Research Paper
Climate Change and DRM Laws Analysis in Developed Countries Based on the SES Framework

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A B S T R A C T

Background: Climate change often leads to more frequent and intense disasters, such as floods, storms, and droughts, directly affecting people's health. It is crucial to address the laws related to climate change and disaster risk management (DRM). This study aims to analyze the climate change and DRM laws in developed countries based on the social-ecological systems (SES) framework.

Materials and Methods: This is a mixed-method study. We first classified developed countries based on the human development index (HDI). Next, the laws related to climate change in these countries were extracted from the climate change laws of the world (CCLW) database. Finally, the qualitative approach (examining, classifying, and analyzing the related documents based on Ostrom's SES framework) and the quantitative approach (time-series and spatial analyses based on the SESs and their subsystems) were combined to conduct the study.

Results: The developed countries have passed 40% of all DRM laws in the world. The time-series analysis showed that most laws had been passed in the last 30 years. Additionally, water, transportation, and economy-wide subsystems were considered first in these laws. The spatial analysis indicated that the European countries and South Korea had passed the most laws.

Conclusion: The DRM laws in the early years primarily focused on emergency aid and the costs of natural disasters. Over time, the laws included more goals, such as planning and establishing systems, reconstruction funds, and prevention systems. The continuity of DRM laws and targets can result in better decision-making and more effective measures to tackle climate change.

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Introduction

The emission of greenhouse gases and the phenomenon of climate change have caused an increase in the frequency and/or intensity, spatial extent, duration, and timing of some weather and climate extremes such as heat waves, heavy rainfall, storms, and droughts in many parts of the world and can result in unprecedented extremes. These events, even if not extreme statistically, can still lead to extreme conditions or impacts by crossing a critical threshold in a social, ecological, or physical system or by occurring simultaneously with other events [1-3]. The frequency of natural hazards has more than doubled due to climate and weather hazards such as floods, tropical storms, and droughts. According to the UN-Water, 90% of natural hazards are water-related [4]. In 2023, there were 240 such climate-related events, and the international disaster database EM-DAT estimated a 60% increase in the number of deaths from landslides, a 278% increase in wildfires, and a 340% increase in storms [5]. The event with the highest per capita cost in 2023 was the wildfire in Hawaii which costed $4,161 per person [6]. Climate change and its consequences have wide-ranging effects on various sectors. This phenomenon can affect health, housing, safety, food, and human activity, posing a fundamental threat to human health. It also affects the physical environment and natural and human systems, including social and economic conditions and the functioning of health systems [7, 8]. Extreme heat is one of the deadliest weather-related events. As ocean temperatures rise, the storms become more intense, leading to direct and indirect deaths. Droughts cause more wildfires, resulting in significant health risks, while more frequent flooding can lead to the spread of water-borne diseases, injuries, and chemical hazards. The expansion of the geographic range of mosquitoes and ticks can also introduce various diseases to new locations [9].

The observed climate impacts on the health sector can be categorized as follows: a) Direct impacts from increased frequency and severity of extreme weather events, such as heat, which can lead to physical injury, death, and mental health problems; b) Ecosystem mediated impacts such as air pollution, temperature shift, or precipitation patterns that can alter the prevalence and distribution of waterborne or foodborne diseases and/or affect nutrition-related health outcomes; c) Socially mediated effects, which occur through impacts on social and human systems such as increased poverty, migration, or conflicts [10]. According to the Intergovernmental Panel on Climate Change (IPCC) report, more

than three billion people live in areas highly vulnerable to climate change. Many are already experiencing the effects of climate change on health, and these effects will worsen without immediate action [11]. The World Health Organization (WHO) estimated that, from 2030 to 2050, climate change will cause 250,000 deaths due to malnutrition, malaria, diarrhea and heat stress. Furthermore, the direct damage costs to the health sector will reach US$ 4 billion per year by 2030 [7].

Natural disasters and the related fatalities, damages, and losses are often caused by poor decisions and actions that exacerbate these risks and make communities more vulnerable to their impacts; therefore, better integration between environmental, developmental, and humanitarian A is needed to enable effective prevention, response, and recovery [12]. Efforts to address climate change through institutions, rules, and procedures began at the Rio Earth Summit in 1992. Subsequently, the United Nations Framework Convention on Climate Change (UNFCCC) was established with the primary goal of promoting international action to stabilize greenhouse gas emissions. The establishment of parties to the UNFCCC also led to the 2015 Paris agreement [13]. Countries worldwide have taken actions to deal with climate change at the domestic level, as well as through negotiation and international agreements. The Sabin Center for Climate Change Law and the Grantham Research Institute on Climate Change and the Environment have collaborated to create an online database of laws, regulations, policy statements, and other directives issued by national governments called the Climate Change Laws of the World (CCLW) database. The primary goals of these laws are to deal with climate change and take action to help governments respond to climate change. The number of climate change laws is rapidly increasing, covering various scopes such as adaptation, mitigation, disaster risk management (DRM), and loss and damage, as well as different sectors such as energy, building, waste, health, etc. [13, 14].

