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Toward the development of a conceptual framework for the complex interaction between environmental changes and rural-urban migration

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Environmental changes can result in dramatic increases in human migration as households become unable to adapt to such changes. Addressing environmental migration is a complex puzzle that can become a wicked problem. Despite the growing literature on the nexus between environmental change and migration, the inextricable link between nature and society has made it difficult to establish causal relations between the two. To examine the relationship between environmental change and migration, it is necessary to develop a conceptual model that includes environmental changes as potential causes of rural-urban migration (RUM). Such a model should be built on an enhanced understanding of the different factors that stimulate environmentally induced RUM. This paper proposes such a model, focusing on loss of agricultural land, loss of agricultural productivity and the economic repercussions of these losses. The model is based on the model of Perch-Nielsen et al. but extends this model by incorporating additional factors. In our model, the three leading causes of RUM are climate change, human maladaptive activities, and hydro-climatic disasters (the push factors). In addition, there may be pull factors in the cities. RUM may be counteracted or reduced by governmental policy and individuals' characteristics. The model was applied to Iran. The results show that the model can help to bridge the knowledge gap regarding environmentally induced RUM and may inform policymaking on RUM and related issues, such as environmental management and adaptation to climate change.

KEYWORDS

environmental migration, climate change, hydro-climatic disasters, human maladaptive activities, rural-urban migration

1. Introduction

Migration policymaking is a multidimensional and complex process that involves and affects different spheres of society at different levels—local, regional, national, and international—and different socio-political actors (Borkert and Bosswick, 2007). Environmental change is likely to affect global migration flows in several ways, particularly by reducing livelihoods in countries depending on agriculture (Martin, 2013; Pourmohamad et al., 2019, 2020). Environmental migration is currently one of policymakers' top priorities (UN DESA, 2013; Ghandehari et al., 2020), with many scientific and policy studies addressing it as a potential security concern (Boas et al., 2019).

Environmental migration may take place both inside and between nations, and it can be either temporary or permanent. Internal migration is predominantly environmentally induced (Hugo, 1996; Leighton, 2007; Stal and Warner, 2009; Martin, 2013; Goodwin-Gill and McAdam, 2017). The Internal Displacement Monitoring Center (IDMC) estimated that in 2021, 23.7 million people were displaced within countries due to natural disasters [Internal Displacement Monitoring Center (IDMC), 2022]. Hence, future research studies must consider internal migration, along with international migration (IOM, 2009; Stal and Warner, 2009).

The most important form of internal migration is rural-urban migration (RUM) (Jahan, 2012). The rising rate of RUM causes many villages to be abandoned. This poses several undesirable consequences, particularly in international border areas, where this may lead to security threats, such as increased drug trafficking. It is predicted that the rate of environmental migration including RUM will increase in the next few decades (IPCC, 2014) due to climate change (IPCC, 2013). By 2050, up to one billion people are predicted to be environmentally displaced (Myer and Kent, 1995; Sachs, 2007; IOM, 2009; Biermann and Boas, 2010; Clement et al., 2021). Despite the uncertainty and debate surrounding these numbers, they highlight the importance of understanding the complex relationship between environmental changes and migration (Boas et al., 2019).

RUM can exacerbate the competition over and pressure on natural resources and increase the burden on infrastructure, services, and social organizations in the destination areas (Abel et al., 2019). This is especially problematic when resources are scarce (Reuveny, 2007). In addition, a major concern for policymakers is the contamination of water, soil, and agricultural products as a result of rapid urbanization (Taghipour et al., 2013). RUM may also alter the habits and beliefs of the individuals concerned.

As RUM and its consequences can be influenced by government policy, it is essential to understand RUM fully. RUM and environmental migration more generally are the results of complex interactions between socio-political, economic, and ecological factors (Schraven, 2012). This makes RUM inherently complex and it is likely to become a "wicked problem" (Levin et al., 2012), due to bad governance and bad management and contingency strategies. To support effective policies for dealing with RUM, a comprehensive conceptual model is necessary that shows the full range of human responses to environmental and climate change.

The effect of environmental changes on migration has been investigated in several studies on climate change (Mcleman, 2013; Nicholson, 2014; Burrows and Kinney, 2016; Mayrhofer, 2016; Martin et al., 2021; Moore and Wesselbaum, 2022). Some scientists suggest that climate change is contributing significantly more to migration than political, economic, and social factors (Brown, 2008; Luetz, 2019). Other scientists, however, argue that migration is the result of multiple factors (Hugo, 1996, 2010). According to El-Hinnawi (1985), environmental migration can be the outcome of natural or anthropogenic disasters, drastic environmental changes (such as dam construction), and gradual environmental deterioration (El-Hinnawi, 1985).

Nature and society are inextricably linked (Mianabadi et al., 2015), each contributing to the resilience and vulnerability of the other (Oliver-Smith, 2003; Young et al., 2006). As long as environmental changes are ascribed to nature only, the influence of human activities (society) can be overlooked (Hartmann, 2009), enabling decision-makers to avoid taking responsibility for addressing migration issues (Oliver-Smith, 2012). However, climate change is not the only cause of migration: human maladaptive activities must be mentioned too. Climate change and human maladaptive activities may both gradually degrade the environment in rural areas, threaten people's livelihoods and, consequently, lead to mass RUM. These signals are embedded in the background noise of the rising frequency and severity of hydro-climatic disasters. A combination of gradual degradation and disasters can result in displacement in the affected areas.

To investigate the environment-migration nexus, a causal conceptual model is needed. This paper presents such a model, focusing on the loss of agricultural land and production and the economic repercussions of this loss (section 4). In this model, RUM is driven by three primary push factors: climate change, human maladaptive activities, and hydro-climatic disasters. Additionally, pull factors in the cities are incorporated in the model too, as well as counter-causes (governmental plans and individuals' characteristics). This conceptual model can be used in empirical studies on the link between human-environmental changes and RUM. In this paper, the model will be applied to Iran (section 5). First, however, the problem of RUM will be discussed (section 2) and the methodology used will be presented (section 3).

