# The chronological account of the impact of tropical cyclones in Nicaragua between 1971 and 2020

Gema Velásquez Espinoza[1,2], Irasema Alcántara-Ayala[3,*]

[1] Faculty of Sciences and Engineering, National Autonomous University of Nicaragua, Unan-Managua, Nicaragua
[2] Postgraduate Programme in Geography, National Autonomous University of Mexico (UNAM), Mexico
[3] Institute of Geography, National Autonomous University of Mexico (UNAM), Mexico
* Corresponding author: ialcantara@geografia.unam.mx

**ABSTRACT**

This article provides a chronological account of the occurrence and impact of tropical cyclones in Nicaragua between 1971 and 2020. While previous research has indicated potential associations between climate change and the higher frequency of intense hurricanes, no known empirical research has focused on systematizing the chronology of the significant tropical cyclones to identify patterns of change in Nicaragua. Therefore, the principal objective of this project was to develop a general overview of the major tropical storms and hurricanes that occurred between 1971 and 2020, triggering disasters in Nicaragua. The empirical data was collected from various documents via qualitative and interpretative methodology. It included reviewing research articles, books, academic websites, databases, documents, credible reports of international organizations, and newspaper sources. This study identified that from 1971 to 2020, Nicaragua was affected by 22 tropical cyclones, which caused catastrophic damage to the territory. There are records of 17 Category 1–5 hurricanes, predominating Category 4, one with no class associated, and four tropical storms. Mitch, Felix, and Joan were the most damaging hurricanes that affected the country in the last five decades. They occurred in 1998, 2007, and 1988, respectively. Of the 22 tropical cyclones, 15 occurred during Cold ENSO, whereas only three in Warm ENSO, and four were neutral. Empirical results presented can be of value to future research on disaster risk reduction.

**KEYWORDS**

tropical cyclones; hurricanes; tropical storms; Nicaragua; disaster risk; disasters; integrated disaster risk management

Received: 28 December 2022
Accepted: 21 April 2023
Published online: 15 June 2023

Velásquez, G. E., Alcántara-Ayala, I. (2023): The chronological account of the impact of tropical cyclones in Nicaragua between 1971 and 2020. AUC Geographica 58(1), 74–95
https://doi.org/10.14712/23361980.2023.7

## 1. Introduction

Central America and the Caribbean (CAC) is one of the regions most threatened and affected by various natural and socio-natural hazards (earthquakes, volcanic eruptions, landslides, floods, etc.). Tropical Cyclones (TCs) are one of the most significant hazards that occur every year. Nicaragua is no exception; disasters caused by hazards, primarily floods, and landslides associated with hurricanes and TSs, are frequent. Nicaragua's climatic exposure derives from its geographical position, given its location between latitudes 11° and 15° North, where several complex meteorological systems converge that cause rain and atmospheric phenomena common to all the tropical countries of the Caribbean Basin. The amount of precipitation depends on the different atmospheric systems; its distribution is mainly due to local factors such as the relief and the orientation of the coasts that mark the differences in precipitation between the Pacific and Atlantic coasts (Incer et al. 2000).

The rapidly increasing and unplanned urban population growth, along with the establishment of informal settlements in lower basins and valleys in Nicaragua, often mirroring the vulnerability of its inhabitants produced mainly by poverty and inequality, have amplified people's exposure to flooding and the consequent impact of associated disasters (GFDRR 2010).

Estimations provided by the World Bank suggest that between 1994 and 2013, in Nicaragua, hydrometeorological triggered disasters involved annual losses of US$301.75 million, much the same as ana yearly loss of 1.71% of its gross domestic product (GDP). These numbers indicate the potential significance of major disaster events in the government's effort to end extreme poverty and face the threat of overturning development (World Bank 2021).