When climate change is a phenomenon that directly overshadows natural disasters and, consequently, people's health, it is crucial to analyze the laws related to DRM. All regions of the world contribute to climate change, but developed countries are major contributors to greenhouse gas emissions due to their high energy consumption [15]. For instance, the USA, Canada, Japan, and most Western European countries, which make up only 12% of the world's population, have been responsible for 50% of greenhouse gas emissions from fossil fuels and industry over the past 170 years [16]. However, they have the capacity to adapt and have more tools and technologies to deal with climate change; therefore, studying their experiences can help identify

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effective methods and technical knowledge in dealing with climate change. This research aims to review the DRM laws related to climate change in developed countries using the CCLW database. These laws are categorized based on three components of the social-ecological system (SES) framework: Resource systems (RS), actors (A), and governance systems (GS), as well as their subsystems. The study considered time and spatial trends, as well as the importance of each subsystem for each other.

Materials and Methods

This is a mixed-method study using a combination of qualitative and quantitative methods. In the qualitative phase, existing written documents were reviewed and classified based on the SES framework. The quantitative phase included time series analysis and legislation trends in the investigated sectors (subsystems) and systems. Quantitative and qualitative analyses were combined as follows:

Time and spatial analysis of the DRM laws related to climate change;

Time and spatial analysis of the DRM laws related to climate change in the SESs;

Time and spatial analysis of the DRM laws related to climate change in RS, A, and GS

Classification of countries based on development

The human development index (HDI) was introduced by the United Nations development programme (UNDP) in 1990 [17, 18]. It is the most widely recognized measure of human development, encompassing economics, education, and human health components [19, 20]. The HDI values range from 0 to 1; the values ≥0.8 indicate higher development [21]. Therefore, countries with an HDI of 0.8 or above can be classified as developed countries. Table 1 presents the HDI of developed countries as well as the number of DRM laws related to climate change.

Quantitative analysis based on the time-series analysis

We used the time-series analysis to study the climate change laws under the scope of DRM. All relevant laws were extracted from the CCLW database. Initially, the time series of laws for 21 developed countries were obtained and listed in Table 1 to assess their contribution to global climate change legislation. Then, these laws were categorized based on three SES framework components of RS, A, and GS according to Ostrom's proposed conceptual framework. The regulation process was then analyzed based on these systems and their subsystems. We conducted our analysis based on the available documents outlining countries' climate policies.

Table 1. The HDI of developed countries and the number of DRM laws related to climate change [23, 24]

Country	HDI	Number of Laws	Country	HDI	Number of Laws
Argentina	0.842	3	Norway	0.961	3
Chile	0.855	1	Portugal	0.866	2
Uruguay	0.809	1	Spain	0.905	1
USA	0.921	4	Switzerland	0.962	1
Belarus	0.808	1	Turkey	0.838	4
Bulgaria	0.800	1	UK	0.929	1
Czech Republic	0.889	1	Japan	0.925	4
Hungary	0.846	3	Kazakhstan	0.811	3
Iceland	0.959	1	South Korea	0.925	7
Italy	0.895	1	Mauritius	0.802	2
Netherlands	0.941	1			

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Qualitative analysis based on the SES framework

Ostrom's SES framework is widely used to diagnose SESs. It was designed to conduct institutional analyses of natural RS and identify collective action challenges. The framework's first tier includes social and ecological factors, external factors, and system interactions and outcomes, each of which is further divided into several variables in the second tier [22]. In this study, due to the fact that there is an international perspective and the research boundary is not a clear geographical boundary, the laws were not divided into endogenous and exogenous groups; we only considered the endogenous factors including RS, A, and GS, and their subsystems. The RS subsystems included land use, land-use change and forestry (LULUCF), coastal zones, cross-cutting areas, environment, waste, and water. The subsystems of the A component included energy, building, transportation, industry, agriculture, health, and tourism. The GS subsystems included economy-wide, public sector, finance, rural, urban, and social development.