2. Environmental RUM: problem or solution?

Developing a conceptual model on the link between environmental change and RUM requires an in-depth understanding of migration and the processes leading up migration. The first step is to determine whether migration is a problem or a solution.

Several authors consider migration as an important form of adaptation to environmental change in some situations (e.g., Mcleman, 2013; Hallegatte et al., 2016; Luetz, 2019; Chhogyel et al., 2020). It can reduce pressure on ecosystems (Lonergan, 1998; Martin, 2013). This is especially important when the environment's carrying capacity is decreasing or the demand for water, food and other resources is increasing as a result of environmental degradation, climate change, population growth or changing lifestyle. In these situations, migration can help to fulfill basic needs and enhance long-term stability (Gemenne and Blocher, 2017). Mendelsohn et al. (2007) suggest that in areas where people are unable to support themselves due to environmental impacts on the local economy, migration is an undesirable but necessary adaptation strategy. In contrast, Adger et al. (2007) believe that migration has enormous social costs and unacceptable impacts related to human rights and sustainability, and thus, it is not a good adaptation strategy. Other authors argue that forced migration reflects limited adaptation plans (Barnett and Adger, 2003; Stal and Warner, 2009) or indicates that previous adaptation strategies have failed (Adger et al., 2003; Black et al., 2011b).

Adaptation options other than migration deal with the economic problems caused by environmental change. Finan and Nelson (2001) argue that providing some adaptation strategies by the government can convince young migrants to return to the countryside. As migration may increase conflicts in both the area of origin and the destination area, it can be seen as posing a security threat. However, security problems may also be a cause of migration. Whether migration is a problem or a solution depends on factors such as the capacity and preparedness of individuals, communities, and countries to cope with environmental changes (Vinke et al., 2020). Bardsley and Hugo (2010) and McLeman (2018) refer to these factors in terms of "thresholds" that may be exceeded or "tipping points" that may be reached (Bardsley and Hugo, 2010; McLeman, 2018). These thresholds and tipping points vary in space and time according to the local social and natural conditions (McLeman, 2018).

To find out whether migration is a good adaptation strategy or not, it is necessary to clarify what we mean by the term adaptation (Stal and Warner, 2009). In the context of climate change, the most popular definition of adaptation is the one given by IPCC: "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2001). Fussel and Klein (2006) define adaptation as "adjust[ing] to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." Often, the term "coping" is used interchangeably with adaptation. Some authors, however, define coping as an immediate short-term response to environmental changes and adaptation as a strategy that involves planning for long-term actions in a sustainable way (Black, 2001; Stal and Warner, 2009; IPCC, 2013; Eslami et al., 2020; Safaee et al., 2020).

In this paper, we define coping capacity as the ability of a system or individual actor to handle natural disasters at a specific moment in time, and adaptation as a process of increasing coping capacity. Some species have a natural mechanism to adapt themselves to new situations gradually and maintain or increase their coping capacity. Sudden changes may still cause problems when they exceed the coping capacity of the system, but slow changes allow the system to adapt and increase its coping capacity. The faster change a system can cope with, the higher its "adaptive capacity" is.

In addition to defining adaptation, it is necessary to delve deeper into the migration process. Historically, RUM has occurred for several reasons (Kojima, 1996; Kim, 2007; Pilehvar, 2021). First, modernization and mechanization in agriculture resulted in a significant decline in agricultural employment, while at the same time employment in the cities increased as a result of industrial development (Boone and Wilse-Samson, 2019). Secondly, population growth and increasing demand for land often changed land-use patterns, and available natural resources often did not meet the requirements of the growing population. Thirdly, environmental changes, including prolonged drought, floods and dust storms, were other critical reasons for RUM. In these cases, migration may help to re-establish an appropriate balance between available resources and population size in rural areas and demand for and supply of labor, and reduce environmental pressure.

Migration is not necessarily a problem, a sign of adaptation failure (Gemenne and Blocher, 2017) or a strategy of last resort (Hampshire, 2002). It may be an appropriate voluntary long-term strategy for dealing with unfavorable conditions (Gemenne and Blocher, 2017). Yet, it can be undesirable. Migration can result from anthropocentric environmental changes, poor infrastructure, mismanagement, a low level of adaptive capacity, a massive gap between urban and rural lifestyles, and a sense of relative deprivation. In such cases, RUM is a way to escape difficult conditions in rural areas. It brings more newcomers to immigrant-receiving cities, usually with no appropriate jobs, leading to many economic and social difficulties. Additionally, it often leads to an unsustainable form of urban growth and consequently creates various problems for urban management (Abdul Rashid and Ghani, 2009). Martin (2013) argues that migration is a significant challenge for destination areas because resources for dealing with the inflow of migrants are often limited, legal structures are often complex, and institutional capacity is often low. Migration can also have undesirable consequences in the area of origin, such as a change in sex and age structures and security threats for the remaining people. As a result, people who stayed behind may also be encouraged to migrate, following their family members and neighbors. This can lead to a low level of investment in these regions.

3. Methodology

This study aims to develop a conceptual model for understanding the linkage between environmental changes and migration by reviewing and analyzing the available literature. The conceptual model is based on the model of Perch-Nielsen et al. (2008), but it extends the model by incorporating additional factors.

The literature review was conducted using various academic databases, such as Web of Science, Scopus and Google Scholar. Combinations of relevant keywords were used, including "environmental changes," "migration," "climate change," "hydro-climatic disasters," "push factors," "pull factors," "intervening obstacles," "personal factors," "human maladaptive activities," "governmental plans" and "individuals' characteristics." The relevant studies were reviewed and analyzed to identify the key factors influencing the migration response to environmental changes.

