Indicadores de resiliencia y sostenibilidad para la vivienda urbana panameña frente al cambio climático
Michelle Alina Ruíz González, Yazmin Lisbeth Mack-Vergara
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RESILIENCE AND SUSTAINABILITY INDICATORS FOR PANAMANIAN URBAN HOUSING IN THE FACE OF CLIMATE CHANGE

INDICADORES DE RESILIENCIA Y SOSTENIBILIDAD PARA LA VIVIENDA URBANA PANAMEÑA FRENTE AL CAMBIO CLIMÁTICO

INDICADORES DE RESILIÊNCIA E SUSTENTABILIDADE PARA A HABITAÇÃO URBANA PANAMENHA DIANTE DAS MUDANÇAS CLIMÁTICAS

Michelle Alina Ruíz González
Ingeniera Civil
Investigadora en el Centro de Estudios Multidisciplinarios en Ciencias, Ingeniería y Tecnología
Universidad Tecnológica de Panamá, Panamá
https://orcid.org/0000-0003-1224-3117
michelle.ruiz@utp.ac.pa

Yazmin Lisbeth Mack-Vergara
Doctora en Ciencias
Investigadora y Docente Universidad Tecnológica de Panamá, Panamá
https://orcid.org/0000-0002-1313-9234
yazmin.mack@utp.ac.pa

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RESUMEN

En las últimas décadas, los centros urbanos han enfrentado enormes desafíos, como el aumento de desastres naturales y la imposibilidad de recuperarse de los mismos. En este contexto, el objetivo de esta investigación es proponer indicadores de resiliencia y sostenibilidad para la vivienda urbana panameña en función de los efectos del cambio climático, a través de un extenso análisis sobre la vulnerabilidad del país. Mediante procesos cualitativos fue posible caracterizar una vivienda resiliente y sostenible validada por profesionales nacionales e internacionales para el desarrollo de una propuesta de 29 indicadores que responden a los impactos actuales y futuros producidos por cambio climático: 15 para resiliencia y 14 para sostenibilidad. En este sentido, se logró elaborar una herramienta útil y sencilla para evaluar la resiliencia y sostenibilidad de la vivienda urbana.

Palabras clave
cambio climático, vivienda, desarrollo sostenible, resiliencia

ABSTRACT

In recent decades, urban centers have been facing enormous challenges with the increase in natural disasters, and the impossibility of recovering from them. In this context, the objective of this research is to propose resilience and sustainability indicators for Panamanian urban housing by considering the effects of climate change through an extensive analysis of the country's vulnerability. Using qualitative processes, validated by national and international professionals, it was possible to characterize resilient and sustainable housing and develop a proposal of 29 indicators that respond to current and future climate change-related impacts: 15 for resilience and 14 for sustainability. Thus, building a simple useful tool to evaluate the resilience and sustainability of urban housing.

Keywords
climate change, housing, sustainable development, resilience

RESUMO

Nas últimas décadas, os centros urbanos têm enfrentado enormes desafios como o aumento das catástrofes naturais e a impossibilidade de recuperação dos estragos causados por estas. Neste contexto, o objetivo desta pesquisa é propor indicadores de resiliência e sustentabilidade para a habitação urbana panamenha em função dos efeitos das alterações climáticas mediante uma análise extensiva da vulnerabilidade do país. Esta informação foi analisada por meio de processos qualitativos que permitiram caracterizar uma habitação resiliente e sustentável validada por profissionais nacionais e internacionais. Isto permitiu desenvolver uma proposta de 29 indicadores que respondem aos impactos atuais e futuros das alterações climáticas: 15 para a resiliência e 14 para a sustentabilidade. Neste sentido, obteve-se um instrumento útil e simples para avaliar a resiliência e a sustentabilidade da habitação urbana.

Keywords
mudanças climáticas, habitação, desenvolvimento sustentável, resiliência.

INTRODUCTION

Cities have played a decisive role in sustaining and shaping the planet's main civilizations since ancient times. That is why throughout history there has been a permanent concern to create and develop prosperous and sustainable cities (Fenollós, 2022). This is demonstrated by recent studies that have developed the ideals of resilient and sustainable cities: City Resilience Program (World Bank, 2020), City Resilience Index (ARUP and The Rockefeller Foundation, 2014), Resilient Cities and Communities (McCarton, O'Hogain & Reid, 2021), Urban surface uses for climate Resilient and Sustainable Cities: A catalogue of solutions (Croce & Vettorato, 2021), The 2030 Agenda - Sustainable Development Goals (SDGs) (United Nations Organization, 2018), Resilience Strategy for Panama City (Municipality of Panama, 2019) and the Emerging and Sustainable Cities Program (ESC) (Inter-American Development Bank, 2022).

