Journal of Environmental Management 230 (2019) 345–354

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Countries' classification by environmental resilience

Sanaz Moghim*, Roja Kaveh Garna

Department of Civil Engineering, Sharif University of Technology, Azadi Avenue, Tehran, Iran

ARTICLE INFO

Keywords:
Resilience
Vulnerability
GHG emissions
Environmental risks
Natural and anthropogenic hazards

ABSTRACT

Rapid population growth, urbanization, and industrialization affect countries' vulnerability to future disasters. This study investigates the vulnerability of 141 countries to natural and anthropogenic hazards using six environmental indicators including air pollution, greenhouse gas (GHG) emissions, access to drinking water, access to improved sanitation, environmental risks (total death and affected people), and energy use. Results confirm that the resilience varies by the location. Furthermore, this work delineates the World countries using the environmental resilience score. The most resilient countries are located in Europe and North America and the least resilient countries are in Africa and Asia. Based on the results, Estonia and Ethiopia are the most and the least resilient countries, respectively. Integrated results can highlight resilient cities as a guide for other regions.

1. Introduction

Most countries have experienced different levels of natural and anthropogenic hazards. The severity level depends on different conditions such as location and topography of the region, dominant climate and weather pattern (hydroclimatology of the regions), and management plans that are applied. For instance, Iran has experienced different environmental degradation. Groundwater depletion in many regions in particular in Northeastern Iran caused land subsidence and saltwater intrusion. Most lakes in Iran are drying including Lake Urmia, the largest salt lake in the Middle East and the home of different species. Drying of the lake causes sand and dust storm around the lake and affects ecosystem functioning and human health. Dust storm over western Iran has disrupted people's lives. Ecosystem degradation such as coral reef bleaching has been occurring in Persian Gulf. Researchers, decision makers, and governments need principles and indicators to quantify environmental issues and corresponding damages, which is crucial for sustainable management plans in different sectors such as environment, economy, health, and society.

Chadha et al. (2007) stated that natural hazards lead to disasters if managers do not have any plan for disaster recovery and increasing resilience. The concept of resilience in natural hazards was initially defined as the substantial argument for the effect assessment of hazards. Mileti (1999) defined resilience "as the ability of a community to recover by its own resources". Resilience can be applied in different fields. The first application of resilience in ecological science was introduced by Holling (1973). Adger (1997) developed resilience in social systems. Moreover, resilience is applied in human-environment systems by Carpenter et al. (2001) and Folke (2006). Norris et al. (2008) characterized the community resilience as a procedure to connect various adaptabilities (e.g. social capital and financial development) to changes that happen after undesirable events such as drought or earthquakes. Blaikie et al. (1994) and Norris (2002) determined the key factors that influence resilience and vulnerability to environmental disasters including social classes, ethnicity, sexual orientation, age, and nationality. Borden et al. (2007) showed a pattern of vulnerability according to the geography over the United States, which confirms variability in vulnerability to natural disaster in different urban areas of the US.

Various forcings including natural and anthropogenic hazards influence most countries all over the world. Poor communities are more vulnerable to those forcing such as climate change and the vulnerability additionally increases with improper management policies (Baker, 2012; Huq et al., 2007). For instance, just one percent of family units in "Naopara" (an Indian town) being secured by the metropolitan water supply. Indeed, fundamental services such as safe water and sanitation are their vital needs (Alam et al., 2016). The security of the water is threatened by human ignorance, wrong policy, widespread development, rapid growth of population, and anthropogenic and natural hazards, which demonstrate the need of having sustainable activities and management plans. Parvin et al. (2013) considered important factors like social deprivation, economic disparity, and power to enhance the water and its frameworks' resilience for big cities.

The criteria for the concept of sustainability are different in various divisions. Thus, different strategies are developed to recognize and measure sustainability. For instance, market analysts usually focus on

* Corresponding author.
E-mail addresses: moghim@sharif.edu (S. Moghim), Rojakaveh@alum.sharif.edu (R.K. Garna).

https://doi.org/10.1016/j.jenvman.2018.09.090
Received 25 April 2018; Received in revised form 27 August 2018; Accepted 25 September 2018

financial and social criteria in sustainable development and environmentalists generally underline the environmental sustainability. In order to assess the vulnerability of the countries to natural and anthropogenic drivers, many studies characterized different indices. The indices can be used as a tool to compare the environmental performance of different countries. Development growth in the 90's led to the new analysis of countries' sustainable development indices. For instance, the global action on Environment and Development (Agenda 21) towards institutional sustainability mainly focused on an integrated management of action, which is taken nationally and locally by associations of the United Nations, Governments, and Major Groups in the main fields that influence changes in the World. The "Commission on Sustainable Development" accentuated application of characterized indices for assessment of sustainable development (Spangenberg et al., 2002). To consider multiple factors, different indicators can be combined to create composite indicators. Composite indicators are valuable tools for policy-making processes and can represent the applicable measures (Saisana and Cartwright, 2007).