Using ideas from previous studies (Lee, 1966; El-Hinnawi, 1985; Perch-Nielsen et al., 2008; Black et al., 2011a; Renaud et al., 2011), the identified factors were classified into three categories: 1) leading causes (push factors: environmental changes, including climate change and hydro-climatic disasters and human maladaptive activities), 2) other causes (pull factors in the cities), and 3) counter-causes (governmental plans and individuals' characteristics) (Figure 1). The model focuses on the loss of agricultural land and productivity and relevant economic consequences of this loss. The conceptual model consists of boxes that represent the relevant factors and arrows that represent the different relations, without indicating the strength of these relations.

4. The conceptual model

In a "common sense" approach (Castles, 2002), migration can be presented as the inevitable result of environmental changes: people are forced to leave their homes when environmental changes occur. This is, however, an oversimplification. Not all individuals may be equally vulnerable to environmental changes, and some of those who are may not be able to migrate (Brown, 2007; Stal and Warner, 2009). This is the so-called "trapped population" (Wiegel et al., 2019). Additionally, some people may choose to migrate voluntarily to regions with better environmental conditions (Mcleman, 2009). This suggests that the migration response to environmental changes is influenced by non-environmental factors as well, such as political, economic, social and demographic factors (Black et al., 2011a). The common sense approach does not account for intervening factors that influence the human reaction to environmental changes (Lonergan, 1998). Thus, a more comprehensive conceptual model is called for (Perch-Nielsen et al., 2008).

Lee (1966) categorized the factors influencing migration into four categories: 1) push factors related to the origin, 2) pull factors related to the destination, 3) intervening obstacles, and 4) personal factors (Lee, 1966). Perch-Nielsen et al. (2008) focused on two environmental events, floods and sea-level rise, to examine the link between environmental changes and migration. Drought, another significant event, was studied earlier by Perch-Nielsen (2004). The present study covers both floods and droughts as types of hydro-climatic disasters. A significant weakness of Perch-Nielsen et al. (2008) model is the exclusion of human maladaptive activities, such as upstream development, which are prevalent in many watersheds and contribute significantly to environmental degradation and migration. These activities are included in the present model. The different factors will be discussed in more detail below.

4.1. Environmental changes

4.1.1. Climate change

The earth's temperature has been trending upwards over the past century (IPCC, 2014), resulting in changes in the global, regional and local climate. Warmer winters, reduced snowpack, decreased renewable water, changes in crop types and growth stages, increased evaporation, decreased soil moisture, and changes in rainfall patterns have had adverse effects on agricultural productivity, leading to long-term decreases in community resilience, economic problems, and migration. In addition to these gradual effects, climate change is also increasing the frequency, intensity and amplitude of floods and droughts (Sharifi et al., 2012; IPCC, 2014, 2018; Almasi and Soltani, 2017). Finally, less precipitation and higher temperatures can also result in the drying out of lakes and severe dust and salt storms.

4.1.2. Human maladaptive activities

In some watersheds, human maladaptive activities contribute significantly to the problems caused by climate change. They can be divided into maladaptive upstream activities and maladaptive downstream activities. Unsustainable development upstream, such as water diversions and deforestation, can increase water scarcity and flooding downstream and sometimes both. When combined with overgrazing, inappropriate irrigation, and over-abstraction downstream, groundwater quality and quantity can decline, soil salinity can increase and the land may degrade generally.

4.1.3. Hydro-climatic disasters

Drought and floods are the main hydro-climatic disasters threatening agricultural production and rural living. Drought can be classified as meteorological, hydrological, agricultural or socioeconomic (Wilhite and Glantz, 1985). Meteorological drought arises from a low amount of precipitation and may lead to a decline in soil moisture (agricultural drought) and less surface and groundwater (hydrological drought). Hydrological drought can reduce irrigation, thus contributing to agricultural drought, and fisheries. Socioeconomic drought refers to the social and economic consequences of meteorological, hydrological or agricultural drought.

While drought is a slow-onset event, floods are sudden-onset events. Sudden-onset events can result in considerable damage to infrastructure and property and loss of life (McLeman and Hunter, 2010). They often force people to evacuate the region before, during, or after the event. Evacuation is often temporary as people try to get back home after the flood. Displacement in response to slow-onset events may be temporary too, at least initially, when people believe the situation to be temporary (McLeman and Hunter, 2010). However, as the situation continues to worsen and they have no alternative means of subsistence, they may decide to migrate permanently.

In many parts of the world, migration in response to sudden-onset events captures more media and scholarly attention than slow-onset events. The latter, however, may cause even more people to leave their homes, at early or more advanced stages of the events (Boncour and Burson, 2009; Gutmann and Field, 2010). In 2016, over 24 million people were displaced in response to sudden-onset events, but exact figures for slow-onset events are lacking (Opitz Sapleton et al., 2013). According to Zetter (2010), it is difficult to distinguish between voluntary and forced migration in the case of slow-onset events because people may migrate voluntarily in the early stage of the event (e.g., a drought), but then be prevented from returning when the drought continues.