In this framework, the world today faces unprecedented problems, such as poor planning, pollution, increased vulnerability to disasters, and climate change (Aguilar, 2020). Population and city growth do not seem to stop (Vaca & Cartuche, 2018), and the challenges, ideas, and opportunities are concentrated and demand sustainable, fair, and democratic solutions (Lima *et al.*, 2020).

However, cities are also a source of inventions, the development of new technologies, and the dissemination of knowledge (Fenollós, 2022), where awareness of resources, their efficient use, and the conservation of ecosystems have become indispensable (Murillo, 2021). From this perspective, it is possible to spearhead a change incorporating climate change adaptation and mitigation measures in cities, from its essential unit, housing (Cobo & Montoya, 2021). In this way, it will be possible to reduce exposure to climate risk and vulnerability, by reducing greenhouse gas (GHG) emissions, improving waste management, using clean energy production, and reducing the carbon footprint (Sodiq *et al.*, 2019), so that the established urban dimensions can coherently evolve with the dynamics they experience (Valdez, 2021).

Although, before identifying the causes and effects of climate change, it should be clarified what this means here. In 1992, the urgency to adopt more forceful international measures regarding the environment gained momentum and was manifested through a global consensus on cooperation in the field of development and environment in the United Nations Framework Convention on Climate Change. It was in Article 1, point 2, that climate change was defined as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (United Nations, p. 3-4, 1992).

Based on this definition, it has been evidenced how the set of natural and anthropogenic substances and processes have altered the Earth (Intergovernmental Panel on Climate Change [IPCC], 2018), in such a way that, since the nineteenth century, it has become a crucial problem, where human anthropogenic activities, a product of economic and demographic growth, are one of the most considerable (Mehmood *et al.*, 2020; Bastidas Pacheco & Hernández, 2019). Indeed, even though the increase in the greenhouse gas concentration in the atmosphere is a natural process, in recent years it has reached unparalleled levels (IPCC, 2018).

More specifically, the "Study of Urbanization in Central America: Opportunities for an Urban Central America" (María, Acero, Aguilera & García Lozano, 2018) indicates that, in Central America, 59% of the population lives in urban areas and it forecasts that, in the next generation, 7 out of 10 people will live in cities. Panama's urbanization process arose from the internal migration of thousands from rural areas to provincial capitals or areas around the capital in search of employment, education, and health opportunities, where, between 1950 and 2000, the urban population increased by 26% (National Institute of Statistics and Census [INEC], 2020). This presents challenges in developing regions with a limited response capacity (Quintana Solórzano, 2017).

Likewise, the National Communications to the United Nations Framework Convention on Climate Change (Ministry of Environment of Panama, 2020) have identified Panama, given its geographical location, as a country with high vulnerability to climate change. These have outlined effects such as sea level rise, temperature increase, rainfall variations, and more frequent natural disasters (floods, extreme winds, and landslides). This vulnerability is recognized as a global challenge for urban areas in coastal areas against which actions must be taken (Villamil-Cárdenas & Osuna-Motta, 2021).

In turn, these National Communications to the United Nations Framework Convention on Climate Change (Ministry of Environment of Panama, 2020) have mapped out the country's future scenarios, following the guidelines of the Intergovernmental Panel on Climate Change (IPCC, 2018). These have forecast worsening effects, indicating their variation by region. Therefore, the measures should respond

