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Ali Ersin Dinçer,
N. Nergiz Dincer
and Abdullah Demir

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Ali Ersin Dinçer*, N. Nergiz Dincer† and Abdullah Demir‡

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Abstract: Disaster resilience is a protective feature aimed at reducing the effects of natural disaster events and losses resulting from these events. The aim of this study is to propose a disaster resilience index (DRI) for the MENA countries, to facilitate a more comprehensive understanding of disaster resilience in the region. The contributions of the paper to the literature are (i) covering disaster prone countries which are mostly missing in Khan et al. (2022) study, (ii) incorporating the indicators to the index through a systematic examination of indicators in the existing literature, and augmenting the dataset outlined in Khan et al. (2022) by integrating relevant indicators that were previously omitted, (iii) integrating geospatial data on disaster risk from GIS into the DRI, (iv) adding the natural hazard risk index to the DRI, and (v) establishing a correlation between the DRI and economic losses, thereby revealing the efficacy and robustness of the newly developed DRI index developed in this study. There are two stages of the methodology: (i) A novel, systematic and comprehensive disaster resilience index is formed for MENA countries and (ii) The relation between the disaster resilience index and economic losses is visualized. The findings reveal a diverse landscape of disaster resilience in the MENA region, with some countries demonstrating high preparedness and resilience, while others face significant challenges. The classification of the DRI enables a detailed comprehension of the strengths and vulnerabilities of the region concerning its capacity to withstand and recover from disasters. The inclusion of novel dimensions such as geographical resilience and natural hazard risk provides a more holistic perspective for policymakers, practitioners, and researchers.

Keywords: disaster resilience index, MENA, economic losses in disasters

* Department of Civil Engineering, Abdullah Gül University, Kayseri, Türkiye. Email: ersin.dincer@agu.edu.tr

† Department of Economics, TED University, Ziya Gökalp Bul. No:48, Kolej, Ankara, Türkiye. E-mail: nergiz.dincer@tedu.edu.tr

‡ Department of Civil Engineering, Abdullah Gül University, Kayseri, Türkiye. Email: abdullah.demir@agu.edu.tr

1 Introduction

Since the beginning of human existence, disasters have posed a significant threat, causing harm and damage to both individuals and their belongings. The frequency and intensity of natural disasters have dramatically increased as a consequence of climate change. Over the past two decades, the world has suffered approximately three trillion dollars in losses due to 7,000 natural disasters (Khan et al. 2022).

Disaster resilience is a protective feature aimed at reducing the effects of natural disaster events and losses resulting from these events. Disaster resilience results from the capacity of social, economic, and government systems to prepare for, respond to, and recover from a natural disaster event, and to learn, adapt, and transform by anticipating future natural disaster events. Transforming societies into a state that is resistant to natural disasters and moreover able to absorb and reduce the negative effects of disasters has become one of the main goals of disaster management. This goal was adopted by 168 countries in the Hyogo Framework for Action (HEF) in 2005 (UNISDR 2005).

The United Nations Sendai Framework for Disaster Risk Reduction 2015-2030, which replaced the HEF in 2015, recommends four actions to prevent new disaster risks and reduce existing disaster risks: (i) understand disaster risk; (ii) strengthen disaster risk governance to manage disaster risk; (iii) invest in disaster mitigation for disaster resilience and; (iv) enhance disaster preparedness for effective response and "building back better" in recovery, rehabilitation and reconstruction. In other words, the Sendai framework aims to increase disaster resilience and significantly reduce disaster risk and disaster-related losses through integrated implementation covering the fields of environment, socio-economic, health, governance, innovation and technology in the next 15 years. On the other hand, Sustainable Development Goal 13 aims to evaluate disaster risk reduction strategies and strengthen resilience to reduce disaster-related losses.

The aim of this study is to propose a disaster resilience index (DRI) for the MENA countries, to facilitate a more comprehensive understanding of disaster resilience in the region. By capturing the multidimensional nature of resilience and adaptive capacity, the DRI will enable policymakers, practitioners, and researchers to assess and monitor the region's preparedness, response, and recovery mechanisms. This, in turn, can inform evidence-based decision-making, aid resource allocation, and foster the development of effective strategies and policies to mitigate the impacts of natural disasters and enhance the region's overall resilience.