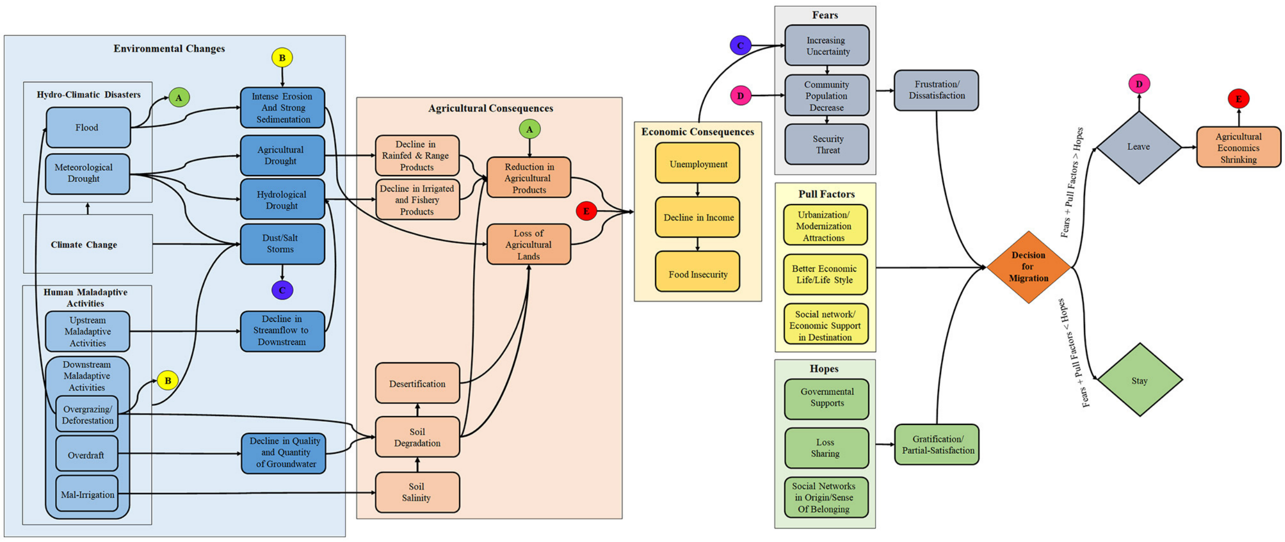

FIGURE 1
Conceptual model for linkages between environmental changes and migration.

4.2. Agricultural consequences

A reduction in agricultural production due to unreliable rainfall and flooding can lead to more hunger and poverty and cause migration (Afifi et al., 2010). Agricultural production can decrease due to a reduction in the yield per hectare and to a loss of agricultural area. Floods can destroy the harvest, but they can also cause intense erosion and strong sedimentation and reduce the fertility of the land. Drought affects both irrigated and rainfed agriculture, as well as fisheries. Declining groundwater quality and quantity arising from over-abstraction and soil salinity from mal-irrigation practices can result in soil degradation and lower yields.

4.3. Economic consequences

The agricultural; consequences outlined above reduce economic efficiency in the agriculture sector and result in low-income levels for the rural population or even food insecurity. They usually have no alternative jobs other than farming. At this point, they are facing the difficult decision to migrate or not.

4.4. Decision to migrate

Most of the rural population typically do not immediately take drastic action in response to unfavorable conditions because they hope the situation will not last. Instead, they try to adapt for the time being (McLeman, 2011). They leave their home only if they cannot tolerate the conditions anymore and do not have any alternative means of subsistence. In the conceptual model, factors that encourage people to migrate or stay are classified into three groups: fears, hopes and pull factors.

4.4.1. Fears

Economic problems increase the uncertainty of the rural people about their future welfare. Some, mostly young adults who are often referred to as the "new economics of labor migration" (Stark and Bloom, 1985), leave their homes at the early stages of change. The resulting decrease in rural population may lead to security threats as typically only the elder, women and children stay behind. Severe dust/salt storms can exacerbate such situations. The resulting frustration and dissatisfaction push the remaining people to leave.

4.4.2. Pull factors

In addition to push factors, pull factors can motivate rural people to migrate to big cities. Urbanization and modernization and structural change from agriculture to industry can result in RUM, even in the absence of environmental changes. While mechanization in agriculture increases agricultural productivity and reduces agricultural employment, urbanization and expanding industries can attract the unemployed to the cities (Boone and Wilse-Samson, 2019; Lyu et al., 2019; Hajdari and Krasniqi, 2021). Moreover, changing lifestyles and seeking better economic conditions are pulling people to cities. RUM mainly results from the uneven geographic distribution of welfare between the countryside and cities (Madani, 2014). Furthermore, a strong social network in the destination area (family members, relatives, acquaintances, people from the same ethnic group) acts as a strong pull factor. Since pull migration is usually meant to be permanent, migrants need to be sure they can afford the displacement expenses (or pay back loans later) and support their families in the destination area. Therefore, people with few resources (money and social networks)

