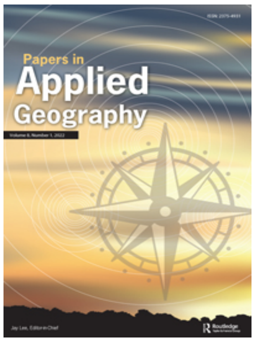

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Natural Disaster Risk Inequalities in Central America

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ABSTRACT

Central America is affected by geological and hydrometeorological hazards that, together with its high exposure and vulnerability, comprise risky scenarios for disasters. This region presents a significant number of casualties and economic losses due to disasters every year. We present an analysis of the origin of extensive risks (high-frequency-low-magnitude hazards occurrences) and intensive (low-frequency-high magnitude hazard occurrences) in Central America from 1990 to 2015 using the disaster databases EM-DAT and DesInventar. Findings reveal that Costa Rica reported the greatest number of both intensive and extensive risks (disaster occurrences) whereas El Salvador, Guatemala, and Honduras experienced the highest number of casualties in terms of injuries and lost, as well as highest number of damaged or destroyed houses by extensive and intensive risks. Disaster databases, like the ones employed in this research, provide useful data for risk assessment, land use planning, and risk management in developing countries. This study stresses the need for exhaustive risk assessment at the local, regional, and national scales.

KEYWORDS

Disaster risk reduction; DesInventar; developing countries; EM-DAT; extensive risks; intensive risks; natural risks; natural hazards; risk assessment

Introduction

Natural hazards exist worldwide; nonetheless, their impact in developing countries is greater due to their limitations in resources for disaster management and programs toward resilience (Alcántara-Ayala 2002). The countries of Central America are located to the south of Mexico and the north of Colombia, as well as bordering the Pacific Ocean to the west and the Caribbean Sea to the east. Depending on their relative location to one of the five major tectonic plates in this region (Cocos, Nazca, North America, Caribbean, and Panama), the countries of Central America experience distinct significant seismic and volcanic activity (Alvarado et al. 2017). Moreover, the climatic conditions in Central America are influenced by major meteorological movements such as the Intertropical Convergence, El Niño-Southern Oscillation (ENSO), tropical cyclones, and cold fronts (Durán-Quesada et al. 2020). These conditions affect the climatic and geomorphic dynamics of Central America's mountains, valleys, and alluvial plains. The population of Central America has important human exposure and vulnerability triggers for disasters due to their land use changes (Alcántara-Ayala 2010; Shi et al. 2016). This geo-climatic framework controls that in general, the region is primarily affected by landslides (Sepúlveda and Petley 2015; Quesada-Román et al. 2018) and floods (Shi and Karsperson 2015; Guevara-Murua et al. 2018).

Over the last two decades, both geological and hydrometeorological disasters in Central America have shown an increasing trend, particularly in recent years with the occurrence of

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earthquakes, volcanic eruptions, and hurricanes. The Central American Integration System (SICA by its initials in Spanish) reported that disasters reduced Gross Domestic Product (GDP; on average, approximately 1.7 percent for each country (CEPREDENAC-SICA 2017). Moreover, the lack of territorial management policies has resulted in significant urban sprawl across cities in the region (Sepúlveda and Petley 2015; Shi and Karsperson 2015). Commonly, these urban spaces are characterized by scattered, low-density, or single-use development and poor accessibility to open spaces, resulting from unplanned growth (Koprowska, Łaszkiewicz, and Kronenberg 2020; Vargas-Bolaños et al. 2020). Overall, these physical and human conditions contribute to a significantly higher level of risk for the population of Central America in term of major loss of lives, livelihoods, homes, and critical infrastructure.

Two disaster databases, EM-DAT and DesInventar, play a key role in disaster risk reduction policy actions at all levels/scales (global, national, and local). The DesInventar dataset is particularly useful because it contains a larger number of records than the EM-DAT (Panwar and Sen 2020). In addition, the accumulated effects of small and moderate events reported in DesInventar may be comparable to the impacts of major disasters (Marulanda, Cardona, and Barbat 2010; Fraser et al. 2020). This research focuses on extensive and intensive risks, where "risks" refer to hazard/disaster occurrences. We hypothesize that levels of extensive and intensive risk have a dissimilar distribution in Central American countries due to their different exposure and vulnerability conditions. In the following section, we define and discuss *extensive* versus *intensive* risks. *Extensive risks* are associated with high-frequency, low-magnitude hazard occurrences mostly resulting in localized hazards (UNISDR – United Nations Disaster Risk Reduction 2015; Alcántara-Ayala 2019). Examples of these events include flash floods, storms, fires, and droughts. Hence, extensive risks usually result from hydrometeorological hazard occurrences. In contrast, *intensive risks* are considered low-frequency, high-magnitude occurrences mainly associated with major catastrophic hazard occurrences (Etinay, Egbu, and Murray 2018, UNDRR – United Nations Disaster Risk Reduction 2019). Hazard occurrences are global or local events, e.g., large volcanic eruptions, earthquakes, tsunamis, flooding in large river basins, or tropical cyclones (UNISDR – United Nations Disaster Risk Reduction 2009).