In the literature, studies have been conducted to measure disaster resilience for different countries with different methods. While Anarudha (2019) measured disaster resilience for an agricultural town in Sri Lanka by surveying 143 people, Kwok et al. (2016) proposed social resilience indicators against disasters with the expert opinions of researchers and policy makers in the workshop they organized for New Zealand. Ostadtaghizadeh et al. (2016) and Kusumastutid et al. (2014) obtained the necessary data to measure disaster resilience through focus group discussions in Iran and Indonesia, respectively. Measuring disaster resilience in Saudi Arabia, Alshehri et al. (2015) conducted a three-stage Delphi study using technology and a panel of local and international experts with in-depth knowledge in the field of disaster management. As a result of the study, a six-dimensional community resilience framework was created, each containing seven to fourteen criteria. In a much more recent study, Ryan (2022) created a Preparedness Competence Index using in-depth semi-structured interviews with 30 emergency agency, local council and non-profit organization staff from all states in Australia.

Studies that create a disaster resilience index for different regions of a country using secondary data provide guidance to policy makers and decision makers. One of the fundamental articles in the literature in terms of methodology and indicators used is Cutter et al. (2010). They applied community disaster resilience to settlements in the southeastern United States and showed that spatial differences in disaster resilience were evident. In another article that was influential in the formation of the methodology, Cutter et al. (2014) created an empirically based disaster resilience measure for US settlements called Core Resilience Indicators for Communities that is easy to calculate and based on a conceptual and theoretical background. This index consists of 6 axes: social, economic, institutional, infrastructure, capital and environment.

There are a limited number of studies that are based on the existing methodology and slightly improved it and applied it to other countries. In their study for Korea, Youn et al. (2015) selected the most appropriate indicators reflecting these factors in order to create a disaster resilience index based on human, social, economic, environmental and institutional factors. Another contribution of the study is that they examined the relationship between the index measuring the degree of resilience of the society against natural disasters and disaster losses for 229 local municipalities using the least squares regression method and geographically weighted regression method. Marzi et al. (2019) propose a composite disaster resilience index at the municipal level for the whole of Italy. The strength of this study is the sensitivity analyzes performed to investigate the impact of methodological choices and assumptions on the resulting results. Scherzer et al. (2019) localized Cutter et al. (2014) methodology to Norway by considering the country-specific factors and created the disaster resilience index for Norway, consisting of six sub-indices and 47 indicators. Parsons et al. (2020) calculated disaster resilience index for 8 axes and 77 indicators for 2084 regions for Australia.

Unlike other country studies, Jha and Gundimeda (2019) examined the vulnerability of flood-affected areas for the Bihar region of Indonesia by integrating various exposure, sensitivity and adaptive capacity indicators into a composite index. This study normalized and aggregated across sub-indices and combined this information with Geographic Information Systems (GIS) to demonstrate social vulnerability to floods.

In summary, the majority of country-specific studies in the field of disaster resilience rely heavily on the frameworks established by Cutter et al. (2010) and Cutter et al. (2014) for selecting relevant data to be incorporated into the DRI. These studies carefully consider country-specific conditions when determining the relevant data. Subsequently, the gathered data is typically synthesized into a composite index, frequently employing techniques such as principal component analysis for aggregation and interpretation.

To the best of our knowledge, there is only one study that provides a global DRI. Khan et al. (2022) developed a comprehensive DRI composed of 9 dimensions: economic stability, emergency workforce, agricultural development, human capital, digitalization, infrastructure, governance, social capital, and women empowerment. The study covers 91 countries.

This study introduces an innovative and comprehensive DRI for MENA countries. The contributions of the paper to the literature are (i) covering disaster prone countries which are mostly missing in Khan et al. (2022) study, (ii) incorporating the indicators to the index through a systematic examination of indicators in the existing literature, and augmenting the dataset outlined in Khan et al. (2022) by integrating relevant indicators that were previously omitted, (iii) integrating geospatial data on disaster risk from GIS into the DRI, (iv) adding the natural hazard risk index to the DRI, and (v) establishing a correlation between the DRI and economic losses, thereby revealing the efficacy and robustness of the newly developed DRI index developed in this study.

Among the highly cited papers in the area, Cutter et al. (2014) and Demiroz and Haase (2020) conduct a comprehensive literature review focusing on disaster resilience indices. Notably, the literature emphasizes the importance of fostering cross-disciplinary input and highlights the necessity for fields to mutually contribute to one another. This paper makes a distinctive contribution by introducing an engineering perspective into the realm of social sciences, thereby addressing this identified need for interdisciplinary engagement.