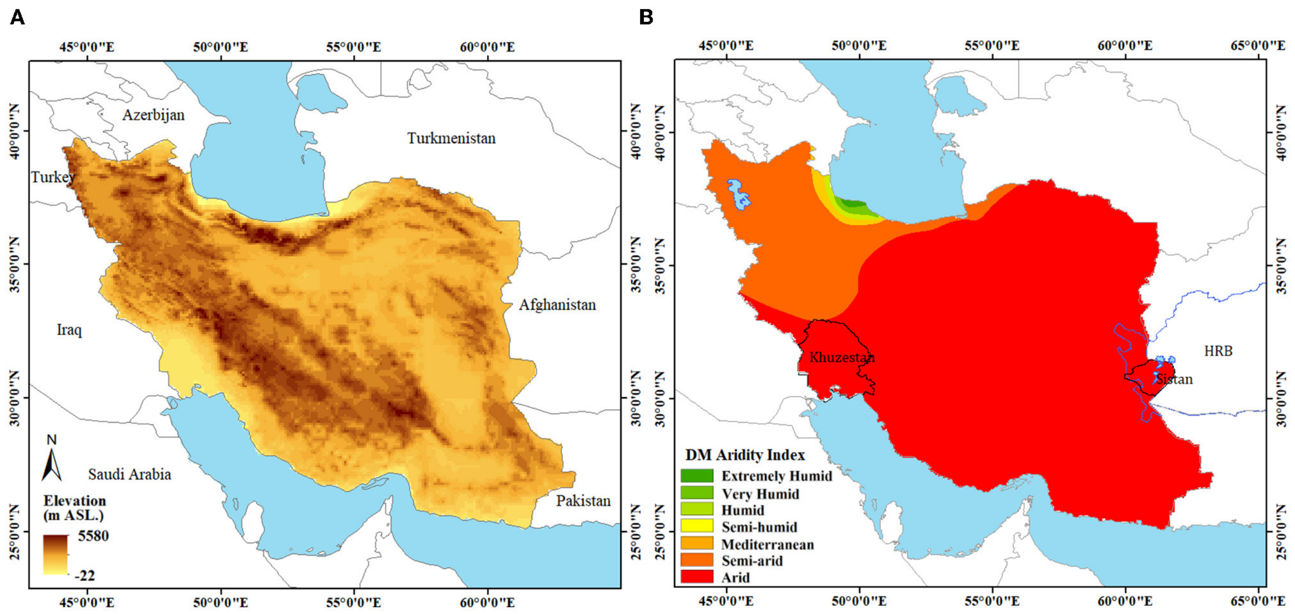

FIGURE 2
The geographical location of Iran with neighbors, elevation **(A)**, and De Martonne Aridity Index **(B)**.

tend to leave their homes later than people with more resources. In some cases, early-stage migrants are forced to leave their homes and subsequently assist the remaining people in moving voluntarily (Hugo et al., 2018).

4.4.3. Hopes

Fears which arise from the leading causes and pull factors can be mediated by some counter-causes, called “hopes” in the proposed model. Factors encouraging people to stay are governmental support, loss sharing and a strong social network in the area of origin or “sense of belonging.” Sense of belonging to land and neighbors is a powerful human emotion, especially belonging to a particular tribe or caste. Therefore, it may be expected that in the early stages of environmental changes, hardly any people decide to leave their homelands unless some of their neighbors, family, or tribe members do the same.

If hopes are stronger than fears and pull factors, individuals will stay, but if fears and pull factors are stronger, they will leave. Pioneer migrants often try to facilitate other members of their community to follow. They also encourage more migration by transmitting favorable information to their area of origin. This may result in migration systems with increasing rates of migration (Bakewell et al., 2012). Migration also reduces the agricultural economy as it reduces the agricultural labor force and investments. This in turn worsens the economic situation of individual farmers who stayed behind, stimulating even more migration. Thus, the linkage between environmental change and migration is a cycle with positive feedback (Figures 1D, E).

The proposed conceptual model can be applied to each region, depending on their unique and special characteristics. In this paper, we applied the model to Iran, as such studies have not been conducted in the country before due to a lack of interdisciplinary research.

5. Application to Iran

5.1. Study area

Iran (Figure 2A) is a developing country in the southwest of Asia. It is the second-largest country in the Middle East, with an area of 1,648,195 km^2 (Madani, 2014). Iran is generally classified as semi-arid and arid (Figure 2B), with a mean annual precipitation of about 250 mm per year. The mean annual temperature ranges from 10°C (in the west) to 35°C (in the center). There are no prevailing climatic seasons in Iran. According to the Koppen climate classification, the south, east and center of Iran have a desert and semi-arid climate. A hot or warm dry-summer continental climate is experienced in the west and northwest of Iran, and the coastal regions in the north of Iran have a Mediterranean climate. These highly variable climate characteristics are due to Iran’s location on the Caspian Sea, the Persian Gulf and the Sea of Oman and the mountain regions Albors and Zagros (Sanjani et al., 2011).

The Statistical Center of Iran (2016) reported that currently, more than 74% of Iran’s population lives in cities and only 26% in rural areas (Statistical Center of Iran, 2016). The urban population is currently much higher than in the 1950s and 1970s, when it was 27% and 44%, respectively (Madani, 2014). Statistics show that from 2011 to 2016, about 30,000 villages across the country were abandoned and the rural population growth has been negative, at −0.73% (Statistical Center of Iran, 2016).

5.2. Climate change

The World Meteorological Organization has reported that Iran experienced a warming of about 1°C during the period 2001–2010 (WMO, 2013). Previous studies have indicated an increase in heat waves and a decline in precipitation in Iran (Rahimzadeh et al., 2009; Nazaripour and Mansouri Daneshvar, 2014). Most stations in Iran have shown negative trends in annual and seasonal precipitation, particularly in the north and northwest (Modarres and Sarhadi, 2009; Somee et al., 2012). A similar study conducted in Iran showed a significant decrease in annual precipitation, especially in winter rainfall (Tabari and Hosseinzadeh Talaee, 2011). In the north of the country, precipitation is relatively evenly distributed throughout the year, while in the south, it is concentrated in only a few months (Raziei et al., 2012). Trend analysis of extreme temperatures has shown a significant increase in the frequency of hot days and nights and a significant decrease in the frequency of cold days and nights (Mansouri Daneshvar et al., 2019). Due to the increase in mean annual temperature and decrease in mean annual precipitation, aridity has increased during 1966–2015 (Mianabadi et al., 2019). It is predicted that Iran will become even drier and hotter between 2020 and 2100 (Madani et al., 2016).

5.3. Human maladaptive activities

Iran is considered one of the pioneer countries in the world in the construction of water resources and efficient water irrigation projects to successfully deal with limited water resources in a sustainable manner (Frenken, 2009; Madani et al., 2016). For instance, the Qanats were widely used by ancient Iranians. However, since the first water pumps were imported in Iran in the early 20th century, the importance of Qanats has become less due to the expansion of water wells. The number of wells increased from 45,000 to 50,000 in the 1970's to 764,000 in 2011 (Nabavi, 2017). This considerable increase has led to overexploitation of groundwater resources, changes in the hydrological cycle, land degradation and desertification (Madani, 2014).