The region also reports the highest poverty levels by country (Guatemala, Honduras, and Nicaragua) in Latin America (Santos and Villatoro 2018). The data in Table 1 report that in terms of GDP and Human Development Index (HDI), there is a clear disparity between the countries of Central America (Kummu, Taka, and Guillaume 2018). Natural hazards and disasters disproportionately affect poor and more vulnerable people worldwide (Hallegatte et al. 2020). Climate-related disasters impact gender equality negatively, especially in terms of women's socioeconomic rights. The effects of disasters reduce the life expectancy of women more than in men (Neumayer and Plümper 2007). These effects become more evident in countries that are less democratic, depend on agriculture, possess ecosystems with higher fragility levels, and have natural resources pressure (Eastin 2018). Commonly, more partisan ideology countries suffer less disaster damages (Wen and Chang 2015). Moreover, small economy countries' agricultural sector is normally more affected to extreme hydrometeorological disasters that earthquakes and extreme temperatures (El Hadri, Mirza, and Rabaud 2019).

We hypothesize that the number of intensive risks (such as regional hurricanes or earthquakes) and/or small to moderate common disasters (extensive risks) affect the physical and human dynamics in the countries of Central America and limit their development. Thus, the objective of this work is to analyze the impacts of extensive and intensive risks on the population of Central America between 1990 and 2015. Our data support the realization of diverse levels of risk at different scales across the region.

Materials and methods

We used DesInventar (http://www.desinventar.org) and EM-DAT (http://www.emdat.be) disaster databases. We extracted the number of geological and hydrometeorological hazardous occurrences

Table 1. Socioeconomic parameters for Central American countries.

Country	GDP/capita (2020)	Population (total, 2020)	Surface area (sq.km, 2020)	Population density (inh/sq.km, 2020)	Urban population (% total population, 2020)	Human Development Index (2019)	Poverty lines (% total population, 2020)
Belize	4435.6	397,621	22,970	17	46	0.716	52
Costa Rica	12,076.8	5,094,114	5100	100	81	0.810	30
El Salvador	3798.6	6,486,201	21,040	313	73	0.673	26
Guatemala	4603.3	16,858,333	108,890	157	52	0.663	59
Honduras	2405.7	9,904,608	112,490	89	58	0.634	48
Nicaragua	1905.3	6,624,554	130,370	55	59	0.660	25
Panama	12,269	4,314,768	75,320	58	68	0.815	22

Source: (IMF – International Monetary Fund. World Economic Outlook Database 2020; World Bank 2021; UNDP – United Nations Development Program 2020).

that impacted the region between 1990 and 2015 in Belize, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama. Updated information from 2015 to 2021 was only available for Costa Rica; therefore, to avoid bias in the results, analysis was conducted for the period of 1990-2015. These databases have been widely used in Latin America and the rest of the world (Marulanda, Cardona, and Barbat 2010; Stäubli et al. 2018; Zaidi 2018; Quesada-Román 2021a). We compiled the data by country at a level of province, department, district, or their equivalent. This helped us identify the number of disaster occurrences with their recurrence intervals and effects on the populace. We present an original approach explaining different impact levels of hazard occurrences, vulnerability, and risk conditions of Central America, one of the least studied regions of the world.

We classified the events into extensive and intensive risks (UNISDR – United Nations Disaster Risk Reduction 2009). Intensive risks included major earthquakes, hurricanes, and volcanic eruptions while tropical cyclones and rainfall events were linked to extensive risks. Secondary hazardous occurrences such as landslides, torrential floods, and floods generated from a primary major event, were considered "combined" risks. In addition, we extracted the number of casualties, affected people in terms of injuries and illnesses, properties and houses damaged and destroyed. We only used houses records, because other information about buildings and road infrastructure was not available for all the countries. Finally, we categorized the occurrences into intensive or extensive risks, which were determined from the casualties (injuries and deaths) and houses and properties affected or destroyed according to definitions set forth by the United Nations International Strategy for Disaster Reduction (UNISDR – United Nations Disaster Risk Reduction 2015). Intensive risks were defined from records with 25 or more casualties or 300 or more destroyed houses while extensive risks include records with values less than 25 casualties or fewer than 300 destroyed houses (UNISDR – United Nations Disaster Risk Reduction 2009). In addition, we used the GDP per capita, Human Development Index, poverty headcount ratio at national poverty lines (% of population) of each country (IMF – International Monetary Fund. World Economic Outlook Database; 2020; World Bank 2021), and their population densities to identify the factors that intensified the impact in some countries compared to others.