Moreover, the country continues to face significant economic vulnerabilities, for example, high public debt levels, the external deficit of its current account, and the large dollarization of its economy (ALADI 2009). In addition, the territory is suffering alterations, such as environmental degradation, that have consequences in the present and are projected to future generations. Disasters and the effects of human activity on the environment affect the quality of life and the population's options since they impact physical, human, and social assets through mortality, loss of housing and infrastructure, or temporary or permanent migration (CEPAL 2002).

According to the Inform Annual Report 2021, considering a rating between 0 and 10, Nicaragua has a risk profile of 4.6, in other words, a medium risk index. While its index of vulnerability and exposure and lack of coping capacity is 5.3, the index for vulnerability is 3.5, and for disasters related to natural hazards is 6.6. (Tab. 1) (Inter-Agency Standing Committee and the European Commission 2021).

Although the risk index of Nicaragua for floods is medium (5.1), the continuous debilitating effects of disasters caused by TCs in the territory have undermined the country's ability to recover, as mirrored by hurricane Mitch in 1998 and, most recently, Eta and Iota in 2020.

Future flood scenarios are of great concern and have been recognized in the last few decades. It has been suggested that the current 'warming of the

**Tab 1.** Nicaragua risk profile.

| | | | |
|---|---|---|---|
| **INFORM RISK** | **4.6** | Inequality | 5.7 |
| 3-year trend | Stable | Economic dependency | 2.4 |
| Rank | 60 | Vulnerable groups | 1.6 |
| Reliability Index* | 3.6 | Uprooted people | 0.9 |
| **HAZARD & EXPOSURE** | **5.3** | Health conditions | 1.0 |
| Natural | 6.6 | Children U5 | 1.2 |
| Earthquake | 9.5 | Recent shocks | 1.9 |
| Flood | 5.1 | Food security | 4.5 |
| Tsunami | 8.1 | Other vulnerable groups | 2.3 |
| Tropical cyclone | 3.6 | **LACK OF COPING CAPACITY** | **5.3** |
| Drought | 4.1 | Institutional | 6.0 |
| Epidemic | 5.9 | Disaster Risk Reduction | 4.7 |
| Human | 3.6 | Governance | 7.2 |
| Projected conflict risk | 5.1 | Infrastructure | 4.5 |
| Current highly violent conflict intensity | 0.0 | Communication | 4.1 |
| **VULNERABILITY** | **3.5** | Physical infrastructure | 5.0 |
| Socio-Economic Vulnerability | 5.0 | Access to healthcare | 4.4 |
| Development & Deprivation | 6.0 | * Reliability Index: more reliable 0-10 less reliable | |

Source: Inter-Agency Standing Committee and the European Commission 2021).

climate system is unequivocal' (IPCC 2007); and that the frequency of intense hurricanes will likely increase with future climate change (IPCC 2012). Similarly, data from several studies have identified that such an increase could result in more intense storms over the next 50 years (Bender et al. 2010; Done et al. 2012; IPCC 2012). Indeed, the presence of hurricanes categories 4 and 5 considerably impacts countries with high vulnerability and exposure, such as Nicaragua.

Matinez et al. (2023) recently suggested an increase in significant hurricane occurrence and intensity in the North Atlantic and Northeast Pacific basins from 1970 to 2021. They argued that most interannual variability could be attributed to physical variables in the North Atlantic basin, comprising Vertical Wind Shear (VWS), Atlantic Multidecadal Oscillation (AMO), and El Niño-Southern Oscillation (ENSO), particularly with La Niña phases. In contrast, the critical variables in the Northeast Pacific basin are sea surface temperatures, relative humidity, and Trans-Niño Index.

It has also been shown that CAC faces significant challenges associated with climate change. Projections of the number of people at risk of future displacement by climate change and sea level rise in this region range from tens of millions to hundreds of millions by the end of this century, depending on the level of warming and conditions of exposure. As such, the influence of climate change on temporary, seasonal, or permanent migration leads to compounding people's exposure and vulnerability. This is highly associated with the impact of disasters triggered by precipitation from hurricanes and TSs. Consequently, population groups in the most vulnerable areas exposed to cascading risks, including Nicaragua, urgently need improved adaptive capacity (IPCC 2022).