Results

Time and spatial analysis of the DRM laws related to climate change

Analysis showed that, out of 928 passed laws, 116(13%) were dedicated to the DRM. Of these, 46 laws (40%) had been passed in developed countries. The first DRM law was passed in 1947 in Japan under the title "disaster relief act (law No. 108)". The analysis reveals that 85% of the laws related to DRM had been passed in the last 30 years, with only 7 laws in place by 1990. Throughout the 1990s, 10 laws were passed. This number increased to 11 in the 2000s and 12 in the 2010s (Figure 1). In recent years, 6 DRM laws have been passed. In terms of spatial distribution, 21 developed countries had passed the laws for DRM, four countries in America, 13 in Europe, three in Asia, and one in Africa (Figure 1). South Korea had the most passed laws (n=7), followed by the USA, Turkey, and Japan (each with 4 laws), and Hungary, Argentina, Norway, and Uzbekistan (each with 3 laws). It should be noted that the laws passed by Uruguay, Belarus, the Czech Republic, Iceland, Italy, Spain, and Japan were not considered in the subsequent analysis as they were not based on the SESs and their subsystems.

Time and spatial analysis of the DRM laws related to climate change in SESs

As shown in Figure 2 and based on the time-series analysis, legislation in the RS began in 1972 with the Federal water pollution control act (clean water act) in the USA. Legislation in the GS started in 1988 with the Stafford disaster relief and emergency assistance act in the USA. For the A system, legislation began in 1990 with the Act on the prevention of and countermeasures against agricultural and fishery disasters in South Korea. Most laws in all three SESs were passed since 2000, with the peak of the increase in the last decade. In terms of spatial analysis, 23 laws were found in the A system, 20 in the GS, and 17 in the RS. Europe had the highest number of laws (n=31), followed by America and Asia (each with 13 laws), and Africa (n=3). The countries with the highest contributions were Turkey (n=14), South Korea (n=11), and the USA (n=9).

Time and spatial analysis of the DRM laws related to climate change in RS

Based on the number of DRM laws in developed countries, the RS included the following subsystems: water (n=10), LULUCF (n=4), and environment (n=4). According to Figure 3, the first law in the RS was passed for the water subsystem in 1972. For the other two subsystems, the laws were passed for the first time in 1993. The spatial analysis revealed that nine countries had passed 10 laws for the RS, with the LULCF subsystem receiving the most laws compared to the other two subsystems. European countries (n=9), and the USA, South Korea, and Switzerland (each with 3 mentions) had the highest contribution to passing laws for the RS.

Time and spatial analysis of the DRM laws related to climate change in the A system