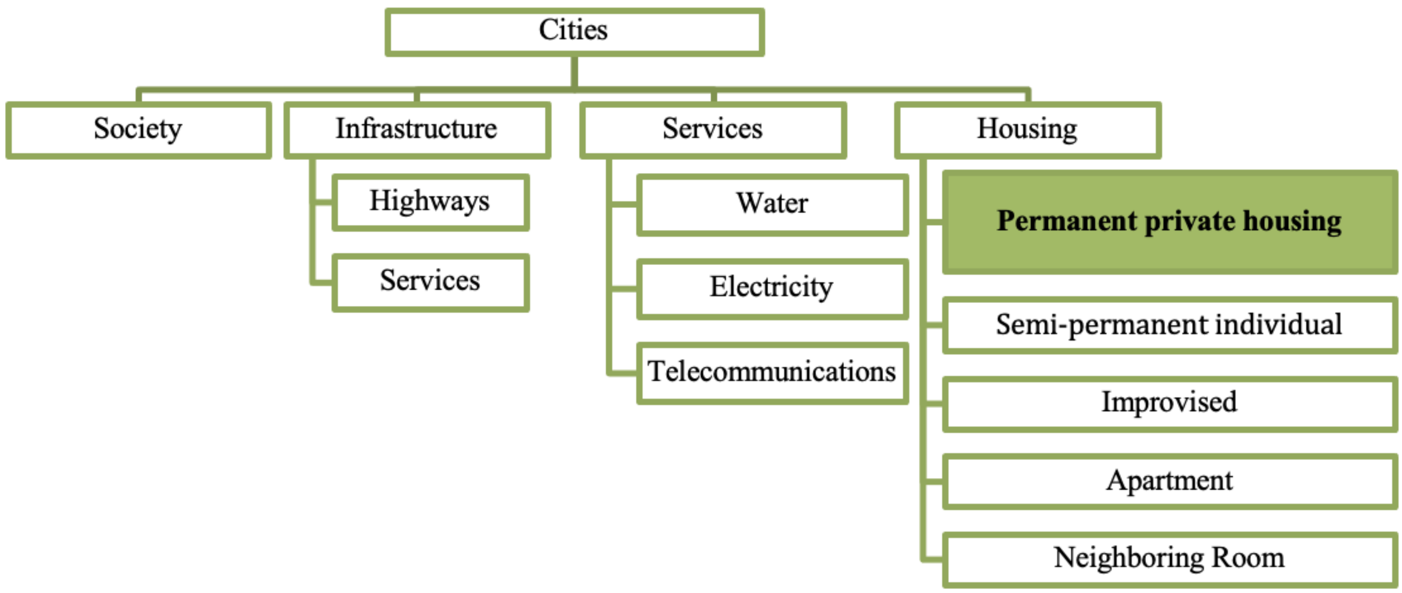

Figure 1. Components of a city according to the Panama 2010 Census. Source: Preparation by the authors.

to the needs of each area, particularly in terms of housing, a central theme of this research.

Thus, the need arises to have tools that allow the evaluation and monitoring of housing performance, but also identify the housing profile in terms of resilience and sustainability (Adamec, Janoušková & Hák, 2021; Koch & Ahmad, 2018). The importance is highlighted, therefore, of having indicators that allow encapsulating a complex reality through the measurement of related conditions or the component parts of housing features. However, its application needs to be fast and the interpretations simple, both for decision-makers and for society in general (Rivero-Camacho & Ferreira-Sanchez, 2021).

This research focused its efforts on proposing a set of resilience and sustainability indicators for Panamanian urban housing based on the effects of climate change. The development of indicators constitutes a cornerstone of quantitative evaluation (Mercader, Camporeale & Cózar-Cózar, 2019), as a valuable information tool to know the current state, as it allows generating evidence for decision-making, monitoring a given process, and evaluating its progress, either with certain goals, when these exist, or compared to the levels observed in a base year (Karis *et al.*, 2019). Without a doubt, it becomes a robust, practical, and easy-to-use instrument (González Vallejo, 2018) when addressing standardized verification processes for resilience and sustainability in construction works (Canales Valderrama-Ulloa & Ferrada, 2021; Chavez, Trebilcock & Piderit, 2021), which generate information to support changes in environmental policies for sustainable development.

METHODOLOGY

This qualitative research collected relevant information on climate change in the current and future national context, looking to achieve a broader and deeper perspective that would allow contextualizing the reality of Panamanian housing and resilient and sustainable housing, to develop a proposal of indicators to measure the resilience and sustainability of Panama's urban housing against climate change. In parallel, case studies were made to evaluate the manageability of the proposed indicators.

UNIT OF STUDY

Those considered "urban areas" according to the INEC (2020) were covered, that is, any region with a population of at least 1,500 inhabitants that has basic service systems. The study focused exclusively on permanent private housing since according to data from the 2010 Housing Census (INEC, 2020), this was the most common and fundamental type of housing in Panama's city structure (Figure 1).

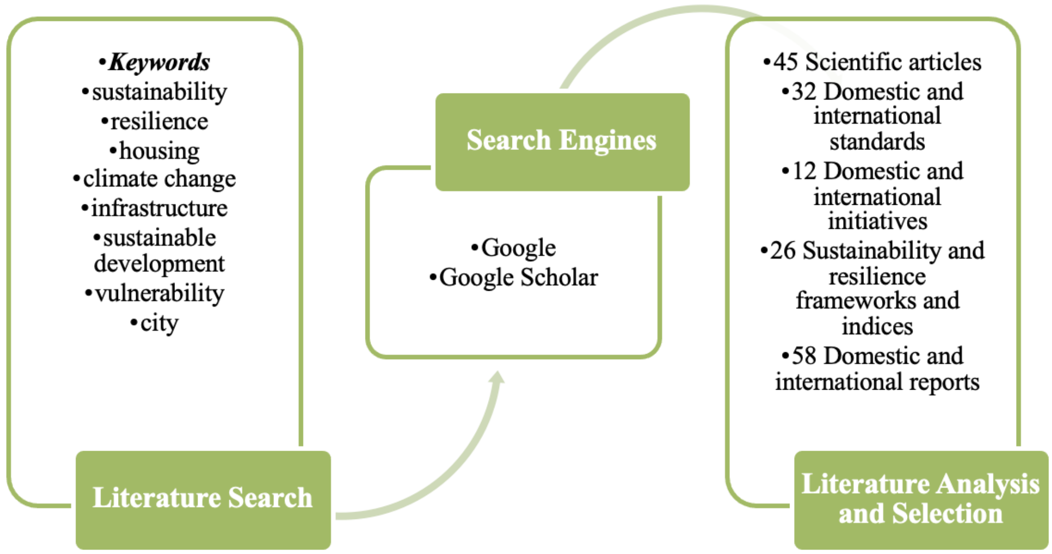

Figure 2. Review process of the specialized literature. Source: Preparation by the authors.