Additionally, significant concerns on water security, severe health effects due to increasing epidemics, in particular vector-borne diseases, coral reef ecosystems degradation due to coral bleaching, food security due to frequent and extreme droughts, along with damages to lite and infrastructure due to floods, landslides, sea level rise, storm surges, and coastal erosion are also derived from climate change (IPCC 2023).

In the COVID-19 pandemic, the severe impact of hurricanes Eta and Iota in 2020 called for a detailed examination of these phenomena through time. This goes hand in hand with the fact that disaster risk knowledge is an essential component of integrated disaster risk reduction and the first step to understanding disaster risk. Likewise, this effort also concerns one of the Sendai Framework for Disaster Risk Reduction guiding principles, emphasizing that attention should be given to multi-hazard approaches and inclusive risk-informed decision-making (UNISDR 2015).

What is clear is that human-caused climate change is already having a considerable impact on weather and climate extremes in every region of the world, and Nicaragua, as all the other vulnerable communities that have in the past contributed to a lesser extent to current patterns of climate change, are excessively affected (IPCC 2023).

Studying the occurrence and impact of disasters triggered by hurricanes and TSs has grown in importance and has contributed genuinely and significantly to understanding disaster risk worldwide. Likewise, hazard knowledge has been acknowledged as a critical element in such an endeavor. However, until now, at the national level, little importance has been given to systematizing information about the historical occurrence of TSs and hurricanes in Nicaragua.

It is contended that in countries such as Nicaragua, lack of information is one of the first reasons for a weak interface between science and the policy domain to improve the decision-making ability of disaster risk management. Therefore, as a first step to such a challenge, the main objective of this work is to present a general overview of the significant TSs and hurricanes between 1971 and 2020, triggering disasters in Nicaragua and widening the gap towards the sustainable development of the country and the region.

## 2. Study area

Nicaragua is in the northern hemisphere, between 11°–15° north latitude and 83°–88° west longitude. It is in the middle of the Central American isthmus. It comprises 15 departments and two autonomous regions,


Fig. 1 Location map of Nicaragua.

the North and South Atlantic Autonomous Regions. The Nicaraguan territory has an approximate area of 130,370 km$^2$, which makes it the largest country in Central America (CA). Its climate is mainly influenced by the two oceans surrounding it, from which air masses loaded with moisture produce little precipitation until the formation of TCs (Incer et al. 2000) (Fig. 1).

It has a tropical climate with slight seasonal variation in temperature, ranging between 21–27 °C. It is characterized by two rainfall seasons: the 'wet' season occurs between May and October, whereas the 'dry' season is from November to April. The 'Canícula' is a dry period that regularly interrupts the wet season during late July and early August. Owing to its geographic location in the path of Pacific cyclones and Atlantic hurricanes, the territory is subject to increased rainfall intensity and strong winds from July–October. El Niño Southern Oscillation (ENSO) fluctuations during June and August bring relatively warmer, drier, colder, and wetter conditions, respectively (CCKP-World Bank n.d.).