Based on the number of DRM laws in developed countries, the A system included the following subsystems: agriculture (n=7), energy (n=6), transportation (n=5), building and industry (each with 2 mentions), and health (n=1). According to Figure 4, the first law in this system was passed for agriculture in 1990. In terms of other subsystems, the first law for transportation was passed in 1993, for energy in 2005, for industry in 2009, for building in 2012, and for health in 2019. The spatial analysis showed that European countries with 11 laws and South Korea with 8 laws had the highest contribution to passing laws for the A system.
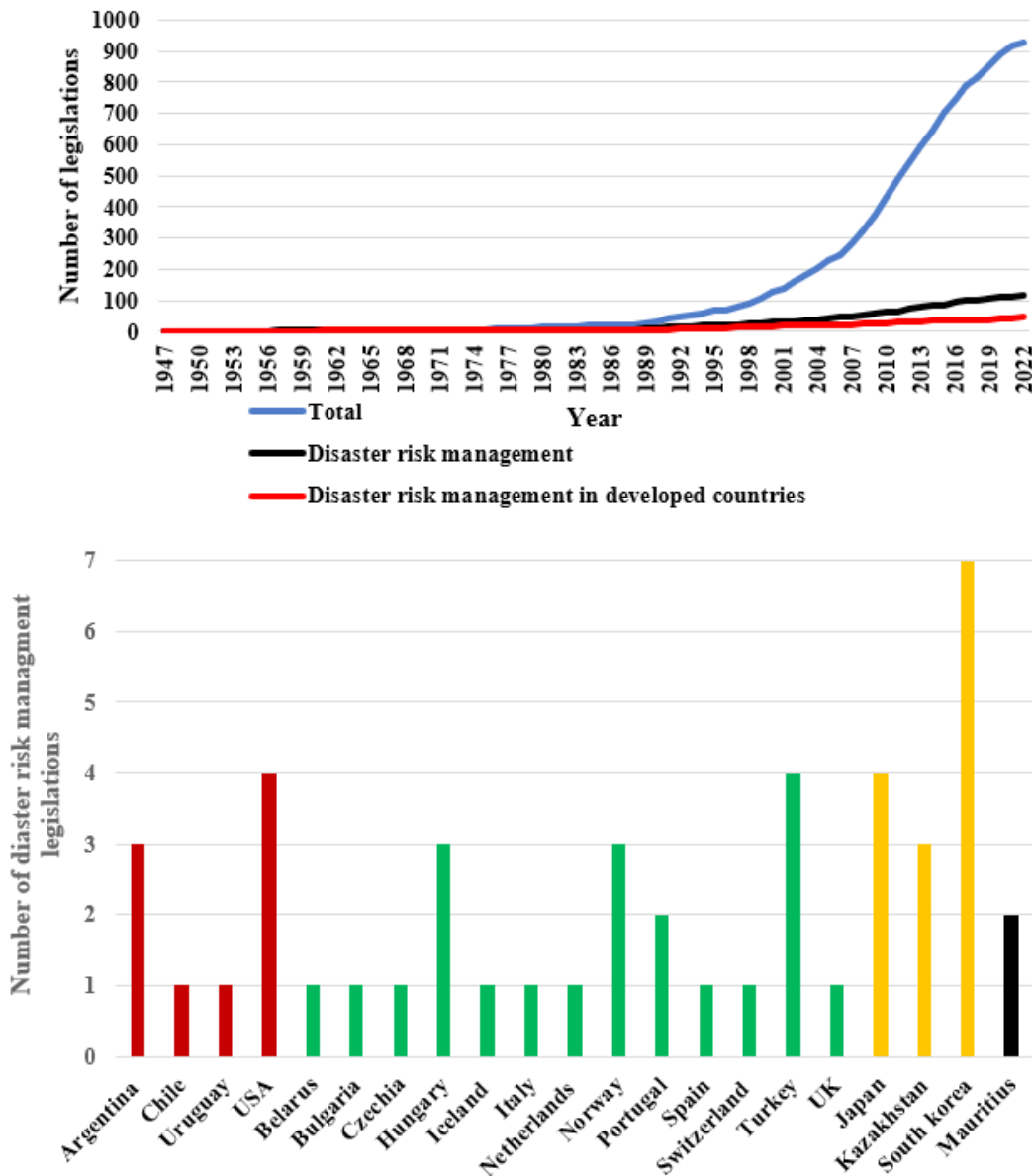
Figure 1. Time and spatial analysis of the DRM laws related to climate change

Time and spatial analysis of the DRM laws related to climate change in GS

Based on the number of DRM laws in developed countries, The GS included the following subsystems: Economy-wide and social development (each with 7 laws), finance and urban (each with 2 laws), and rural and public sectors (each with one law). According to Figure 5, the first law in GS was passed for the economy-wide subsystem in 1988, for the social development sector in 1996, for the urban sector in 2001, for the finance and rural sectors in 2019, and for the public sector in 2020. The spatial analysis showed that 9 countries had passed laws in this system. European countries (n=11) and Turkey (n=8) had the highest contribution to passing laws for the GS.