The plan of the study is as follows: Next section discusses the conceptual framework of the disaster resilience index. Section 3 presents the methodology and data, while Section 4 provides the results. Finally the last section concludes.

2 Conceptual Framework

The term disaster resilience is based on the work of Holling (1973). The concept of disaster resilience has multiple definitions in different disciplines in the literature and there is no single generally accepted definition (Klein et al., 2003; Manyena, 2006). Resilience, especially the concept of community resilience, has become a de facto framework for improving disaster preparedness, response and recovery at the community level in the short term and adaptation to climate change in the long term. Although there is no consensus on a precise definition of disaster resilience, there is a consensus view that disaster resilience improves a community's ability to prepare and plan for, absorb, recover from, and adapt more successfully to actual or potential adverse events in a given situation (Cutter et al., 2014).

Cutter et al. (2008) presented a comprehensive conceptual framework and theoretical background to improve deficiencies in existing vulnerability and resilience models on disaster resilience and establish foundations for measuring resilience, and developed a disaster resilience (DROP) model that integrates discipline-based literature. The DROP model, which presents resilience as a dynamic process depending on previous conditions, the severity of the disaster, the time between hazard events and the effects of external factors, is used as the theoretical basis of disaster resilience indices.

The empirical application of the DROP model, which was introduced as a theoretical model, was found in Cutter et al. (2010) study. The transition from conceptual framework to assessment is difficult due to the multifaceted nature of resilience, which includes physical, social, institutional, economic and ecological dimensions. The majority of evaluation techniques are quantitative and use selected indicators or variables as proxies because it is often difficult to measure resilience in absolute terms without any external reference to verify the calculations (Schneiderbauer and Ehrlich, 2006). Important criteria for indicator selection include validity, sensitivity, robustness, reproducibility, coverage, usability, affordability, simplicity, and appropriateness (Birkmann, 2006). Several criticisms of the quantitative indicator approach have been discussed by researchers, including subjectivity regarding variable selection and weighting, unavailability of certain variables, problems with aggregation at different scales, and difficulties in validating results (Luers et al., 2003). However, the usefulness of quantitative indicators in reducing complexity, measuring progress, mapping and setting priorities makes them an important tool for decision makers.

A composite indicator is a mathematical combination of individual variables or thematic clusters of variables that represent different dimensions of a concept and cannot be fully captured by any indicator alone (OECD, 2008). Composite indicators are increasingly recognized as useful tools for policy making and public communication because they carry information that can be used as performance measures (Saisana and Cartwright 2007). The literature on composite indicators is extensive and includes many methodological approaches for index construction and validation. Much of the literature emphasizes the need for an indicator construction process that requires a number of specific steps (Freudenberg 2003; OECD, 2008). The first step involves developing or applying a theoretical framework that will provide the basis for variable selection, weighting, and aggregation.

Cutter et al. (2010) developed the DROP model and presented the first empirical model, called BRIC, for the development of repeatable and robust key indicators to measure and monitor resilience to disasters. Thus, Cutter et al. (2010) study is leading in providing measurements that are easily understood, allow for comparison across regions, and can be applied to the decision-making process. Another useful outcome of the BRIC index is the visualization of the results, which provided a quick and comparative overview of where improvements in resilience key indicators were most needed. Cutter et al. (2014) expands the BRIC model to include a more comprehensive set of variables and a much larger and heterogeneous study area. Peacock et al. (2010) developed the CDRI model, which is based on the same theoretical framework.

3 Methodology and Analysis

There are two stages of the methodology: (i) A novel, systematic and comprehensive disaster resilience index is formed for MENA countries and (ii) The relation between the disaster resilience index and economic losses is visualized.

3.1 Forming Disaster Resilience Index (DRI)

3.1.1 Data

Following Sendai Framework, there is a growing literature on forming disaster resilience index. There are some studies forming DRI within a country such as Marzi et al. (2019) for Italy, Yoon et al. (2016) for Korea, Rifat & Liu (2020) for US and Wu et al. (2020) for China.

In recent years, there have been significant advancements in the field of disaster resilience research. To the nest of our knowledge, there is only one study proposing the implementation of a DRI for multiple countries. Khan et al. (2022) suggest a novel comprehensive disaster resilience index for 91 countries using panel data of 62 indicators for the period 1995-2019. The indicators used in the study captures economic stability, emergency workforce, agricultural development, human capital, digitalization, infrastructure, governance, social capital, and women empowerment.