SPECIALIZED LITERATURE REVIEW

An extensive bibliographic review included domestic and international documents, books, scientific articles, and current laws and regulations. Google Scholar was used as a scientific-academic literature search engine, since it has most of the scientific publications, while Google was used as a general literature search engine. The keywords for the document search, used in different combinations, in Spanish and English, were: sustainability, resilience, housing, climate change, infrastructure, sustainable development, urban area, vulnerability, and city.

Based on this, the respective antecedents at a regional and national level were determined: history, development, current and future situation, as well as the definitions of climate change since its beginnings, in the United Nations Framework Convention on Climate Change (United Nations, 1992), to the most recognized, fostered by the Intergovernmental Panel (IPCC, 2018). And under this concept, its causes and effects were identified through different reports, articles, and other documents.

In this way, the selection of frameworks, scientific articles, and government initiatives was made that would act as guides for evaluating and measuring the degree to which housing meets resilience and sustainability conditions. Terms that, in turn, were defined and established for the context of the research. This specialized literature review generated enough information to analyze and discuss (Figure 2), and then to systematically codify and group. In short, the basis behind the proposal of resilience and sustainability indicators for Panamanian urban housing in the face of climate change was formed.

QUALITATIVE ANALYSIS

Qualitative analysis was used to delve deeper, contextualize, and present data and information on the vulnerability of housing and people, after identifying the causes of climate change and its current and future effects in Panama. This was a chain used to mark out the frameworks, articles, and documents that supported the resilient and sustainable housing indicators proposal for measuring and monitoring the level of service, quality, comfort, and performance of housing in urban areas of Panama. It also made it possible to specify the tools available domestically and internationally for its application.

The aforementioned proposal for Panamanian urban housing was then made based on characteristics considered and validated through an open-ended and judgment questionnaire, which included sociodemographic variables (Table 1), such as nationality, area of study, area of work, and experience. The sample used was of a non-probabilistic qualitative nature, since it fell on a select group of local and international experts, who assessed its representativeness, *online*, through the Microsoft Forms tool, and through email for a period of one month (August 1, 2021, to August 31, 2021), considering the country's housing needs to face the effects of climate change.

SURVEYED	COUNTRY	AREA OF STUDY			AREA OF WORK			POSITION				INSTITUTION	YEARS OF EXPERIENCE
		Engineering	Architecture	Specialization	Academia	Industry	Others	Researcher	Professor		Other		
A	Panama	x		Structural Engineering	X			x	x			Technological University of Panama	25
B	Panama	x		Environmental Sciences	X			x				Technological University of Panama	35
C	Panama	x		Civil Engineering and Geotechnical Engineering		x					x	Private Company	14
D	Colombia	x		Cement and building materials	X			x				National University of Colombia	29
E	Panama	x		Construction	X				x			Technological University of Panama	25
F	Panama	x		Environmental Sciences	X				x			Technological University of Panama	35
G	Panama	x		Civil Engineering		x					x	Private Company	12
H	Panama	x		Project management		x					x	Private Company	11
I	Panama	x		Health and Environmental Sciences	x				x			Technological University of Panama	26
J	Panama	x		Geotechnical Engineering	x					x		Technological University of Panama	26
K	Panama	x		Civil Engineering	x		x		x	x		Technological University of Panama	45
L	Brazil		x	Civil Engineering, Sustainability.	x			x	x			Federal University for Latin American Integration	18
M	Panama	x		Structural Engineering		x				x		Technological University of Panama	15
N	Panama	x		Construction	x		x	x	x	x	x	Technological University of Panama	45
Ñ	Panama	x		Water management	x			x	x			Technological University of Panama	4
O	Russia	x		Sustainable Construction	x			x				ETH Zurich	4
P	Germany	x		Cement, Additives, and Sustainable Construction	x			x				BAM Federal Institute of Material Research	16
Q	Brazil	x		Construction materials and techniques	x			x				University of Sao Paulo	20
R	Brazil	x		Industrial Ecology	x				x			University of Sao Paulo	20

Table 1. Profile of the groups of experts. Source: Preparation by the authors from the survey data.

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Figure 3. Literature analysis process for the development of resilience indicators. Source: Preparation by the authors.