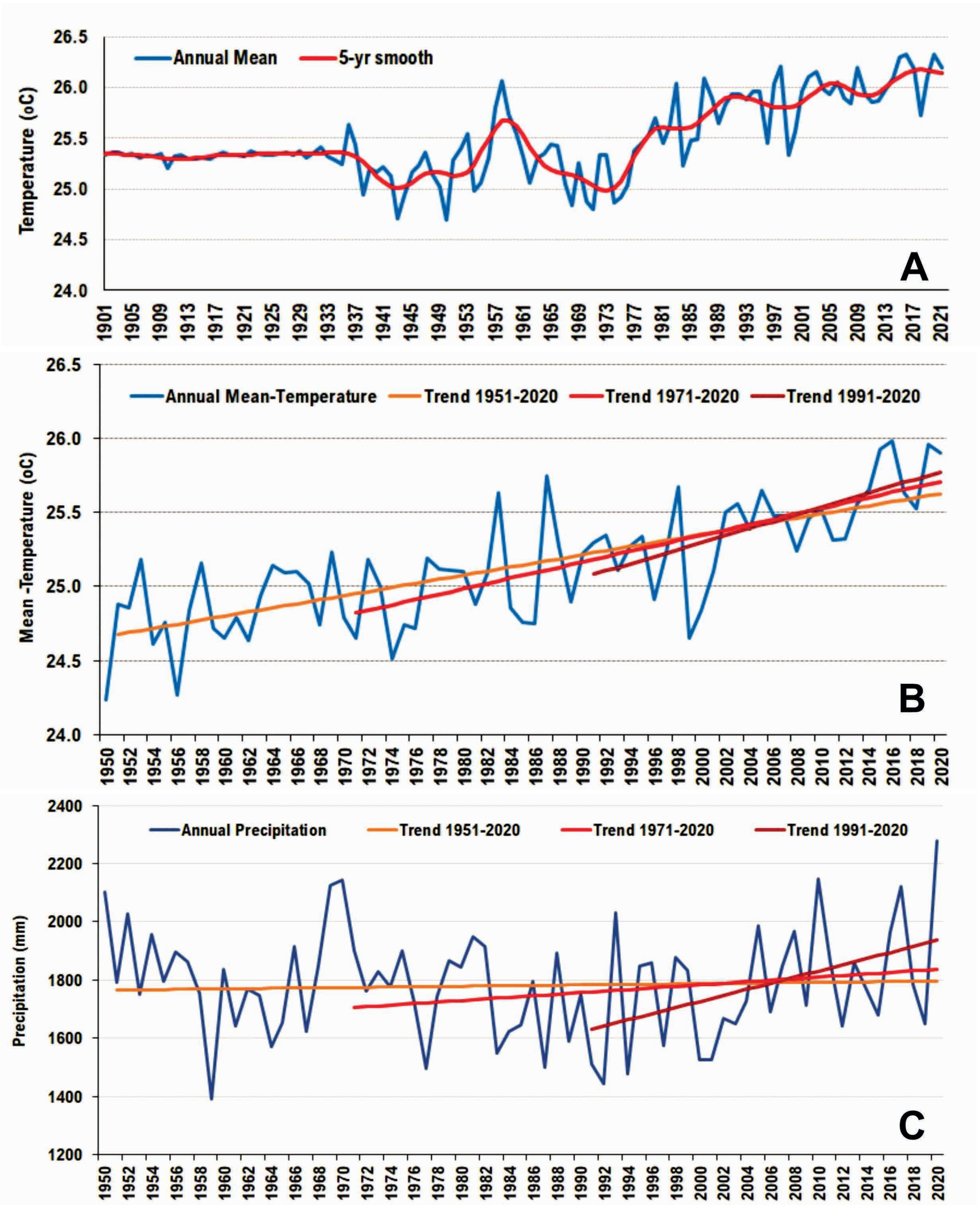


Fig. 2 Observed average annual mean-temperature for 1901–2021 (upper graph), mean-temperature annual trends (middle chart), and mean-precipitation annual trends (lower graph) with the significance of trend per decade and in Nicaragua.
Source: CCKP-World Bank n.d.

The population of Nicaragua is more than six million inhabitants (three million men and three million women), and its economically active population is 3,017,985 (World Bank 2021). Most economic activities occur in the Pacific coast's lowlands; the Atlantic coast is less developed, lacks infrastructure, and has forestry, fishing, and mining resources. The country has a long agricultural tradition on which it has based its economy, generating the main export crops (coffee, sugar cane, cotton, bananas, sesame, and peanuts) and domestic consumption (rice, beans, corn, and sorghum) (ALADI 2009).