Efforts to address climate change involve establishing targets, macro policies, and legislation at national and international levels. This leads to the implementation and effectiveness of programs, solutions, and measures. By examining the continuity of these institutional arrangements, better decisions can be made, and more effective actions can be taken to address climate change. The continuity of institutional arrangements includes continuity between legislations and targets, policies,
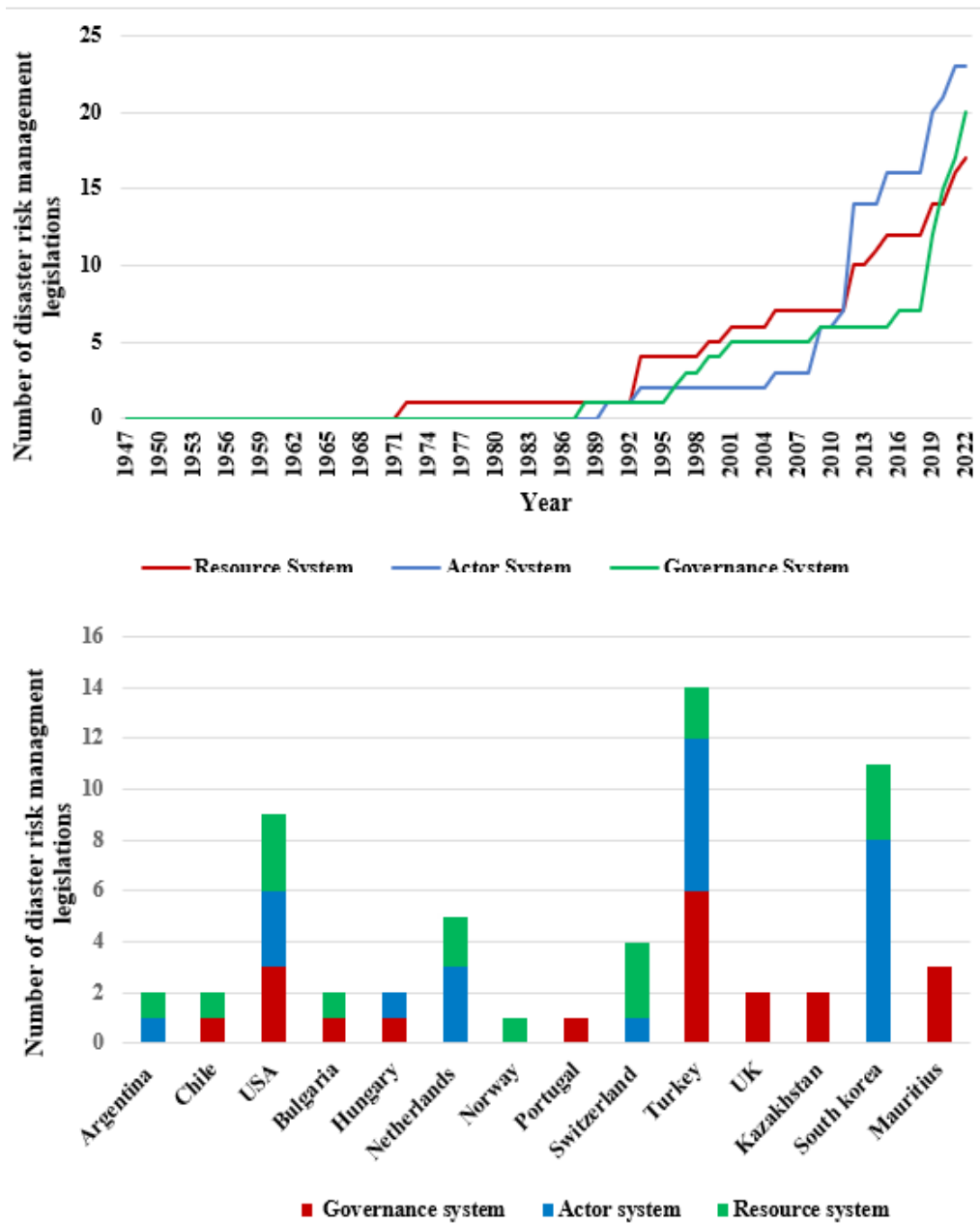
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Figure 2. Time and spatial analysis of the DRM laws related to climate change in SESs

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and targets. Turkey demonstrated this continuity in the 11th national development plan (2019-2023) approved in 2019, with the disaster management targets of "number of houses and workplaces with compulsory earthquake insurance" (from 8.9 Million in 2018 to 12.1 Million in 2023), "number of provinces where disaster reduction plans will be prepared" (from zero in 2018 to 81 in 2023), and "number of provinces included in digital radio system"(from 1 in 2018 to 81 in 2023)