Specifically, the indicators aim to evaluate and monitor the degree to which housing complies with resilience and sustainability characteristics, through a valorization questionnaire that covers each of the proposed objective-type indicators. These are a binary assessment, one with limited ranges, and/or a combination of both. A binary scale is understood to be based on a yes-no question, which is given a weighting of one or zero, respectively. Meanwhile, the limited ranges describe specific scenarios that highlight the best and worst scenarios, assigning scores to each, and asking participants to choose which scenario best describes the current situation. Therefore, the valorization of the questionnaire has been cataloged with numerical values to classify the house by its characteristics.

These indicators were validated through case studies to evaluate the ease and competence of their use. To do this, all the information was found online and used to answer the compliance questions of the resilience and sustainability indicators (Table 2 and Table 3).

RESULTS AND DISCUSSION

After an exhaustive investigation of different frameworks, indices, and tools for measuring resilience and sustainability applicable to housing, 29 indicators capable of responding to the current and future impacts of Panama to climate change were proposed, of which 15 address issues of resilience and 14, sustainability factors. The proposed indicators are detailed below.

RESILIENCE INDICATORS

The framework of basic resilience indicators for housing was chosen based on the City Water Resilience Framework (Stockholm International, Water Institute The Rockefeller Foundation, The Resilience Shift and ARUP, 2019), City Resilience Profiling Tool (United Nations Human Settlements Programme, 2018), City Resilient Index (ARUP and The Rockefeller Foundation, 2014) and a series of scientific articles and government initiatives that proposed guidelines to raise common infrastructures to resilient levels (Figure 3).

It should be noted that these indicators included the main effects to be considered in the future for climate change, as described above. Thus, Table 2 shows the resilience indicators to be applied in Panamanian homes.

SUSTAINABILITY INDICATORS

For this point, tools were used that outline sustainability metrics for the construction industry such as the Sustainable Infrastructure Framework Guidance Manual (Institute for Sustainable Infrastructure, 2018), The 2030 Agenda, and the Sustainable Development Goals (United Nations, 2018) (Figure 4). A set of indicators was obtained that consider the future effects of climate change.

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Land use and zoning	Is the dwelling located on a site that has established land use and zoning?		
	This was not considered or was without information.	There is no TOP in the area, but the National Urbanization Regulation was used	There is a TOP in the area and it used the National Urbanization Regulation.
	0	1	2
Location regarding areas at risk of flooding, high winds, or landslides	Are there detailed local data available in modeling and/or mapping studies with risk information?		
	There is no data collected and/or updated or there is no information.	Data not updated, validated, and/or with partial coverage of the site.	The data is up-to-date, validated, and covers the entire site.
	0	1	2
	Is there data on the frequency of flooding in the dwelling's area?		
	There is no data collected and/or updated or there is no information.	The data is not updated, validated, and/or partially covers the site.	The data is up-to-date, validated, and covers the entire site.
	0	1	2
	Is there data on the frequency of landslides in the dwelling's area?		
	There is no data collected and/or updated or there is no information.	The data is not updated, validated, and/or partially covers the site.	The data is up-to-date, validated, and covers the entire site.
	0	1	2
	Is there any data on the frequency of high winds in the dwelling's area?		
	There is no data collected and/or updated or there is no information.	The data is not updated, validated, and/or partially covers the site.	The data is up-to-date, validated, and covers the entire site.
	0	1	2
Characteristics of building codes and standards regarding resilience	Number of intergovernmental agreements dedicated to resilient design or planning used		
	There are no agreements dedicated to resilient design or planning, or there is no information.	There is at least one agreement, but this was not used in full	There are several agreements dedicated to resilient design or planning and they were used
	0	1	2
Application of building codes and standards	Does the dwelling have plans designed and executed by qualified professionals?		
	There are no plans, the housing was built empirically or without information.	There are plans, but not with the necessary permits.	It has plans and the necessary permits.
	0	1	2

Characteristics of the foundation	If the dwelling is located in a flood-risk area, does it have a raised foundation?		
	It is in a risk area, but it has no elevated foundation or there is no information.	It is not in a risk area.	It is in a risk area and has an elevated foundation
	0	1	2
	Is there any data on the frequency of high winds in the dwelling's area?		
	There is no data collected, updated, and systematized, or there is no information.	The data is up-to-date, but it does not cover the entire site.	The data is up-to-date, validated, and covers the entire site.
	0	1	2
	Percentage of slabs, footings, and foundations protected from erosion		
	0% of the total or there is no information	50% of the total	100% of the total
	0	1	2
Accessibility and evacuation capacity	Number of entrances/exits in the dwelling		
	1 entrance	2 entrances	More than 3 entrances
	0	1	2
	Have adequate accessibility features been employed to meet these needs (e.g., suitable access features such as ramps for all users with mobility restrictions, among others)?		
	No features have been implemented or there is no information	Some features have been implemented	Several features have been implemented
	0	1	2
Adaptability to the effects of climate change	Percentage of water-resistant coatings		
	0% of the total or there is no information	50% of the total	100% of the total
	0	1	2
	Percentage of the permeable area of the built space with porous and draining materials as a percentage of the total land area of the dwelling		
	0% of the total or there is no information	50% of the total	100% of the total
	0	1	2
	Subtotal		
	Percentage of water-resistant equipment (doors and windows)		
	0% of the total or there is no information	50% of the total	100% of the total
	0	1	2
	Does the design contemplate wind loads as established by REP 2014?		
	No	Yes	
	0	1	