As for any part of the world, in Nicaragua, the emergence of the climate change signal over the historical period increases towards the present. The annual mean temperature from 1901 to 2020 shows a clear increasing tendency (Fig. 2A). The minimum annual mean temperature was recorded in 1943 and 1950 (24.7 °C), whereas the maximum of 26.3 occurred in 2015, 2016, and 2020. The intensification of the forced change over the natural variability can be identified by comparing an entire period with trends over more recent intervals. Accordingly, the three trend lines, 1951–2020, 1971–2020, and 1991–2020 (Fig. 2B), represent progressive trends toward present-day temperature variables in Nicaragua. Precipitation records in the last decade show trends ranging from 1631.3 mm in 1991 to 1936.3 in 2020 (Fig. 2C) (CCKP-World Bank n.d.).

Monthly anomalies of mean temperatures over longer-term time horizons using a 10-year averaging for Nicaragua are illustrated in Tab. 2. The difference in magnitude across the seasons shows higher anomalies in 2011–2022, particularly in July, August, and September.

Mean monthly precipitation trends by decades are also a good indicator of change; downward trends associated with predominant natural variability contrast those of anthropogenic nature. In the case of Nicaragua, these trends are illustrated in Tab. 3. Increasing trends were found mainly in 2011–2020, with October being the month with the highest increase and January, August, November, and December through several decades.

## 3. Methods

This paper employs a qualitative and interpretative design of a documentary type, which is empirical in nature. The analysis domain for this investigation is spatially restricted to Nicaragua during 1971–2020. Best historical storm and hurricane tracks were obtained from the Hurricane Research Division of the National Oceanic and Atmospheric Administration database HURDAT2 (1971–2020). Essential core data on the occurrence and effects of disasters in Nicaragua was retrieved from the Emergency Events

**Tab. 2** Mean monthly temperature trends by decades in Nicaragua. Source: CCKP-World Bank n.d.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2011–2020** | 0.50 | 0.52 | 0.23 | 0.48 | 0.40 | 0.54 | 0.70 | 0.64 | 0.61 | 0.52 | 0.54 | 0.60 |
| **2001–2010** | 0.30 | 0.34 | 0.30 | 0.27 | 0.14 | 0.28 | 0.30 | 0.33 | 0.35 | 0.38 | 0.10 | 0.33 |
| **1991–2000** | 0.10 | 0.09 | −0.03 | 0.13 | −0.03 | −0.01 | 0.03 | −0.07 | −0.05 | −0.04 | 0.03 | 0.01 |
| **1981–1990** | −0.12 | −0.02 | 0.00 | −0.03 | 0.11 | 0.00 | −0.19 | −0.12 | −0.17 | −0.11 | 0.11 | 0.03 |
| **1971–1980** | −0.21 | −0.31 | −0.18 | −0.37 | −0.09 | −0.24 | −0.13 | −0.29 | −0.26 | −0.17 | −0.07 | −0.32 |
| **1961–1970** | −0.15 | −0.16 | −0.05 | −0.27 | −0.14 | −0.22 | −0.19 | −0.17 | −0.26 | −0.22 | −0.38 | −0.23 |
| **1951–1960** | −0.43 | −0.47 | −0.28 | −0.21 | −0.39 | −0.37 | −0.52 | −0.33 | −0.21 | −0.36 | −0.34 | −0.41 |

**−0.4** **−0.2** **0** 0.2 0.4 0.6 0.8

**Tab. 3** Mean monthly precipitation trends by decades in Nicaragua. Source: CCKP-World Bank n.d.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2011–2020** | 0.47 | 4.67 | 4.98 | 2.77 | 30.88 | 0.00 | −32.21 | −10.76 | 2.87 | 44.14 | 22.60 | 9.30 |
| **2001–2010** | −1.49 | −0.28 | −1.20 | −1.61 | 29.46 | −11.66 | 6.31 | 14.63 | −9.37 | −10.63 | 4.01 | −6.49 |
| **1991–2000** | −5.81 | −3.75 | −5.85 | −7.98 | −17.27 | −4.68 | −13.95 | 0.38 | 1.02 | −10.93 | −4.61 | −9.57 |
| **1981–1990** | −4.49 | 1.46 | −1.05 | −10.60 | −19.50 | −8.96 | 19.11 | 12.08 | −1.44 | −30.20 | −18.79 | 2.34 |
| **1971–1980** | 3.66 | −1.65 | 1.92 | 8.40 | −18.23 | −9.00 | −1.94 | 5.14 | 24.65 | −7.17 | 8.86 | −11.05 |
| **1961–1970** | 6.38 | −1.72 | 5.31 | 11.94 | −14.90 | 10.88 | −14.71 | −17.78 | 7.30 | 15.71 | 6.13 | 7.84 |
| **1951–1960** | 1.27 | 1.27 | −4.10 | −2.92 | 9.55 | 23.42 | 37.40 | −3.70 | −25.03 | −0.92 | −18.19 | 7.62 |