The country is experiencing considerable challenges of environmental degradation, mostly related to water issues. As in the other countries in the Middle East, most of the water challenges are rooted in bad governance and mismanagement, to a large extent arising from an oil-based economy with remarkable social and economic changes, such as urbanization, rising standard of living, high rates of consumption and infrastructure development (Taremi, 2005). Moreover, despite improvement of the social and physical assets in rural areas during the last decades, the rural economy still depends on agriculture and water. Thus, based on its "Hydraulic Mission" strategy, Iran over-invested in water storage and distribution infrastructures to meet the increasing demand for water in the last decades. Overexploitation of groundwater reserves and over-investment in dams and inter-basin water transfer projects with minimum concern about environmental consequences have led to drastic environmental changes in some parts of the country. Besides, the lack of appropriate socio-economic and political plans for dealing with these environmental degradations, as well as the current economic, power and services inequalities between rural and urban areas, increase the rate of RUM (Madani, 2014).

Moreover, the construction of dams to provide water for agriculture and domestic purpose and generate electricity were the priority of the policymakers during 1955–1962 (Katouzian, 1978). This aligned with a global movement during the 1930's—1970's that considered dam construction as a sign of modernization, development, and economic growth (WCD, 2001). Currently, there are 316 dams in Iran, 100 dams are under construction, and a further 300 dams are being considered for development (Madani et al., 2016), while in the 1970's, there were only 12 dams in the country (Beaumont, 1974). Notwithstanding their benefits, these dams have resulted in damage to the ecosystem, changes in land cover, human displacement and more development and water use downstream due to the perception of water abundance (Madani, 2014).

After the Islamic Revolution and due to international sanctions, the policy of Iran was to be self-sufficient. Thus, the policymakers decided on rapid development by constructing major infrastructural works without considering long-term consequences and the complexity of the human-natural system. This has resulted in many environmental challenges, including "drying lakes and rivers, declining groundwater resources, land subsidence, water contamination, water supply rationing and disruptions, forced migration, agricultural losses, salt and sand storms, and ecosystem damages" (Madani, 2014). Additionally, climate change, prolonged droughts, and frequent floods have exacerbated environmental degradation in some regions. These factors together have led to massive RUM.

These activities have resulted in drying water bodies in many watersheds (Madani, 2014), many other environmental challenges, and migration. In recent decades, the implementation of different development plans and overexploitation of biological resources have affected the eco-regions of Iran (Makhdoum, 2008; Kolahi et al., 2012). According to the last available report, the World Bank reported that in 2002, the annual cost of environmental degradation in Iran was about 8.4 billion US$ (The World Bank, 2005).

Dust storms are a big problem in Iran, especially in the southeast and southwest. In the Sistan area in the southeast of Iran, part of the Hirmand River Basin (HRB) (see Figure 2B), shared by Iran and Afghanistan, human-made infrastructures in Afghanistan and debilitating dust storms have brought life to a standstill. Lake Hamoun in HRB (Figure 2B) has dried up due to the conflict between Iran and Afghanistan over the utilization of the Hirmand River (Madani and Hipel, 2011). All research on dust storms in the Sistan area believes that the dry lake bed is the main cause (Middleton, 2019).

Salt storms also occur, for example, in the northwest of Iran from Lake Urmia (Figure 2B). Lake Urmia, the largest lake in the Middle East, has shrunk significantly due to upstream human maladaptive activities as well as frequent droughts (Sima and Tajrishy, 2013; Fathian et al., 2015). In addition to the direct consequences for the lake's ecosystem and regional economy, the shrinkage of the lake also leads to salt storms in the surrounding cities and villages (Madani, 2014). Both dust and salt storms cause many physical and mental health problems, as well as the loss of agricultural lands, forcing, in some cases, many people to leave their homes.

Groundwater is the primary source of water used for domestic, industrial and agricultural consumption in Iran (Jafary and Bradley, 2018). Increased water demand has led to the overexploitation of groundwater (Ashraf and Nazemi, 2021), such that the country is one of the top groundwater miners in the world (Gleeson et al., 2012; Döll et al., 2014).

5.4. Hydro-climatic disasters

Iran is one of the most disaster-prone countries in the world. Floods and droughts are the biggest concerns of the Iranian government and play a significant role in migration.

Iran has several large rivers that flood in spring, causing considerable damage to agriculture. For example, in March and April 2019, precipitation with a 200-year return period occurred in most parts of Iran, especially in the west and north. During 16 days (17 March to 1 April), the amount of precipitation was about 72 mm, almost 29% of the average yearly precipitation, resulting in a runoff of 119 MCM (Iran Water Resources Management Company, 2019). This flood affected 3,899 villages and more than 2,100,000 people. The total damage to the agricultural sector was IRR 38,528 billion (US$ 321 million).

In Iran, severe and long-lasting droughts occur regularly. In the last 50 years, the country experienced 27 droughts (Abbaspour and Sabetraftar, 2005; Keshavarz et al., 2013, 2017). One of the severest droughts since the 1940's occurred from 1998 to 2000. In 1989–1999 alone, about 4.2 million head of livestock died and about 12 million hectares of agricultural lands were damaged. The damage to agricultural production during 1989-1999 was about US$ 4.3 billion (Abbaspour and Sabetraftar, 2005). Approximately 11 km^3 of groundwater was abstracted and many wells and Qanats dried up (Abbaspour and Sabetraftar, 2005). In 2000–2001, rangeland production was reduced by about 70%. About 80,000 tons of rangeland production have been lost in Kordestan province and 40,000 tons in Guilan province (Abbaspour and Sabetraftar, 2005). OCHA (2001) reported that, "based on the official estimates, this year's drought [2000] is directly affecting more than 2.6 million hectares of irrigated farms, 4 million hectare[s] of rainfed agriculture, 1.1 million hectare[s] of orchards and more than 75 million animals." After a brief spell, the most severe, prolonged and extensive drought over the last 30 years has occurred since 2003, with undesirable consequences for many rural communities in the center, east and south of Iran (Keshavarz et al., 2013). Drought has caused many rural people in Iran to lose their jobs and income, especially people whose lives depended on water and agriculture, and forced them to migrate.