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Backup power to face floods and/or high winds	Percentage of backup power from renewable sources		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
	Number of electricity sources providing at least 5% of the total power supply capacity		
	1 source	2 sources	More than 3 sources
	0	1	2
Recovery capacity of the energy system to face floods and/or high winds	Percentage of separate circuit installations (with circuit breakers)		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
	Percentage of electrical installations raised by 50% above ground level		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
Backup water to face floods and/or high winds	Number of sources providing at least 5% of the total water supply capacity		
	1 source	2 sources	More than 3 sources
	0	1	2
	Percentage of water use from water recycling		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
The capacity of the water system to recover from floods and/or high winds	Dwelling's water reserve capacity		
	0% of the total to be used	Up to 50% of the total to be used	Up to 100% of the total to be used
	0	1	2
Thermal comfort	Is there any external shading that minimizes solar gain overheating?		
	No	Yes	
	0	1	
	Percentage of the total area covered by treetops		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
	Percentage of the dwelling's area covered with high albedo materials that contribute to mitigating urban heat islands		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
	Solar reflectance index (SRI) of the dwelling.		
	This was not considered or was without information.	0.30 < SRI < 0.60	0.61 < SRI < 1.00
	0	1	2
Permeable areas	Percentage of the green area of the total land of the dwelling		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2

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Efficiency of materials for floods and high winds.	Percentage waterproofed surface of the dwelling's total		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
	Percentage of water-resistant materials used in construction		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
	Percentage of equipment/furniture (doors, windows) doubly secured compared to the total		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
Housing manual	Detailed information about the dwelling is developed and provided: plans, materials, design, and upkeep specifications		
	There is no information about the construction of the dwelling	It has the plans and certain materials used for the construction of the dwelling	There is detailed information on the construction and upkeep of the dwelling
	0	1	2

Table 2. Resilience indicators related to housing. Source: Preparation by the authors.

Figure 4. Specialized literature analysis process to prepare the sustainability indicators. Source: Preparation by the authors.

Site selection	Is the dwelling located on land with at least 75% previously developed?		
	This was not considered or was without information.	It is located on land with less than 75% developed	It is located on land with more than 75% developed
	0	1	2
Reduction of water consumption	Was the total indoor and outdoor water consumption reduced by at least 20% compared to standard practices?		
	This was not considered or was without information.	It was reduced by less than 20%.	It was reduced by more than 20%.
	0	1	2
	Percentage of hydrants that are WaterSense certified, or its equivalent		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
Use of alternate water sources	Percentage of on-site recycled water of the total household water expenditure		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
	Percentage of rainwater collected compared to the total water expenditure of the dwelling		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
Water use monitoring	Was a meter installed for the entire dwelling?		
	No	Yes	
	0	1	
Energy efficiency practices, design, and features	Percentage reduction below the initial energy budget		
	0% of the total or there is no information	Up to 10% of the total	Up to 20% of the total
	0	1	2
Adoption of renewable energy	Percentage of total energy derived from renewable sources, as a percentage of total energy consumption		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
Energy usage monitoring	Was a meter installed for the entire dwelling?		
	No	Yes	
	0	1	
Reducing the heat island effect	Percentage of the area with green cover		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
	Is shade provided over a percentage of the surface area of facades and the roof area?		
	No	Yes	
	0	1	

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Ventilation	Concentration of fine particles (PM2.5)		
	It was not considered, was without information, or the daily average of greater than 75 µg/m3	Daily average of up to 75 µg/m3	Daily average less than 50 µg/m3
	0	1	2
	Concentration of particulate matter (PM10)		
	It was not considered, was without information, or the daily average is greater than 37.5 µg/m3	Daily average of up to 37.5 µg/m3	Daily average less than 25 µg/m3
	0	1	2
	Concentration of sulfur dioxide (SO2)		
	It was not considered, was without information, or the daily average is greater than 50 µg/m3	Daily average of up to 50 µg/m3	Daily average less than 20 µg/m3
	0	1	2
	Ozone concentration (O3)		
	It was not considered, was without information, or the daily average is greater than 160 µg/m3	Daily average of up to 160 µg/m3	Daily average less than 100 µg/m3
	0	1	2
Lighting	Is the internal lighting zoned to allow occupant control?		
	No	Yes	
	0	1	
	Average daylighting factor		
	This was not considered or was without information.	Achieves a daylighting factor of 1.5%	Achieves a daylighting factor of 2.0%
	0	1	2
Quality of materials	Percentage or number of primary and secondary suppliers that have sustainability sourcing/procurement/management certification		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
Use of recycled materials	Percentage of project materials that are reused or recycled (plants, soil, rocks, and water are not included)		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
Availability of building materials	Percentage of total materials used that come from local sources		
	0% of the total or there is no information	Up to 50% of the total	Up to 100% of the total
	0	1	2
Life cycle analysis	Is the life cycle of cement analyzed?		
	No	Yes	
	0	1	
	Is the life cycle of steel analyzed?		
	No	Yes	
	0	1	