The most prevalent combined indicators are Environmental Sustainability Index (ESI), Human Development Index (HDI), Social Progress Index (SPI), and Environmental Performance Indicators (EPI). The Environmental Sustainability Index (ESI), introduced in 2002, is a measure that shows the total progress towards environmental sustainability. The index gives a composite profile of national ecological stewardship in light of an aggregation of indicators obtained from fundamental datasets (Index, 2005). Human Development Index (HDI) is defined as a measure of three elements including (1) knowledge, (2) health and life span, (3) decent standard of living. HDI is calculated as the geometric mean of normalized indices for those factors (UNDP, 2016). The Social Progress Index (SPI) is able to evaluate a country performance in various facets of environmental and social impacts that are related to all levels of the country economic growth (Porter et al., 2014). Another indicator called Environmental Performance Index (EPI) is based on ranking 180 countries according to nine environmental issues including preservation of human health and improving ecosystem vitality. The main purpose of this index is moving from environmental discussions to action (Hsu and Zomer, 2016).

Resilience is the ability of a system to remain stable. In other words, the function, structure, and identity of the resilient system do not change when it undergoes severe dangers (Walker et al., 2004). The 2015 FM Global Resilience Index (Global and Metrica, 2015) characterized resilience as a combination of the vulnerability of a country to disturbance and its capacity to recover from such disturbance. The index distinguishes four key factors including political risk, the quality of the infrastructure, exposure to natural hazard, and commitment to risk management. These factors consider three wide fields (e.g. economic, risk quality, and supply chain), which can be combined to frame an index. The combined index ranked 130 countries and regions around the world.

Arcadis, a global network, engineering, and management counseling organization, introduced another sustainable city index in 2016. Arcadis confirmed that a proper approach to understand the sustainability of a city is to incorporate different perspectives of people, profit, and ecosystem to shape a broad view of each city. This approach can help to define a sustainable region. Arcadis considered many urban communities in Europe as the resilient regions (e.g. Vejle in Denmark and Rotterdam in Netherlands) and categorized them based on their urban economy, condition, and essential elements of well-being. Grosvenor is another property organization that characterized vulnerability and resilience using 5 factors including climate, environmental capacity, resource capacity, infrastructure, and community.

This study intends to define a resilience score using different environmental issues (natural and anthropogenic factors) such as air pollution, GHG emissions, access to drinking water, access to improved sanitation, environmental risks (total death and affected people), and energy use that is illustrated in Fig. 1. The overall environmental resilient score can show the ability of the country to recover from a crisis and to adapt to a new environment. Furthermore, this score can illustrate the geographical pattern of environmental resilience.

2. Materials

This study uses six groups of datasets related to environmental issues including air pollution, GHG emissions, access to drinking water, access to improved sanitation, environmental risks (total death and affected people), and energy use. These groups construct indicators that can be combined to form a composite resilience score. Table 1 summarizes the indicators used in the analysis.

2.1. Environmental risk

Risk can be defined as the probability of damage or any negative impact posed by internal or external adverse events that threaten individuals, community, and ecosystem. Note that in this study, environmental risk includes the impact of the disasters such as drought, earthquake, flood, extreme temperature, and landslide on the countries. The impacts include total death and total affected people from 1900 to 2016 considering the frequency of different disasters (data are publicly available at http://www.emdat.be/).

2.2. Energy

Total amount of energy that is used by people around the world is called world energy consumption. It includes all energy sources in industrial and technological sector for each year. World energy consumption has a significant impact on the country's financial-political circle. Energy use intensity is one of the most proper measures to determine energy use index. This index can be obtained by dividing unit of energy per unit of gross domestic product (GDP). The data are available from 1990 to 2016 (https://yearbook.enerdata.net/).

2.3. Air pollution

Air pollutant is visible or invisible substances in the atmosphere that has undesirable impacts on people and ecosystem. It can be in form of solid, liquid, or gas. Pollutants can be produced naturally or by human in the ecosystem. In fact anthropogenic activities can significantly increase pollution. Pollutants are categorized in two distinctive groups including primary and secondary pollutants. Primary pollutants are generally originated from a natural process, such as slag from eruption of a volcano, carbon monoxide gas released from motor vehicle or the sulfur dioxide discharged from industrial activities. Secondary pollutants are produced indirectly. They can be created in the atmosphere when primary pollutants have reaction or interaction. For instance, ground level ozone can be considered as the secondary pollutants. Note that some pollutants can be released directly in the air and also formed from the primary pollutants so they are considered in both groups (e.g. nitrogen dioxide NO2).

World Health Organization (WHO) defined air quality standards and limits on air pollution. Over 80 percent of people who live in urban areas breathe the air that not only approaches these limits but also exceeds them (WHO, 2018). About 98 percent of urban areas in the low- and middle-income countries with the population of more than 100,000 do not meet WHO's air quality rules while in high-income countries this percent decreases to 56 percent (Vidal, 2016). Air pollution data are available from 1990 to 2013 (WHO, 2017a).

2.4. Greenhouse gas

Greenhouse gas (GHG) is a gas that allows downward shortwave radiation to reach the surface. On the other hand, GHG is able to absorb infrared radiation and emit heat in all directions. These features cause