Accordingly, drought is a common phenomenon and a part of normal life in Iran; however, it is predicted that the country will become even hotter and drier due to climate change, resulting in more pressure on water resources (Afshar and Fahmi, 2019) and agriculture (Karimi et al., 2018). Agricultural activities in Iran are susceptible to droughts: one mm of rainfall below the historical average leads to approximately US$ 90 million of losses in the agriculture sector (Madani et al., 2016).

5.5. Agricultural consequences

Agriculture in Iran depends mostly on groundwater: in about a third of the country, more than 80% of the land is irrigated with groundwater (Karimi et al., 2012). During 1993–2007, the area irrigated with groundwater increased by 39%, while that irrigated with surface water declined by 15% (Collins, 2017). Reduction in groundwater levels, with an average of 0.4 m per year across the country (Karimi et al., 2012), threatens the agriculture sector. Moreover, the over-abstraction of groundwater has led to environmental degradation and water salinization (Jafary and Bradley, 2018). Irrigating crops with saline water results in the concentration of salts in the soil and a decrease in grain yields (Mojid et al., 2014; Collins, 2017).

It is estimated that soil salinization in Iran has led to an economic loss of more than US$1 billion (Jafary and Bradley, 2018). Overgrazing and deforestation directly cause soil degradation, leading to both a decline in agricultural production and a loss of agricultural land. Soil degradation indirectly–through desertification–results in the loss of agricultural land. In the case of climate change, it is predicted that with a 2.7–4.7°C increase in temperature in Iran, the average yield reduction in rain-fed wheat crops will be about 18% by 2025 and 24% by 2050 (Nassiri et al., 2006). Currently, ∼46% of the total cultivated area in Iran is irrigated (Statistical Center of Iran, 2016). However, due to environmental changes, this is becoming less, with considerable economic consequences in rural areas.

5.6. Economic consequences

The economic consequences, such as unemployment, decline in income and food insecurity, have not been thoroughly investigated in Iran. However, a few studies have provided some information about these consequences. According to the interviews conducted by Khavarian-Garmsir et al. (2019), especially dust storms have contributed to the economic downturn and unemployment in Khuzestan province, southwest of Iran (Figure 2B). The interviewees from Masjed Soleiman, a city in this province, indicated that unemployment is the oldest reason for migration. In the Urmia Lake Basin in the northwest of Iran, environmental changes and recent drought cycles have led to a reduction in agricultural productivity, a higher rate of unemployment, economic problems and migration (Delju et al., 2013). In the Sistan area in the southeast of Iran, people believed that the economic problems arise from water scarcity and prolonged drought in the area (Mianabadi et al., 2021).

5.7. Fears, hopes, and pull factors

The majority of rural people in Iran are employed in the agricultural sector. Agricultural degradation and economic problems increase uncertainty in the life of rural people. Many rural people are unsure whether to leave their homes and emigrate to cities (Statistical Center of Iran, 2016). For example, according to the interviews conducted in Khuzestan, some unemployed people out-migrate to find a job in cities and, some employed people are looking for a better economic situation and a better future (Khavarian-Garmsir et al., 2019). Studies in Khuzestan province show that 35–40% of rural migrants changed their jobs over the last four census periods due to environmental and economic factors (Mohammadi Dehcheshmeh and Ghaedi, 2020). Seeking better economic opportunities, combined with the attractions of urban life and social networks in cities, increases the rate of RUM. This migration leads to a decrease in the population of rural communities, which can result in security threats, frustration and dissatisfaction.

The findings of Khavarian-Garmsir et al. (2019) in Khuzestan showed that, in addition to environmental changes and economic decline, the market downturn is also affected by political factors. They also indicated that in some areas, basic facilities are not available and uneven economic development and inequity in job opportunities and life quality may lead to mass RUM. Another critical issue in Khuzestan province is the impact of the Iran-Iraq war and the government's inadequate efforts to rebuild the damaged areas. This makes many people to be dissatisfied with their current situation. Accordingly, Khuzestan province is known as the emigrant-pole in Iran, such that more than 50% of rural-urban migrants come from this province (Statistical Center of Iran, 2016). Such situations are also observed in the Sistan area in the southeast of Iran, where 55% of the rural population depends directly on agricultural activities for their income (Ebrahimzadeh and Esmaelnejad, 2013). During the drought in the early 2000s, 124 villages were abandoned and unemployment rates increased significantly (Thomas and Mahmoudzadeh Varzi, 2015). These situations indicate that, although migration is an individual decision, it occurs in the larger context of structural and institutional inequities.

Mass RUM in Iran shows that hopes are not so strong to keep people in villages. This could be due mainly to a lack of wise management and preparedness plans for dealing with the consequences of environmental changes and the lack of governmental supports such as providing water, jobs, investment and amenities, allowing border markets, and engaging local people, especially young people, in managing local challenges. Additionally, Mianabadi et al. (2021) showed that sense of belonging, or current place attachment, and trustworthy social network in the villages in the Sistan area are key factors that encourage people to stay in their homelands. However, unpleasant situations make rural livelihoods increasingly at risk and threaten the communities and households that are more dependent on natural resources (Keshavarz et al., 2017).