Table 3. Sustainability indicators related to the dwelling. Source: Preparation by the authors.

Figure 5. Floorplan of project A. Source: Preparation by the authors based on the original project outline.
Figure 6. Floorplan of project B. Source: Preparation by the authors based on the original project outline.

Classification	Points obtained in resilience	Points obtained in sustainability
Good	42 to 62	26 to 38
Satisfactory	21 to 41	13 to 25
Deficient	0 to 20	0 to 12

Table 4. Classification of Panamanian housing according to its resilience and sustainability characteristics. Source: Preparation by the authors.

The sustainability indicators (Table 3), following the goal of this research, aim to establish standards that allow measuring and monitoring the level of service, quality, comfort, and performance in terms of the housing's sustainability.

Following what is described in the methodology, these indicators use binary evaluations, limited ranges, and/or a combination. At the same time, they follow an objective typology by being based on quantitative measurements. However, the need arose to translate these data into numerical values that are useful to generate an index. So, considering each of the questions within the indicators, 62 points were related to resilience and 38, to sustainability; parameters that, when established in categories, allowed classifying the housing according to its characteristics (Table 4).

CASE STUDIES

To estimate the applicability and ease of use of the proposed indicators, projects were chosen at random and obtained from the internet to identify their resilience and sustainability weighting.

Project a

the first project is located in La Chorrera, West Panama. The chosen model has an approximate price of B/. 80,000.00 and at least 120m^2 of land, where approximately 70m^2 is the built area comprising two bedrooms, a bathroom, a living–dining room, a kitchen, a laundry area, and a parking space (Figure 5).

Project b

Project B is located in Arraiján, West Panama, and stands out for having a forestry reserve within the location's area. The model chosen has a price of B/. 120,000.00 and has sites from 200 m^2, where the built area covers approximately 120 m^2 distributed into three bedrooms, two bathrooms, a living-dining room, kitchen, laundry area, and two parking spaces (Figure 6).

Valorization of the projects

By valorizing the chosen projects with the resilience and sustainability indicators, Project A obtained a total score of 15 points, for which it classified as deficient housing in terms of the aforementioned indicators. Meanwhile, Project B accumulated 23 points, and is classified as deficient housing in terms of resilience, and satisfactory in terms of sustainability. As a summary, Table 5 presents the points obtained in each indicator.

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Indicator	Score		Comments
	Project A	Project B	
Resilience indicators			
Land use and zoning	1	1	There are no Territorial Organization Plans (TOP) in the projects' locations. However, the developer respected the zoning according to the regulations.
Location regarding areas at risk of flooding, high winds, or landslides	0	0	There is no information on the frequency of extreme events in the areas.
Characteristics of building codes and standards regarding resilience	0	0	Currently, there are no agreements on resilience applied to housing.
Application of building codes and standards	2	2	Both projects have all the corresponding permits and these have been made by qualified personnel.
Characteristics of the foundation	1	1	According to the information and location collected, the dwellings are located outside flood-risk areas.
Accessibility and evacuation capacity	1	1	Neither project considers inclusion characteristics, but the dwellings have at least two entrances.
Adaptability to the effects of climate change	0	0	They do not provide information about resistant materials or equipment.
Backup power to face floods and/or high winds	0	0	They do not contemplate any type of renewable or alternative energy.
Recovery capacity of the energy system against floods and/or high winds	0	0	They do not establish any strategy for compliance with this indicator.
Backup water capacity to face floods and/or high winds	1	0	Project A has a reserve water tank, while project B does not have any strategy to comply with this indicator.
Capacity of the water system to recover from floods and/or high winds	1	0	Project A has a reserve water tank; project B does not have any strategy to comply with this indicator
Thermal comfort	2	0	Project A has eaves on all windows to prevent the direct entry of the sun's rays during hours with greater radiation. In addition, it incorporates protective landscaping on the exterior facade to block the direct contact of the sun's rays with the wall, resulting in a more pleasant temperature. However, Project B does not have any strategy to comply with this indicator.
Permeable areas	1	1	Initially, both projects have land with green areas, but continuing with this will fall upon the owners. It is also important to note that Project B has a forestry reserve within the general area of the project.
Efficiency of materials for floods and high winds.	0	0	They do not establish any strategy for compliance with this indicator.
Housing manual	1	1	They allow project visits and explain the materials. They also indicate that they are willing to provide copies of the design plans.
Total resilience points	11	7	According to the established categorization, both projects are rated as Deficient.