This research assesses the existing literature to formulate a comprehensive Disaster Resistance Index (DRI) tailored for the countries of the MENA region. All dimensions previously outlined in Khan et al. (2022) have been integrated into the present study. Moreover, the dimensions[1] have been refined through the inclusion of additional explanatory variables that were utilized in other studies, constituting a distinctive contribution of this paper.

[1] The digitalization dimension identified in Khan et al. (2022) has been integrated with the infrastructure dimension.

Furthermore, this paper introduces two novel dimensions—incorporating geographical resilience and natural hazard risk—into the DRI framework, thereby augmenting its comprehensiveness. This strategic inclusion serves as an additional scholarly contribution. Geographical resilience is evaluated based on five indicators, and their values are determined through calculations within the Geographical Information System (GIS), with the assistance of ArcGIS. Illustrated in Figure 1 is an example involving the computation of distances from densely populated settlement areas to the nearest airports. This process involves two main steps: firstly, the calculation of Euclidean distances from each airport within a country; and secondly, the identification of the furthest settlement area from the airports using land cover images obtained from the Sentinel 2 satellite. The length of roads and railways are also determined using GIS.

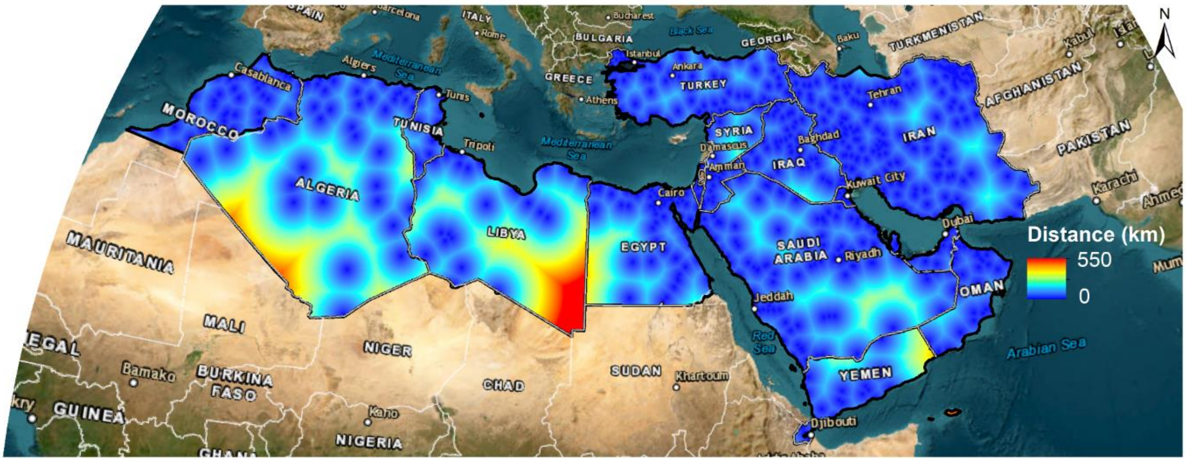

Figure 1. Euclidean distance from airports for each MENA country

Consequently, the DRI for MENA countries encompasses 10 dimensions and a total of 75 indicators. The specifics of the indicators under each dimension, including their units and sources, are detailed in Table 1. The data is the average of the period 2010-2022[2].

Table 1 Dimensions and indicators of DRI

Dimensions	Indicators	Explanation/Unit	Data Source
	Employment, total	% 15+ population	WDI (2023)
	Financial depth	%, ratio of broad money to GDP	WDI (2023)
	GDP per capita	constant 2015 US$	WDI (2023)
Economic Resilience	Total reserves per capita	%, include gold	WDI (2023)
	Trade	%, ratio to GDP	WDI (2023)
	Non-dependence on agriculture	Percent population not employed in agriculture	WDI (2023)
	Commercial bank branches	(per 100,000 adults)	GSD (2023)

[2] For the years with missing data interpolation methods are used. For the countries with missing data local resources or data from other international institutions are utilized.