Results

Between 1990 and 2015, the countries of Central America experienced a total of 23,727 disastrous events, triggered by geological and hydrometeorological hazards. Costa Rica reported the highest number of reports (11,750), followed by Guatemala (3581), El Salvador (3205), Honduras (2775), Panama (1622), Nicaragua (681), and Belize (113) (Table 2 below). Costa Rica has the most extended record due to the continued alliance between civil protection and academia. The years that registered more than 1000 occurrences due to intensive, extensive, and combined risks were 1998, 2005, 2007, 2008, 2010, 2011, and 2012 (Figure 1 below). These years reported

Table 2. Number of disaster occurrences classified by extensive, intensive, and combined risks in Central American countries between 1990 and 2015.

Country	Extensive	Intensive	Combined	Total
Belize	79	1	33	113
Costa Rica	225	327	11,198	11,750
El Salvador	50	374	2781	3,205
Guatemala	813	194	2574	3,581
Honduras	654	149	1972	2,775
Nicaragua	58	22	601	681
Panama	43	55	1524	1,622
Total	1922	1122	20,683	23,727

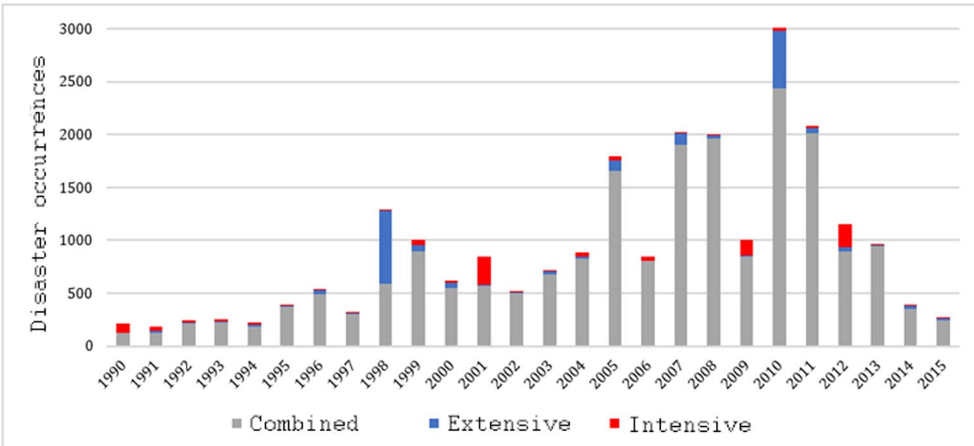

Figure 1. Annual disaster occurrences by combined, extensive, and intensive dynamics for Central America countries between 1990 and 2015.

moderate to strong negative averages in the Oceanic El Niño Index and were related directly to the La Niña phase (NOAA – National Oceanic and Atmospheric Administration 2021). Regional, strong hydrometeorological events such as tropical cyclones, floods, heavy rains, or landslides comprised the highest number of records of disaster occurrences in the region in those years.

The months with the highest number of reported occurrences (May to November) coincided with the rainy season in the region (Figure 2). The years with the most reports (1998, 2005, 2007-2008, 2010-2011) were associated with La Niña phenomenon influence (greater rainfall) or tropical cyclones. This was evident in 2005, when one of the most active hurricane seasons recorded in the history of the Western Atlantic basin occurred, affecting Central America in July and October mostly (NOAA – National Oceanic and Atmospheric Administration 2021).

From the total number of recorded events, 23,012 corresponded to intensive risks and 215 to extensive risks. The distribution by country indicated that El Salvador recorded the highest number of occurrences (125) by intensive risks, which were associated with low-pressure systems and tropical storms. The extensive and combined risks have been the main trigger for intensive risks in the region. Costa Rica's highest number of registered intensive risks are associated to Limon's earthquake in 1991 (Quesada-Román 2016, 2021b); however, the largest number of extensive risks (11,746) are related to floods, landslides, and storms in the Great Metropolitan Area mainly (Figure 3).