Discussion

Climate change and its consequences have had direct and indirect negative impacts on human health. In such a situation, governments seek to address climate change and its consequences, including natural hazards and disasters and the risks they pose. Legislation related to climate change is an important effort in this field, covering various scopes, including DRM. This research analyzed the DRM laws related to climate change in developed countries. The countries were initially classified based
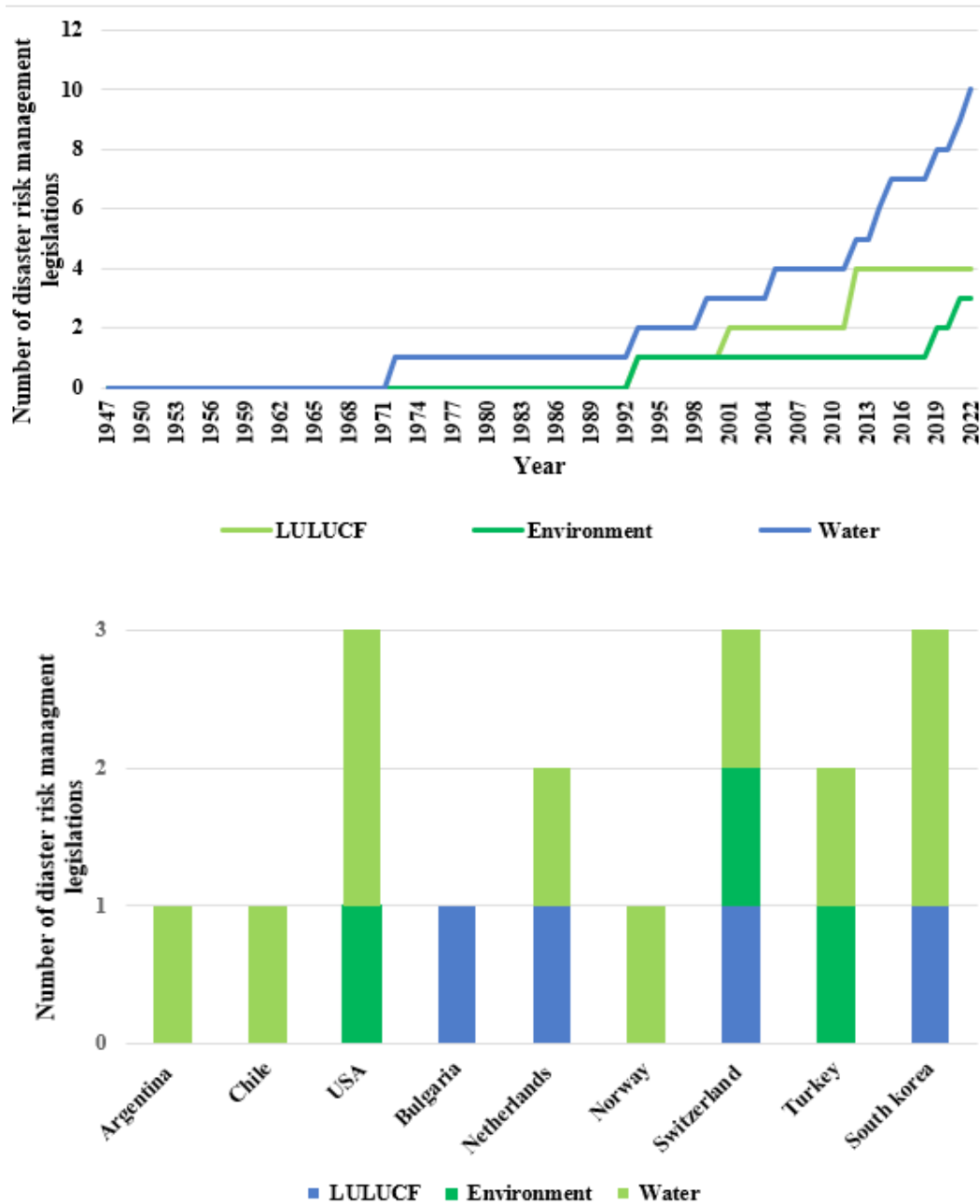
Figure 3. Time and spatial analysis of the DRM laws related to climate change in RS

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on development using the HDI. The DRM laws were then extracted from the CCLW database, and their time and spatial trends were analyzed quantitatively and qualitatively based on the SESs of RS, A, and GS and with their subsystems.