**−40** **−30** **−20** −10 0 10 20 30 40 50

Database (EM-DAT) database launched by the Centre for Research on the Epidemiology of Disasters (CRED) EM-DAT (1971–2020).

To establish the chronology of TCs that affected Nicaragua, the trajectory segments of the hurricanes in the base of Hurdat2 (1971–2020) were imported into a Geographic Information System (GIS). The Hurdat2 data on which the description was based include the post-tropical phases of storms that started as TCs. Data imported to the GIS included recording the specific dates on which they affected the territory considering its intensity, record of maximum speed reported (m/s), and pressure (Pa).

To conduct this empirical study, research articles, books, academic websites, databases, documents, credible reports of international organizations, and newspaper sources were reviewed and searched based on the aim of the investigation. The information corresponding to those TCs classified as hurricanes and some TSs that have caused disasters in the Nicaraguan territory throughout its five decades of history was extracted from the NOAA HURDAT database. Information on the impact of disasters associated with hurricanes was recollected from EM-DAT. Additionally, due to the limited information available on TCs from a historical perspective, a review of technical reports from SINAPRED (National System for Disaster Prevention, Mitigation, and Attention) and newspaper archives was conducted.

## 4. Results

Nicaragua has historically been affected by hydrometeorological phenomena; 170 events were recorded in the 20th century. Data after 1900 is only found in references in colonial reports and chronicles. It is known that, since the discovery of America, 216 hurricanes have directly and indirectly affected the Nicaraguan territory. Of all, 90 are from this century, and half arrived directly on the coast. In the last thirty years, climatic phenomena have been the most frequent threat in Nicaragua (Incer et al. 2000). From 1971 to 2020, Nicaragua was affected by 22 TCs, which caused catastrophic damage to the territory. Of these TCs, there are records of 17, with a predominance of Category four and one with no class associated, along with four TSs (Alleta, Bret, Alma, and Matthew) (Tab. 4).

**Tab. 4** Hurricanes and TSs that triggered disasters in Nicaragua from 1971 to 2020. Source: compiled from HURDAT database.

| Name | Typology | Date | Maximum winds (m/s) | Pressure (Pa) | Category |
|---|---|---|---|---|---|
| **Period 1971–1980** | | | | | |
| Edith | H | September 5–17, 1971 | 72 | 94,300 | 5 |
| Irene | H | September 16–20, 1971 | 34 | 98,900 | 1 |
| Fifí | H | September 14–22, 1974 | 49 | 97,100 | 2 |
| **Period 1981–1990** | | | | | |
| Alleta | TS | May 22–28, 1982 | 26 | – | – |
| Joan | H | October 10–23, 1988 | 64 | 93,200 | 4 |
| **Period 1991–2000** | | | | | |
| Bret | TS | August 4–11, 1993 | 20 | 100,200 | – |
| Gert | H | September 14–21, 1993 | 44 | 97,000 | 2 |
| Cesar-Douglas | H | July 24–29, 1996 | 38 | 98,500 | 4 |
| Mitch | H | October 22–November 5 1998 | 80 | 90,500 | 5 |
| Keith | H | September 28–October 6, 2000 | 59 | 93,900 | 4 |
| **Period 2001–2010** | | | | | |
| Michelle | H | October 29–November 5 2001 | 62 | 93,300 | 4 |
| Isidore | H | September 14–27, 2002 | 56 | 93,400 | 3 |
| Stan | H | October 1–5, 2005 | 36 | 97,700 | 1 |
| Beta | H | October 26–31, 2005. | 51 | 96,200 | 2 |
| Félix | H | August 31–September 5, 2007 | 72 | 93,400 | 5 |
| Alma | TS | May 30, 2008 | 28 | 99,980 | – |
| Ida | H | November 4–10, 2009 | 36 | 98,500 | 1 |
| Matthew | TS | September 23, 2010 | 26 | 99,800 | – |
| **Period 2011–2020** | | | | | |
| Otto | H | November 20–26, 2016 | 51 | 97,500 | 3 |
| Nate | H | October 4–8, 2017 | 41 | 98,100 | 1 |
| Eta | H | October 3–November 13, 2020 | 67 | 92,200 | 4 |
| Iota | H | November 13–18, 2020 | 46–69 | 91,700 | 5 |