The sub-national level distribution (departments, municipalities, or districts) analysis showed that Costa Rica had the greatest concentrated of occurrences, specifically in municipalities located in the Great Metropolitan Areas of San José and Alajuela, which registered 3702 and 1971 reports respectively. Other sub-national units that reported more than 600 occurrences

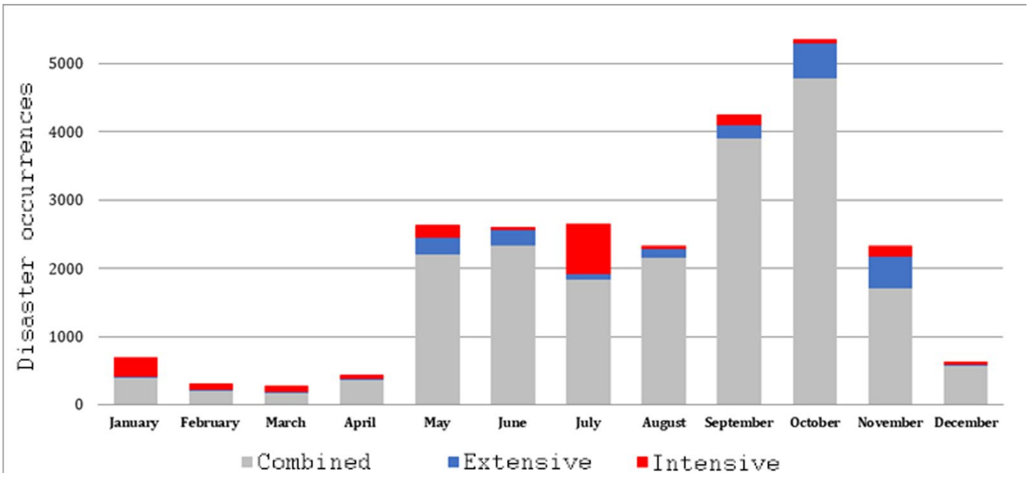

Figure 2. Monthly disaster occurrences by combined, extensive, and intensive risks for Central America between 1990 and 2015.

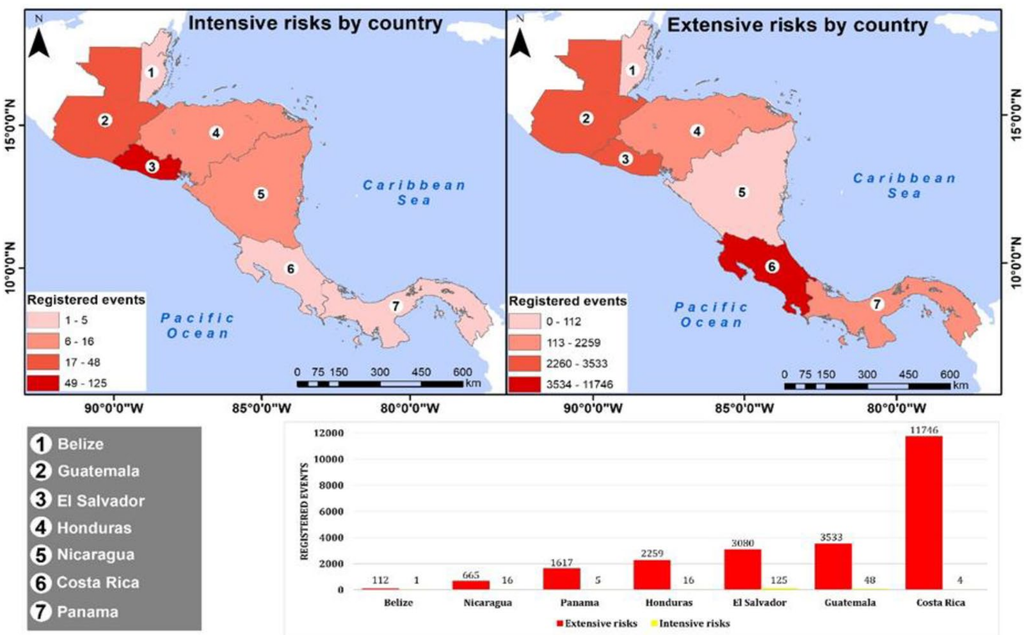

Figure 3. Extensive and intensive risks for the Central American countries between 1990 and 2015.

were the department of San Salvador (El Salvador), with 863 occurrences as well as Guatemala, with 636 occurrences. All the risks were related to floods and storms (Figure 4 below).

Extensive risks (high-frequency, low magnitude occurrences) have the greatest impact on the population of the region. Guatemala presented the greatest number of casualties (1340), accounting 41% of the total casualties in Central America. This is expected since Guatemala has the largest population in the region: almost 17 million people with a population density of 159 people per square kilometer in different urban centers. This includes a significant number of rural towns in mountainous areas, which commonly produce landslides and floods occurrence. On the other hand, countries reporting the lowest number of extensive risks included Costa Rica, Belize, and Panama. The numbers and ratios in Table 3 report that