Among the leading causes of RUM, climate change cannot be mitigated at the local scale, and hydro-climatic disasters cannot be avoided completely. The only manageable leading cause is human maladaptive activities; thus, governmental policies to deal with migration should focus on this issue. Satisfactory and reliable economic conditions can incentivize people to remain in their villages. These conditions can be provided in different stages of environmentally-induced migration. Factors encouraging people to stay in villages include investment in small businesses, supporting economic activities other than agricultural ones, such as greenhouse production, border trade and markets (in rural areas near the border) and engagement of all stakeholders in local governance. Policymakers can provide direct financial support before and after the consequences occur. They can also focus on coping and adaptation strategies to avoid unpleasant consequences of environmental changes by increasing resilience and decreasing the vulnerability of individuals and communities with the aim of reaching a sustainable livelihood (Scoones, 1998). These strategies have been categorized into four areas: natural resources, economic and financial support, human resources and social capital (Scoones, 1998). In our (and similar) case(s), the strategies can include sustainable development of the region through land-use planning, using water diplomacy tools to meet environmental demands, especially for transboundary wetlands and lakes, considering the socio-political aspects of water management and development projects, and sustainable participation of local communities in policy and decision making. However, migration is a complex and nuanced problem that requires a complex solution. Thus, there is no single solution for dealing with mass RUM. Depending on their unique and special characteristics, a unique and special solution might be helpful for each region.

6. Discussion and conclusion

Investigation of the linkages between environmental changes and migration requires transdisciplinary research. It involves a variety of disciplines, such as environmental and natural resources science, social science, economics, geography and political science. Building linkages among various disciplines is a challenging issue for transdisciplinary research, which needs to integrate diverse concepts, methods, frameworks and data for appropriate cooperation among disciplines (Perch-Nielsen et al., 2008).

Due to the multi-causal nature of environmental migration, lack of appropriate data is a key gap for developing models in Iran as a developing country. This is even more evident for slow-onset events (Zetter, 2010). Insufficient data makes it impossible to determine the importance of each factor (i.e., climate change, human activities, or hydro-climatic disasters) as a key driver of migration. Collecting data is a significant challenge. For example, data on hopes, fears and pull factors are not sufficient for the scientists to develop physical models and the policymakers to develop appropriate policy responses.

Furthermore, individuals' reactions to environmental changes are not predictable. Their reactions to slow- and sudden-onset events differ, and the trends and patterns of migration often cannot be identified clearly. While humans are a central part of an ecosystem (Pande and Sivapalan, 2016), many environmental or climate models have failed to take into account the impacts of individual choice and human activities and the potential of policy actions at local and international levels. It is also difficult to distinguish between natural and anthropogenic environmental changes.

Another challenging issue is to distinguish between the impact of environmental changes on migration and the impact of economic, social, demographic and political factors. It is often not clear whether a migrant is pushed out by environmental changes or pulled away by the promise of a better economic situation elsewhere (Luetz, 2019). Other challenges, specifically in Iran, are economic problems and inflation, making it difficult for policymakers to develop appropriate preparedness plans and to fund data collection and research.

The aim of this paper was to provide a conceptual model that helps policymakers to identify and understand the causal interaction between environmental changes and RUM. The conceptual model proposed in this study serves this purpose. The model is built on an enhanced understanding of the different factors that stimulate environmentally induced RUM. The model focuses on the decline of agricultural lands and productivity as well as the economic repercussions. The model is based on the model of Perch-Nielsen et al. (2008), but extends this model by incorporating additional factors. The key factors influencing the RUM were identified through the literature review. The model then was applied to Iran to test its usefulness in specific cases. This show that environmental changes in Iran lead to a decline in agricultural lands and productivity, which in turn cause many problems for rural communities and stimulate RUM. To deal with RUM, policymakers should develop appropriate plans to help affected people in a way that prevents further degradation of the rural environment. For example, when farmers lose all or part of their livestock during a drought, government currently helps them with subsidies, loans, or insurance. Farmers then buy more livestock and use more water and pastures for feeding them, leading to more environmental degradation and more loss of livestock in the next drought. This clearly is not a sustainable policy.

Since some causes of RUM are inevitable, policymakers should focus on the factors they can influence. Climate change cannot be prevented at the local or even the national level, and hydro-climatic disasters cannot be avoided completely either. The only manageable leading cause is human maladaptive activities, and governmental policies to deal with migration should focus on this issue. Human maladaptive activities can be managed by both governments and people. By using natural resources sustainably and increasing individuals' and communities' coping capacity, undesirable consequences can be prevented or reduced and migration can be appropriately managed.

Environmental challenges are likely to become more acute due to climate change and the increasing severity and frequency of hydro-climatic disasters. Future research should therefore focus more on the issue of environmental migration and its consequences. Important research questions include when migration is necessary and when it is undesirable; which strategies policymakers can use to manage necessary and prevent undesirable migration in both the areas of origin and the destination areas; whether strategies for slow-onset and sudden-onset events should differ; which areas are most vulnerable to environmental change; how migration rates may change in the future climate; whether migration is more related to climate change or to human interventions; which groups of people are most likely to migrate (i.e., age, occupation, gender, marital status); and finally, clarifying the concept of mobility in relation to migration. These questions should be studied in different individual regions because the response to environmental changes is likely to differ, depending on the coping and adaptive capacity of the communities in the region, their knowledge, and the applicable governments' policies. Given the importance of local, non-scientific knowledge, tacit knowledge should be considered as well.

The conceptual model was developed using the available literature, which may have limitations in terms of coverage and accuracy. Therefore, the model does not pretend to capture all factors influencing migration response to environmental changes. Moreover, the model only focuses on the decline of agricultural lands and productivity and relevant economic consequences, and it may not be applicable to other types of environmental changes. Hence, future research may lead to extensions or changes in the model, including contingent approaches. Finally, quantitative models can be developed using the conceptual model as a basis, provided sufficient data can be collected.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AM and KD developed the conceptual model with the contribution of MK. AM, MK, and HM collected the required information. AM prepared the figures and wrote the first draft of the manuscript. KD, HM, MK, and EM reviewed the paper and contributed to the discussions. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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