Social Resilience	Civil society participation	0-1	GSD (2023)
	Power distributed by social group	0-1	GSD (2023)
	Power distributed by socio-economic position	0-1	GSD (2023)
	Social class equality in respect for civil liberties	0-1	GSD (2023)
	Social rights and equality	0-1	GSD (2023)
	Female	%, ratio to total population	WDI (2023)
	Transportation access	% Households with at least one vehicle	WHO (2023)
	Mental health support	Psychosocial support facilities per 10,000 persons	WHO (2023)
	Population under 15	%, ratio to total population	WDI (2023)
	Place attachment	Net international migration	WDI (2023)
Institutional Resilience	Control of Corruption	− 2.5 to 2.5	WGI (2023)
	Government Effectiveness	− 2.5 to 2.6	WGI (2023)
	Political Stability No Violence	− 2.5 to 2.7	WGI (2023)
	Regulatory Quality	− 2.5 to 2.8	WGI (2023)
	Rule of Law	− 2.5 to 2.9	WGI (2023)
	Voice and Accountability	− 2.5 to 2.10	WGI (2023)
	Freedom of expression	0-1	GSD (2023)
	Freedom of religion	0-1	GSD (2023)
	Media freedom	0-1	GSD (2023)
	Personal integrity and security	0-1	GSD (2023)
	Access to justice	0-1	GSD (2023)
	Basic welfare	0-1	GSD (2023)
	Civil liberties	0-1	GSD (2023)
	Engaged society	0-1	GSD (2023)
Infrastructure Resilience	Fixed broadband subscriptions	per 100 people	WDI (2023)
	Individuals using the internet	% of population	WDI (2023)
	Mobile cellular subscriptions	per 100 people	WDI (2023)
	Fixed telephone subscriptions	per 100 people	WDI (2023)
	Access to electricity	% of total	WDI (2023)
	Access to basic drinking water services	% of total	WDI (2023)
	Access to basic sanitation services	% of total	WDI (2023)
	Energy Index	%	RISE (2022)
Agriculture Resilience	Access to electricity, rural	% of rural population	WDI (2021)
	Agricultural land	% of land area	WDI (2021)
	Agriculture, forestry, & fishing, value added	% of GDP	WDI (2021)
	Cereal yield	kg per hectare	WDI (2021)
	Employment in agriculture	% of total employment	WDI (2021)
	Food production index	2014–2016 = 100	WDI (2021)
	Livestock production index	2014–2016 = 100	WDI (2021)
	Rural population	% of total population	WDI (2021)
	Rural population growth	annual %	WDI (2021)
Geographical Resilience	Total length of roads per sq. km.	per square km	OSM (2023)
	Total length of railways per sq. km.	per square km	OSM (2023)
	Distance from denser settlement areas to airport	km	OSM (2023)
	Number of dams	total dam number	OSM (2023)
	Mean elevation of the county	m	SRTM (2013)
Natural hazard risk	Natural hazard risk index	%	WRI (2022)
Emergency Workforce	Armed forces personnel	% of total labor force	WDI (2021)
	Domestic general govt. health expenditure	% of general govt. expenditure	WDI (2021)
	Hospital beds	per 1000 people	WDI (2021)
	Military expenditure	% of general govt. expenditure	WDI (2021)
	Nurses and midwives	per 1000 people	WDI (2021)
	Physicians	per 1000 people	WDI (2021)
Women Empowerment	Access to justice for women	0–1	GSD (2023)
	Employers, female	% of female employment	WDI (2023)
	Freedom of discussion for women	0–1	GSD (2023)
	Labor force, female	%, ratio to total labor force	WDI (2023)
	Seats held by women in national parliaments	%	WDI (2023)
	Self-employed, female	%, ratio to female employment	WDI (2023)

	Gender equality	0-1	GSD (2023)
	Labor force participation rate, female	%, ratio to female ages 15+	WDI (2023)
	Literacy rate, adult female	%, ratio to female ages 15+	
Human Capital	Employment	per 100 people	WDI (2023)
	Kilocalories per person per day	0-1	GSD (2023)
	Life expectancy at birth, total	years	WDI (2023)
	Literacy rate	%, ratio to population 15+	WDI (2023)
	Population ages 15-64	%, ratio to total population	WDI (2023)
	Human Development Index (HDI)	0-1	WDI (2023)
	Compulsory education, duration	years	WDI (2023)
	Government expenditure on education	%, ratio to government expenditure	RISE (2022)

3.1.2 Data Preprocessing

This research employed the IMF's index creation process as in Khan et al. (2022), which involves winsorization of the chosen variables, normalization of the winsorized variables, estimation of Principal Component Analysis (PCA) weights for the normalized variables, and the development of the disaster resilience index using the determined PCA weights (Svirydzenka, 2016).