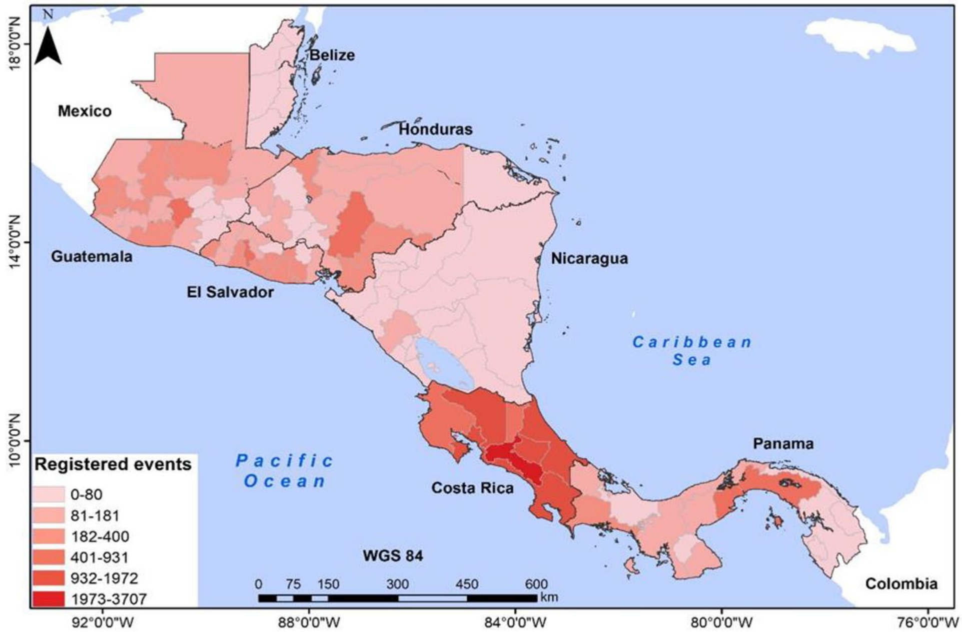

Figure 4. Spatial distribution at the sub-national level by extensive and intensive risks for the Central American countries between 1990 and 2015.

Table 3. Casualties and affected people by extensive and intensive risks in Central America between 1990 and 2015.

	Extensive risks			Intensive risks		
Country	Casualties	Affected people	Ratio	Casualties	Affected people	Ratio
Costa Rica	350	724,557	1:2070	46	48,650	1:1058
El Salvador	458	1,122,191	1:2450	2,798	1,758,205	1:628
Guatemala	1340	6,097,725	1:4550	1029	699,199	1:679
Nicaragua	185	2,697,000	1:14,578	721	181,709	1:252
Honduras	631	2,839,358	1:4500	9,154	3,507,404	1:383
Panama	206	388,208	1:1884	44	68,079	1:1547
Belize	40	72,548	1:1814	30	20,000	1:667
Total	3,210	13,941,587	1:4343	13,822	6,283,246	1:455

these countries are less likely to have loss of lives as well as housing and property damage (Table 3).

In the case of intensive risks (low-frequency, high magnitude occurrences), Honduras, El Salvador, and Guatemala account for 93% of the total casualties (12,981) and 94% of the affected people throughout the region (5,964,808; Tables 2 and 3). These three countries concentrate roughly 70% of Central America's population. Moreover, Nicaragua and Honduras are expected to have more casualties' ratios related to their affected people for intensive risks (Figure 5). They also gather population densities between 55 and 313 inhabitants per square kilometer; their GDP per capita and HDI and poverty headcount ratio lies at national poverty lines (% of population) are below the average of the region (IMF – International Monetary Fund. World Economic Outlook Database 2020; World Bank 2021). These conditions favor increased risk conditions which are likely to result in a greater number of injuries and lives lost due to high levels of poverty and unmet basic needs.

Settlements in hazardous places like valley slopes or floodplains increase their risk exposure and vulnerability to natural hazards such as landslides and floods (Carrión et al., 2021; Pinos and Quesada-Román, 2021; Quesada-Román 2021b, 2022). The numbers and ratios in Table 4 report countries with higher exposure and vulnerability reflected in the houses destroyed and damaged.