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Sustainability indicators			
Site selection	2	2	They are located on sites with more than 75% developed.
Reduction of water consumption	0	0	They do not establish any strategy for compliance with this indicator.
Use of alternate water sources	0	0	They do not establish any strategy for compliance with this indicator.
Water use monitoring	1	1	They consider a meter authorized by the Institute of National Aqueducts and Sewers (IDAAN, in Spanish). This meter only measures flow but does not detect faults or leaks in the system.
Energy efficiency practices, design, and features	1	0	Project A tried to incorporate energy efficiency, although the design used has no established control of the reduction of electricity consumption. On the other hand, project B did not establish any strategy to comply with this indicator.
Adoption of renewable energy	0	0	They do not establish any strategy to comply with this indicator.
Energy usage monitoring	1	1	They consider the meter provided by the energy distribution company, which only monitors consumption.
Reducing the heat island effect	2	0	Project A has eaves and protective landscaping on the exterior facade to block the direct contact of the sun's rays. In addition, there is a forestry reserve in the project area. Meanwhile, project B does not incorporate any strategy to comply with this indicator
Ventilation	2	0	The housing of project A includes cross ventilation around the entire house to extract the warm air. Project B does not show any strategy to comply with this indicator.
Lighting	1	1	Both projects ensure that their homes have lighting by areas within the reach and control of all. However, the design of project A considered the orientation of the house following the annual solar path.
Quality of materials	1	1	They consider using concrete from environmentally responsible companies.
Use of recycled materials	0	0	They do not establish any strategy for compliance with this indicator.
Availability of building materials	2	2	They use domestic materials in more than 50% of cases.
Life cycle analysis	0	0	They do not establish any strategy to comply with this indicator.
Total sustainability points	13	8	According to the established categorization, project A is rated as Satisfactory. While Project B is rated as Deficient.

Table 5. Valorization by indicator for the case study's projects. Source: Preparation by the authors.

As could be observed, none of the dwellings comply with all the resilience and sustainability indicators. However, the indicators that were not complied with can improve their score, such is the case of the *Adoption of renewable energy,* which could be optimized with the incorporation of a renewable energy system such as solar panels, or, the *Reduction of water consumption*, through strategies such as using efficient equipment. When it comes to resilience indicators, strategies could also be included to increase the *energy recovery and backup capacity to face floods and/or high winds* through storage batteries, or, the *Adaptability to the effects of climate change* in terms of equipment or future improvements to the house.

It should be added that, regarding indicator manageability, a usability test that questioned the ease of learning, efficiency of use, ease to remember how they work, error checking, and level of satisfaction, was considered. In this way, the users who applied the indicators to evaluate the case studies indicated that they were simple to use, since the guides-questions speed up the scoring process. They also suggested that, if possible, the valorization be applied by several users to compare, discuss, and analyze the information and opinions regarding the characteristics of the project and reach the most real classification possible. As a measurement tool, this is a good basis for verifying the resilience and sustainability capacity of Panamanian housing against the present and future risks of climate change. In addition, it facilitates the identification of current weaknesses, while suggesting the necessary changes to strengthen the home.

CONCLUSIONS

Through the research, collection, and analysis of data on climate change, and the assessment of vulnerability in Panama, guidelines were established that allowed identifying the characteristics of resilient and sustainable housing for urban areas in Panama to face the challenge of climate change.

29 indicators were prioritized and established that respond to Panama's current and future impacts under climate change: 15 on resilience and 14 on sustainability. As a whole, they considered the life cycle processes of housing, from its planning to its implementation, to become useful and simple tools for evaluating and verifying its resilience and sustainability. These instruments were applied in two case studies of projects offered on the Panamanian real estate market, whose scores were, in short, far from a positive range. The projects ignored the effects of climate change from the fundamental aspects of location and design, so, if they were located in areas considered risky, there would be no solution that would correct the housing.

However, it was found that the indicators, as a measurement tool, constitute a good basis for verifying the resilience and sustainability of Panamanian housing against the present and future risks of climate change, while managing to point out the changes needed to strengthen housing in the future.

Consequently, the results of this research promote and facilitate significant progress in the country's efforts to meet the Sustainable Development Goals, as well as allow incorporating actions based on science.

It is recommended that future lines of research should be complemented in the fields of economics and finance, urban planning, environmental management, and public policies, to contribute to improving monitoring systems to guarantee the economic, social, and environmental resilience and sustainability of urban areas where most of the population will live in the coming decades.

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