H: Hurricane, TS: Tropical Storms

## 4.1 Decadal impact of hurricanes

### 4.1.1 Period 1971–1980

#### *4.1.1.1 Hurricane Edith*

Hurricane Edith was the strongest hurricane (Category 5) that formed during the 1971 Atlantic hurricane season. It was first observed on September 2, near 12° N and 35° W. On September 8, Edith reached hurricane strength with sustained winds of 33 m/s and a central pressure of 99300 Pa. Edith's trajectory was controlled by a narrow, high-pressure ridge that extended from the southern Atlantic to the south of the Gulf of Mexico and protected it from southern currents that would have turned it north. It is worth mentioning that the behavior of Hurricane Edith was like that of Hurricane Camille (1969) and Celia (1979). Riehl (1979) considered that this phenomenon is because the transformation in the upper troposphere may be the source of the baroclinic release of energies that cause explosive deepening in some hurricanes (Fig. 3A) (National Hurricane Center 1997a).

This hurricane entered Nicaraguan territory with winds of 80 m/s and pressure of 94,300 Pa, affecting the North Atlantic Autonomous Region (RAAN). The highest accumulations of precipitation during this event were in Corinto (178 mm), Rivas (170 mm), and Chinandega (111 mm) (INETER 1998). In addition, 80 deaths were reported, 600 houses were destroyed, and approximately 4,000 people were without food. Two fishing boats sank, large banana plantations were destroyed, and Cabo Gracias a Dios was held incommunicado for several days. In Chinandega, several communities were flooded (El Nuevo Diario 2005).