The results indicated that 21 developed countries, including Argentina, Chile, Uruguay, USA, Belarus, Bulgaria, Czech Republic, Hungary, Iceland, Italy, Netherlands, Norway, Portugal, Spain, Switzerland, Turkey, UK, Japan, Kazakhstan, South Korea, and Mauritius, have passed a total of 46 DRM laws. It was found that in seven countries (Uruguay, Belarus, Czech Republic, Iceland, Italy, Spain, and Japan), there were no defined laws based on SESs and their subsystems. Therefore, these countries were not considered in further analysis. The DRM laws related to climate change in remaining countries included issues such as natural disaster relief, emergency aid, related costs and measures, natural damage insurance, and assistance to farmers against agricultural
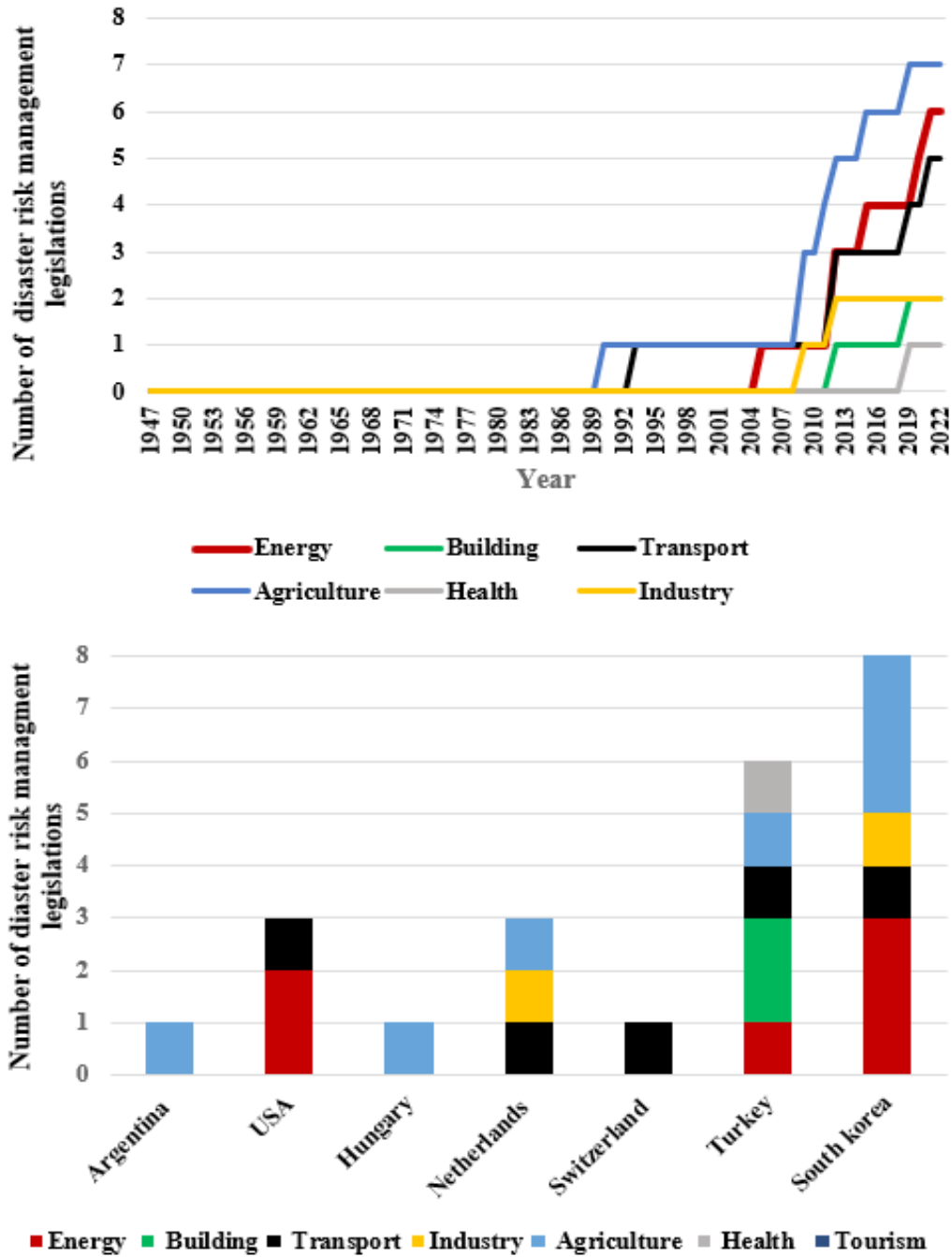
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Figure 4. Time and spatial analysis of the DRM laws related to climate change in the A system