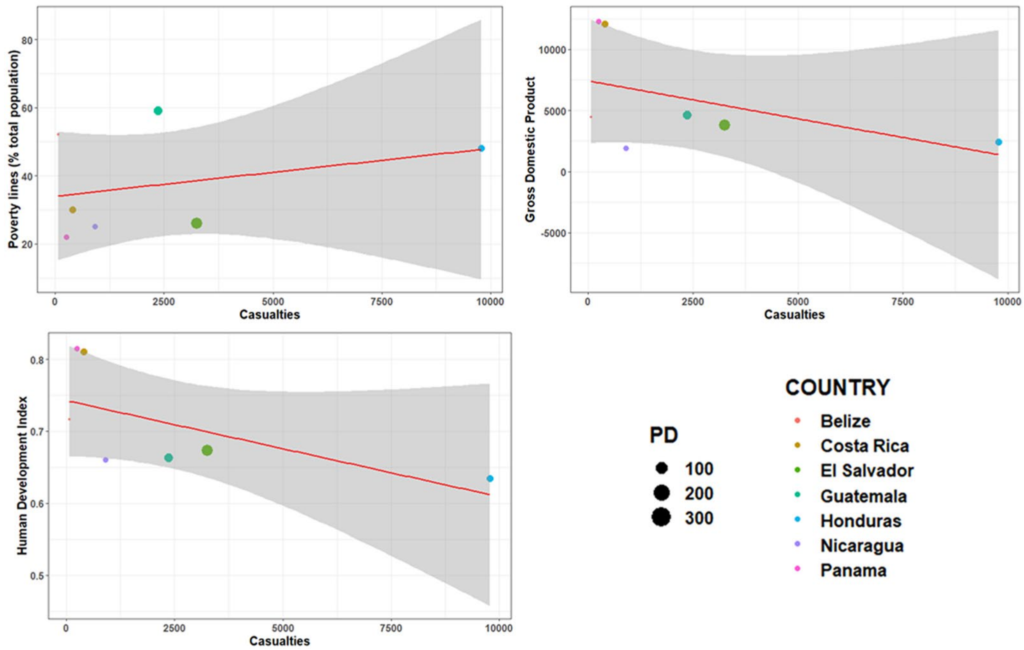

Figure 5. a) Poverty lines (% of total population), b) Gross Domestic Product, c) Human Development Index versus casualties' distribution according to population density (CT) by country.

Table 4. Numbers of destroyed and damaged houses by extensive and intensive risks in Central America between 1990 and 2015.

	Extensive risks			Intensive risks		
Country	Destroyed houses	Damaged houses	Ratio	Destroyed houses	Damaged houses	Ratio
Costa Rica	3,840	56,317	1:15	4,238	7,507	1:2
El Salvador	10,549	70,660	1:7	141,750	133,302	1:1.06
Guatemala	14,619	139,234	1:10	23,775	49,088	1:2
Nicaragua	1,597	30,082	1:19	9,473	5,582	1:1.69
Honduras	6,294	57,550	1:9	36,804	50,417	1:1.36
Panama	1,569	48,767	1:31	3,840	6,320	1:1.64
Belize	203	15,433	1:76	0	0	0
Total	38,671	418,043	1:11	215,642	252,216	1:1.16

Guatemala and El Salvador comprise 65% of the destroyed houses by extensive risks in the region. In particular, El Salvador, where intensive risks produce damaged and/or destroyed homes, represent 65% and 52% of the region's total respectively. El Salvador reports the highest population densities in Central America which generates urban overcrowding conditions. In addition, construction in hazardous areas increase their risk conditions not only in cities but also in rural areas as there are no clear land-use regulations (Quesada-Román, Castro-Chacón, and Feoli-Boraschi 2021b).

El Salvador accounted for 58% of the intensive risks in Central America (Tables 3 and 4). The risks correspond directly to its population density of 310 inhabitants per square kilometer, especially in urban areas such as San Salvador, Santa Ana, and San Miguel. This region is the most densely populated in Central America and one with the lowest GDP per capita. In 1990, it barely reached $899, and in 2020, $3798. This hardly represents 23% of Panama GDP ($12,269), the country with the best macroeconomic data in the region (IMF – International Monetary Fund. World Economic Outlook Database 2020; World Bank 2021). Similarly, HDI is low, and the poverty headcount ratio lies at national poverty lines (% of population) which varies from 22%