Winsorization involves adjusting statistical data by limiting extreme values, effectively reducing the impact of potentially misleading outliers. In this study, the 5th and 95th percentiles are employed as cut-off values to exclude outliers.

The objective of normalization is to standardize features to a comparable scale. Opting for scaling within a specified range is a suitable approach when the rough upper and lower bounds of data, post-winsorization, are known, and the data is roughly uniformly distributed within that range. The normalization process utilizes the following equation:

$$x_{norm} = \frac{x - x_{min}}{x_{max} - x_{min}} \quad (1)$$

Compound indices simplify complex data by combining multiple variables into a single measure. Through the assignment of suitable weights, these indices accurately reflect the importance of each variable within the broader concept. To derive a compound index, the data is first normalized, and then PCA weights for each indicator are calculated. PCA is a statistical technique that identifies the fundamental factors or components influencing the variability in a dataset. Once the weights for each indicator are determined, the next step involves multiplying these weights by the corresponding values of the normalized indicators. The results for each indicator are then summed, yielding the final disaster risk index for each country. This process combines the weighted contributions of various indicators to provide a comprehensive assessment of disaster risk for each specific country.

3.2 The relation between the DRI and Economic Loss

Resilient communities have taken proactive measures to decrease their susceptibility to disasters and enhance their ability to adapt and respond to them, aiming to minimize the negative consequences and harm caused by such events. Therefore, an increase in disaster resilience would lead to a decrease in economic losses arising from disasters. The relation between disaster resilience index and economic loss is visualized using the scatter diagrams. Economic loss data for the period 2010-2023 is taken from the EM-DAT database.

4 Results and discussion

The DRI for MENA countries reveals a diverse spectrum of preparedness and resilience. The data is categorized into five distinct ranges of the Disaster Resilience Index, each associated with a specific level of resilience as indicated in Figure 2. Looking at the high end, some smaller countries like Malta, Israel, and Qatar showcase a high level of preparedness and resilience in the face of potential disasters. Larger countries like Saudi Arabia and Tunisia also have high DRI scores. On the other hand, Yemen, Djibouti, Iraq, Egypt and the Syrian Arab Republic appear to face significant challenges in terms of disaster resilience. A low score suggests a critical need for enhanced disaster preparedness, response, and recovery measures in the country. For many countries in the region, the DRIs fall within a moderate range, indicating a reasonably balanced approach to disaster resilience.

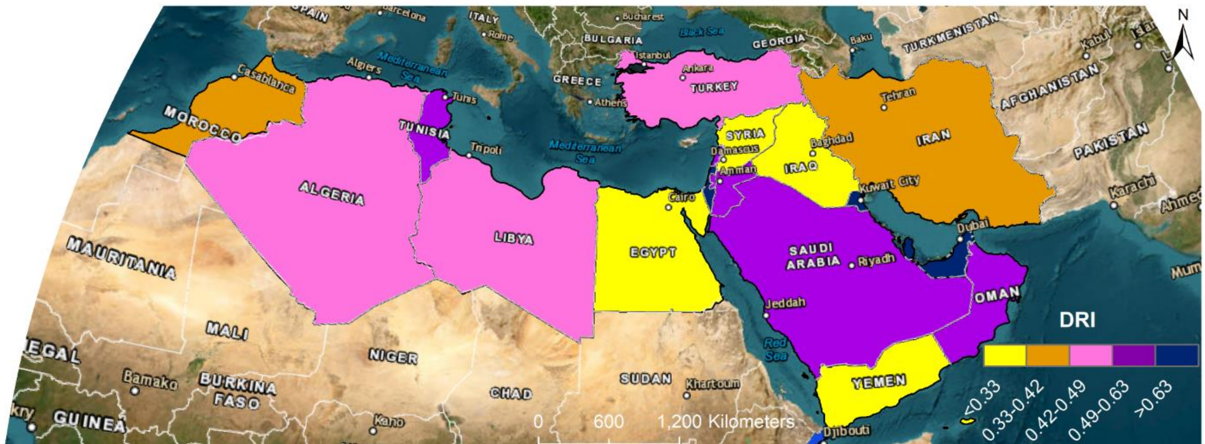

Figure 2 Disaster resilience index of MENA countries

There are differences between a previous study conducted to calculate DRI values for the world (Khan et al., 2022) and the present study. First of all, Khan et al. (2022) could not calculate the DRI values for many MENA countries due to the lack of data. Additionally, the data used in the present study is expanded mainly including geographic resilience and energy index. Finally, the DRI values calculated from this study are normalized. Accordingly, the DRI values calculated in the present study are different than the values in Khan et al. (2022).