disasters before 1990. Over time, with the rise in awareness of the importance of addressing climate change, legislation evolved to include more comprehensive goals and various aspects. This led to the establishment of a commission for monitoring natural disasters, a fund for farm reconstruction and development, an integrated rescue system, a national system for comprehensive risk management and civil protection, disaster and safety management, spatial planning, civil protection, a national system for the prevention and mitigation of agricultural emergencies and disasters, a disaster and emergency management authority, reorganization of areas at risk of
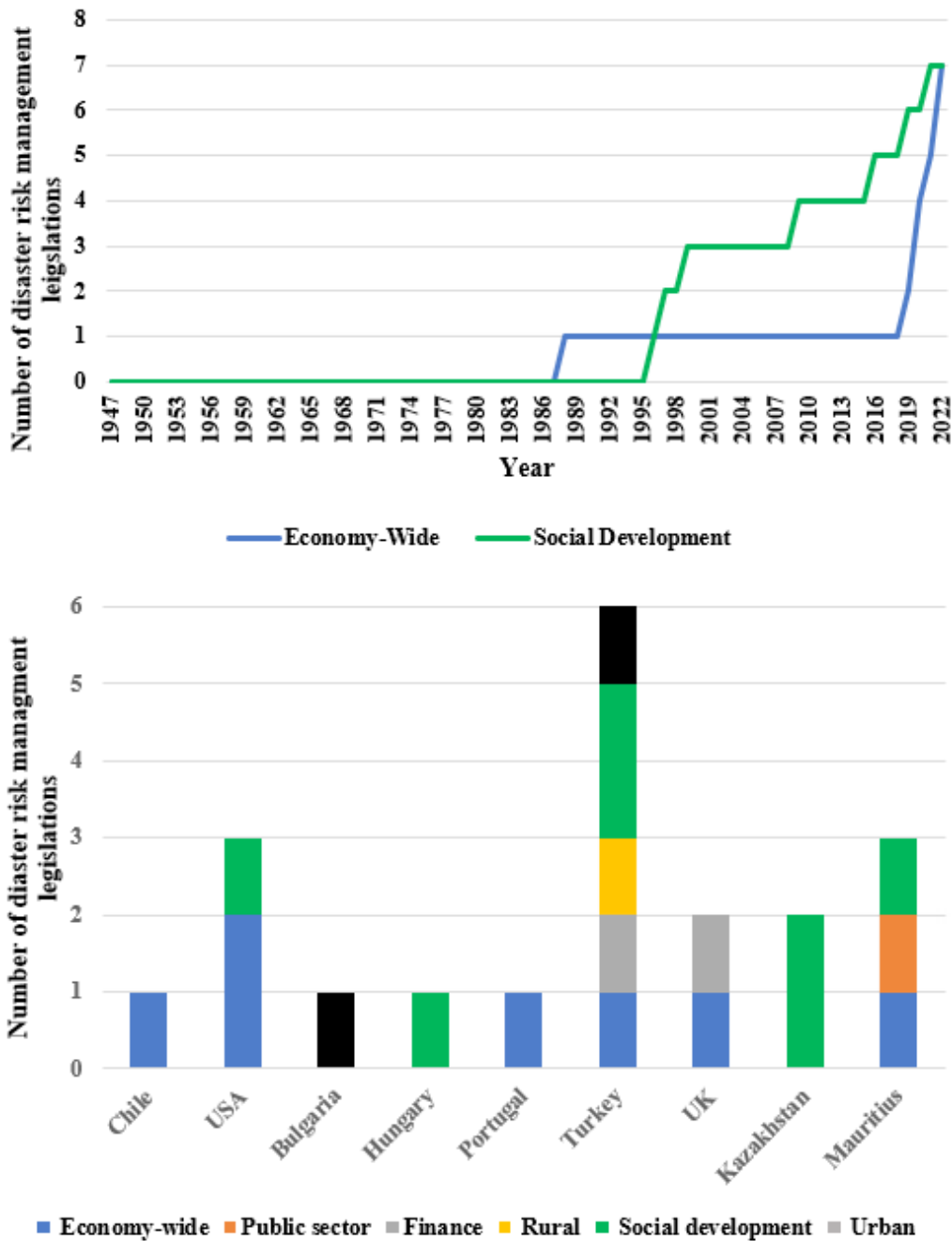
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Figure 5. Time and spatial analysis of the DRM laws related to climate change in GS

natural disasters, a national disaster risk reduction and management act, a basic act for national resilience, etc. Health is an important sector. It has received significant attention in recent years and was specifically mentioned in Turkey's 11th national development plan (2019-2023). More countries are expected to pass laws for this sector in the coming years.

Conclusion

Developed countries contribute to about 13% of all laws related to climate change, of which 40% is related to DRM. Japan passed the first legislation in this field in 1947. Based on the continental classification, the highest number of laws belong to Europe. Based on the SESs, the laws have been passed first in the RS and then in the

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GS and A systems. Most laws belong to the A systems, followed by GS and RS. European countries and Turkey have the highest number of laws. In addition, Europe has passed more laws for all three SESs. The USA, Switzerland, and South Korea had the highest laws for the RS; South Korea had the highest laws for the A systems; and Turkey had the highest laws for the GS.

The continuity of laws and targets can lead to better decisions and more effective actions to address climate change. The DRM laws have included more comprehensive goals over time. In several countries, the health sector has been mentioned more in the laws, indicating its increasing importance, which is expected to be included in more laws in the future.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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