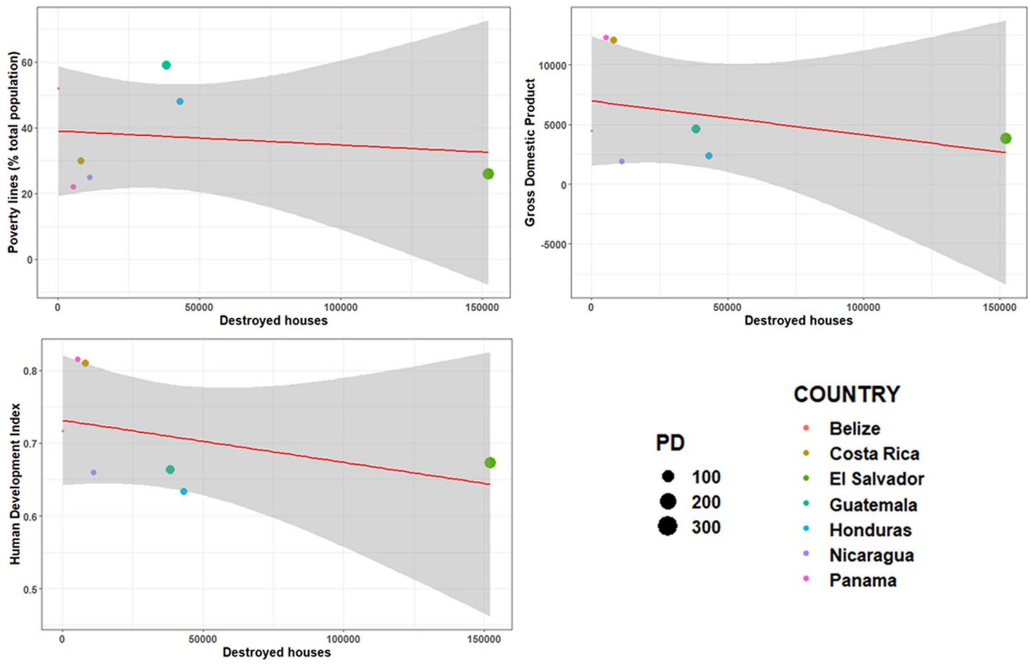

Figure 6. a) Poverty lines (% of total population), b) Gross Domestic Product, c) Human Development Index and destroyed houses distribution according to population density (CT) by country.

in Panama to 59% in Guatemala in 2020 (IMF – International Monetary Fund. World Economic Outlook Database 2020; World Bank 2021). Moreover, El Salvador has the higher ratio between destroyed and affected houses both in extensive and intensive risks of Central America (Figure 6). Interestingly, the rest of the countries, except Belize, reported high ratios relationships among destroyed and affected houses in intensive risks such as great tropical cyclones or earthquakes. El Salvador and Nicaragua reported more destroyed than affected houses among 1990 and 2015.

Discussion

Our results identified spatial and temporal trends in the occurrence of extensive risks, intensive risks, and combined risks. Combined "risks", where hazard occurrences were characterized by both intensive and extensive risks, sum most disaster events in Central America, especially those secondary hazards related to landslides, torrential floods, and floods. Central America's tectonic complexity and high seismicity favor the susceptibility of slope failing (Campos-Durán and Quesada-Román 2017). Central America has a significant record of earthquake-related landslides (Bommer and Rodríguez, 2002). In addition, earthquakes are plentiful along the tectonic boundaries of the Pacific coast, particularly along the coasts and the Mesoamerican subduction Trench linked by the interface with the Cocos and Caribbean plates, and the Panama block (DeMets, Gordon, and Argus 2010).

The El Niño-Southern Oscillation severely affects precipitation fluctuations (Maldonado, Alfaro, and Hidalgo 2018). Regional warm or wet responses diverge amid water catchments draining to the Pacific and the Caribbean basins and act contrarily to ENSO conditions (Durán-Quesada et al. 2020; Hidalgo et al. 2020). In the Pacific facing slopes of Central America, the influences with El Niño typically favor drier environments while La Niña phases tend to promote wetter conditions (NOAA – National Oceanic and Atmospheric Administration 2021). Furthermore, Maldonado and colleagues (2018) detect a statistically positive linear tendency in the annual number of intense hurricanes in the Caribbean Sea during the decade of 1970. La Niña conditions favor the intensification of extreme events such as tropical cyclones (Hidalgo et al. 2020). Hence, Central America has an intense correlation among mean daily rainfall totals and daily landslides (Ishizawa and Miranda 2019). Such extremes occurrence proves to activate landslides (Froude and Petley 2018; Carrión-Mero et al. 2021) and floods (Shi and Karsperson 2015; Guevara-Murua et al. 2018; Quesada-Román et al. 2022) in Central America.

Our results indicated that the most affected countries also had lower GDPs, and higher poverty levels and population densities. Disasters are not natural (Chmutina and Von Meding 2019). Disaster risk is the latent loss of life, injury, and devastated or damaged assets that might occur to people in a precise range of time, as a probabilistic function of hazard, exposure, vulnerability, and capacity (Chmutina et al. 2020). These conditions for each country favor the increase of risk conditions at different scales. The impact of a physical event or the expansion of human failure produces a sequence of events in human subsystems that result in successive physical, social, or economic disturbances known as cascading disasters (Alexander 2018; Kelman 2018). Moreover, there is a direct relationship between hazard, exposure zones and informal settlement's locations in developing countries (Satterwaite et al., 2020). Normally, an ineffective territorial planning increase the exposure and vulnerability conditions in the region investigated in this study creating larger risk scenarios (Quesada-Román et al. 2019).

