, p. 6, doi: 10.1186/s40728-014-0009-z.

Wilkinson, E., Kirbyshire, A., Mayhew, L., Batra, P. and Milan, A. (2016), "Climate-induced migration and displacement: closing the policy gap", Overseas Development Institute (ODI), London, UK, available at: https://cdn.odi.org/media/documents/10996.pdf

Xia, X.F., Sun, Y. and Wu, K. (2016), "Optimization of a straw ring die briquetting process combined analytic hierarchy process and grey correlation analysis method", *Fuel Processing Technology*, Vol. 152, pp. 303-309.

Zhang, Y. and Wu, Y.M. (2006), "Analysis of coupling mechanism and space-time coordination of industrialization and urbanization in regions of China", *Urban Development Studies*, Vol. 13 No. 6, pp. 46-51.

Zhou, H.H. and Chen, X.H. (2019), "Coupling relationship and its response mechanism between smart development and environmental quality in Chinese resource-based cities", *Journal of Natural Resources*, Vol. 34 No. 8, pp. 1620-1632.

Further reading

Ajibade, I., Sullivan, M. and Haeffner, M. (2020), "Why climate migration is not managed retreat: six justification", *Global Environmental Change*, Vol. 65 No. 1021187, pp. 1-8, doi: 10.1016/j.gloenvcha.2020.102187.

Hsiang, S.M., Burke, M. and Miguel, E. (2013), "Quantifying the influence of climate on human conflict", *Science*, Vol. 341 No. 6151, doi: 10.1126/science.1235367.

Li, Z., Guan, Z. and Zhang, J. (2012), *Applied Fracture Mechanics*, Beihang University Press, Beijing.

McLeman, R. (2019), "International migration and climate adaptation in an era of hardening borders", *Nature Climate Change*, Vol. 9 No. 12, pp. 910-918, doi: 10.1038/s41558-019-0634-2.

Jetoo, S., Tynkkynen, N., Joas, M., Hellström, M., Sjöqvist, C. and Törnroos, A. (2021), "Climate change and the governance of the baltic sea environment", *Journal of Baltic Studies*, doi: 10.1080/01629778.2021.1989472.

UN DESA (2019), "United nations, department of economic and social affairs, population division, 2019", Probabilistic population projections Rev. 1 based on the world population prospects 2019 rev.1. 2020 [Cited 2020 Feb 2], available at: http://population.un.org/wpp/

UN doc A/73/12 (Part II) (2018), "Global compact on refugees", United Nations, New York, NY, available at: www.unhcr.org/5c658aed4.pdf

UN doc A/RES/73/195 (2018), "Global compact for safe, orderly and regular migration", United Nations, New York, NY, available at: https://refugeesmigrants.un.org/sites/default/files/180713_agreed_outcome_global_compact_for_migration.pdf

Wang, H., Jing, W.C., Zhao, G.C. and Jin, X. (2020), "Fatigue life prediction for hydraulic support foundation based or grey system model GM (1, 1) improved miner criterion", *Journal of Shanghai Jiao Tong University*, Vol. 54 No. 1, pp. 106-110.

Wang, J., He, S., Wang, W., Chen, X.F. and Li, P.Y. (2018), "Study on wind speed prediction based on mixed grey theory", *Acta Energiae Solaris Sinica*, Vol. 39 No. 12, pp. 3544-3549.

Zhao, Y.Y. and Yu, F.W. (2015), "The evaluation of coordinated development of economic and eco-environment in Qinghai province", *Ecological Economy*, Vol. 31 No. 8, pp. 63-66.

Appendix 1

	Correlation coefficient of each variable				
	Greenhouse gas emission intensity	NDVI	Per capita distributed freshwater	Per capita wastewater	Per capita solid waste
2012	0.718	0.805	0.698	0.878	0.840
2013	0.819	0.817	0.797	0.799	0.990
2014	0.926	0.841	0.815	0.729	0.971
2015	0.877	0.334	0.892	0.799	0.924
2016	0.968	0.829	0.970	0.785	0.785
2017	0.838	0.843	0.944	0.974	0.971
2018	0.748	0.810	0.856	0.883	0.946
2019	0.881	0.794	0.797	0.854	0.857
2020	0.892	0.909	0.911	0.910	1.000
2021	0.993	0.757	0.672	0.927	0.712

Notes: PS: resolution coefficient $\rho \in (0, \infty)$, ρ the smaller, the greater the resolution, the general ρ the value range of is (0, 1), and the specific value depends on the situation. When $\rho \leq 0.5463$, the resolution is the best, usually $\rho = 0.5$

Table A1. Correlation coefficients of immigrant and environmental outcome in each year

Appendix 2

Table A2. Correlation coefficients of immigrant and local governance in each year

	Correlation coefficient of each variable				
	Waterworks infrastructure	Sewage infrastructure	Electric power infrastructure	Waste disposal facilities	Pollution abatement and control
2012	0.574	0.579	0.574	0.585	0.405
2013	0.653	0.659	0.659	0.662	0.455
2014	0.687	0.710	0.687	0.706	0.496
2015	0.741	0.739	0.727	0.694	0.530
2016	0.829	0.837	0.865	0.866	0.969
2017	0.948	0.962	0.971	1.000	0.852
2018	0.907	0.913	0.903	0.915	0.599
2019	0.700	0.710	0.704	0.718	0.504
2020	0.551	0.556	0.556	0.561	0.423
2021	0.426	0.436	0.434	0.433	0.500

Notes: Postscript: resolution coefficient $\rho \in (0, \infty)$, ρ The smaller, the greater the resolution, the general ρ The value range of is (0, 1), and the specific value depends on the situation. When $\rho \leq 0.5463$, the resolution is the best, usually ρ = zero point five

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