Figure 3 illustrates the relationship between the DRI and the fatalities caused by natural hazards. The data, sourced from the EM-DAT database (2023), encompasses natural hazard events occurring between 2010 and 2022. The figure indicates a clear inverse correlation between the DRI and total deaths resulting from natural hazards. As the index increases, reflecting a higher level of resilience, there is a noticeable decrease in the number of fatalities, aligning with expectations. This observed inverse correlation serves as compelling evidence supporting the soundness of the methodology employed in the study.

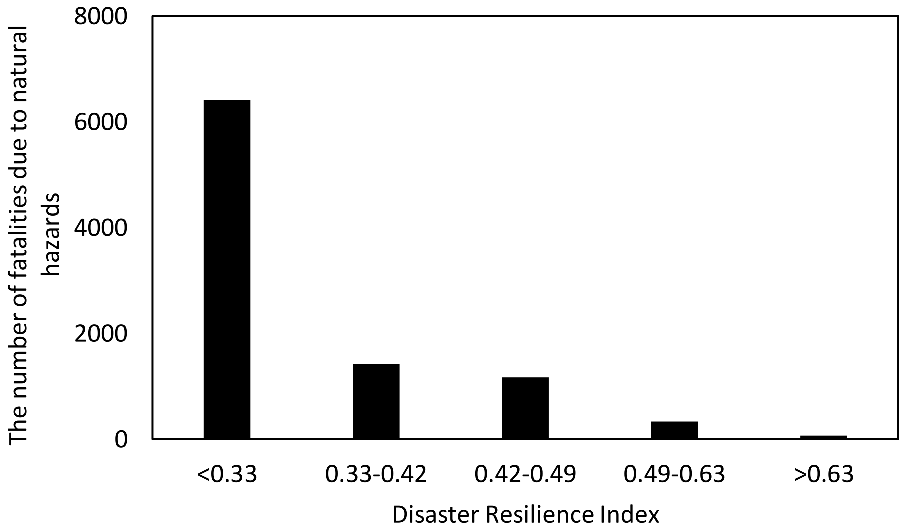

Figure 3 The effect of disaster resilience on the number of fatalities due to natural hazards

5 Conclusions and policy implications

This study introduces a novel and comprehensive DRI tailored specifically for the MENA countries, addressing a critical need for region-specific disaster preparedness and resilience assessment. The DRI incorporates 10 dimensions and 75 indicators, capturing economic, social, institutional, infrastructure, agricultural, geographical, natural hazard risk, emergency workforce, women empowerment, and human capital resilience. Notably, this index extends beyond existing frameworks by integrating geospatial data on disaster risk from GIS, adding the natural hazard risk index, and establishing a correlation between the DRI and economic losses.

The findings reveal a diverse landscape of disaster resilience in the MENA region, with some countries demonstrating high preparedness and resilience, while others face significant challenges. The classification of the DRI enables a detailed comprehension of the strengths and vulnerabilities of the region concerning its capacity to withstand and recover from disasters. The inclusion of novel dimensions such as geographical resilience and natural hazard risk provides a more holistic perspective for policymakers, practitioners, and researchers.

Furthermore, the study establishes a clear inverse correlation between the DRI and total deaths resulting from natural hazards. As the index increases, indicating a higher level of resilience, there is a discernible decrease in the number of fatalities. This correlation supports the efficacy and robustness of the DRI methodology, reinforcing the importance of comprehensive resilience assessment in minimizing the impact of natural disasters.

Policymakers in the MENA region can utilize the DRI to prioritize interventions and allocate resources effectively. Countries with lower DRI scores may benefit from targeted investments in disaster preparedness, response, and recovery mechanisms. Additionally, implementing policies aligned with the Sendai Framework for Disaster Risk Reduction and the Sustainable Development Goal 13 can further enhance disaster resilience and reduce associated losses.

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