It is necessary to monitor zones impacted by earthquakes earlier, specifically along unusual rainfall events such as tropical cyclones (Piciullo, Calvello, and Cepeda 2018). Due to the lack of baseline information and natural hazards cartography, disasters data resolution needs to be improved in Central America (Quesada-Román et al. 2020). Additionally, Central America is one of the least studied regions of the world in terms of hazard and risk assessment. Hence, the number of investigations about risks in the region should increase to help reduce disasters (UNDRR – United Nations Disaster Risk Reduction 2019; Quesada-Román, Villalobos-Portilla, and Campos-Durán 2021a). When reference data is scarce, pioneering, and applied methods must be employed as disaster risk assessment tools (Quesada-Román and Villalobos-Chacón 2020; Quesada-Román 2021c).

Our results unveiled a known reality of the region. First, there is a strong disaster risk assessment centralization at country scale. Second, prevention tools should be performed at different scales incorporating community approaches. Third, new technologies should be considered in prevention and reconstruction civil infrastructures. Therefore, it is vital to decouple dependency from disaster risk decision-making at the national level in the region (Alcántara-Ayala, 2019; UNDRR – United Nations Disaster Risk Reduction 2019) and to particularly assess risk conditions of urban agglomerations which normally present more disasters recurrence (García-Soriano, Quesada-Román, and Zamorano-Orozco 2020; Quesada-Román and Mata-Cambronero, 2021). Government decentralization and disaster risk assessment can improve disaster governance in small cities, districts, or municipalities (Rumbach 2016). Hence, this process will shorten the gap among citizens and their administration, refining different scales governance capacity (Kong et al. 2020). Risk assessment success depends on inter-scale coordination, planning, and mitigation measures (Froude and Petley 2018). Early warning systems implementation and operative communication tools are key to reduce potential casualties and economic losses (Alexander 2018). Besides, land use planning actions with engineering projects (e.g., flood levee or slopes protection) are suitable to prevent disasters using high resolution imagery (Granados-Bolaños, Quesada-Román, and Alvarado 2021; Quesada-Román 2021b; Sajan and Gautam 2021). Resilient fiscal rules to separate resources in eventual disasters should be a practical tool in developing countries such as Central America to ensure funding during national or regional emergencies (Cevik and Huang 2018, Nakatani 2021).

Conclusions

Physical-natural, economic, and sociocultural conditions shape Central America as one of the most affected regions in the world by extensive and intensive risks. Its location in a tectonically and volcanically active zone along tropical climates with extraordinary rainfall events make it physically susceptible. These countries are economically dependent on primary and secondary sectors exports, which in 2015 represented a GDP per capita ranging from $1905 in Nicaragua to $12,269 in Panama. Moreover, national population poverty lines vary from 22% in Panama to 59% in Guatemala. These economic asymmetries reflect the exposure and vulnerability conditions that control the risk scenarios for each of the countries in the region.

The number of casualties and the destroyed or affected houses allowed an estimate of the cost of the disasters in the region; nevertheless, much information is incomplete or fully absent. The use of disaster databases to generate regional and local analyses through the historical record proves valuable to develop a baseline for land use and risk assessment in developing countries. Nonetheless, there are important disparities in the disaster's records, e.g., Costa Rica has a complete record while Belize has data only for a few years. This represents a limitation for generating a baseline in the region that allows the consolidation of risk management studies (hazard scenarios or exposure and vulnerability estimates) that are more accurate to the authentic situation of each country. Therefore, it is necessary for the public, private, and non-government institutions to promote strategies to improve data collection processes and strengthen resilience mechanisms with gender equity and environmentally sustainable development.

The Central American Integration System (SICA), in its Climate Change and integrated Risk Management pillar, should include a regional project as a system for continuously recording events (intensive and extensive risks) in the region. In addition, different methodologies should be established and applied to generate hazard maps in the most affected areas. Moreover, it is key to develop exposure and vulnerability studies to identify risk conditions in the region at different scales. This is essential for the public policies focusing on risk and climate change in the region according to its political-administrative management.

Risk mapping is key to risk assessment and management toward reducing disasters at different scales in Central America, especially in warming climate scenarios that are expected to result in more intense and recurrent extraordinary hydrometeorological hazards (IPCC, 2014). It is difficult to manage natural risks in the region due to the dependance on highly centralized, national level decision-making. The internal improvement of each country in the investment to plan and organize their territories, along with risk management in local, regional, and national scales, will help mitigate the micro and macroeconomic effects that extensive and intensive risks provoke each year. Therefore, government decentralization may increase disaster risk governance in municipalities. Moreover, the success in risk assessment, planning, and implementation of risk management depends on the inclusion and participation of communities. Community participation must include addressing the issue through several perspectives including, gender, income class, education, and other factors.

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