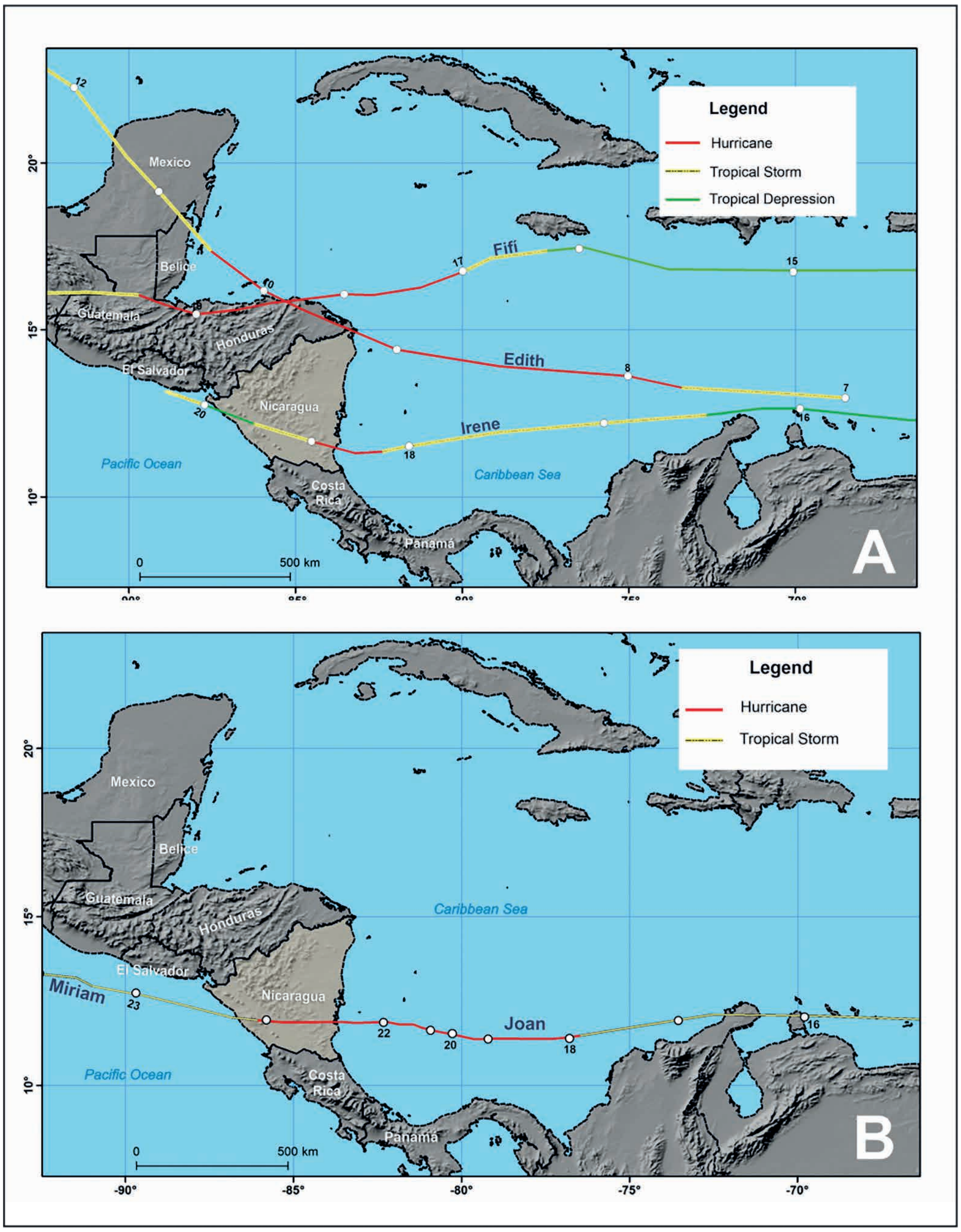


**Fig. 3** The trajectory of hurricanes in Nicaragua in 1971–1980 (A) and 1981–1990 (B). Source: *HURDAT database*.

#### 4.1.1.2 Hurricane Irene

A week after Hurricane Edith affected Nicaraguan territory, between September 16 and 20, 1971, the country was again impacted by another hurricane called Irene. This hurricane affected the South Atlantic Autonomous Region (RAAS), specifically in Punta Gorda, Bluefields (Fig. 3A). The highest accumulations of precipitation during the five days of affectation of this event were recorded in Rivas (212 mm), Corinto (200 mm), and Bluefields (192 mm). Its winds were 27.7 m/s, destroying 27 houses in Bluefields and San Juan del Norte (Consorcio ERN America Latina n.d.). In the department of Rivas, two people died due to the floods; 1,500 affected people were reported (INETER 1998).

#### 4.1.1.3 Hurricane Fifi

Fifi was the third hurricane to form in the 1974 Atlantic hurricane season. Between September 14 and 22, Hurricane Fifi penetrated the southern part of Honduras, reaching hurricane strength with sustained winds of 49 m/s and a central pressure of 97,100 Pa. Hurricane Fifi is among the most devastating hurricanes that have hit the Western Hemisphere, with Honduras being the country where it caused the most significant disaster (National Hurricane Center 1997b) (Fig. 3A). In Nicaragua, heavy rainfall was generated, causing floods throughout the country. Some communities were isolated, and some houses were destroyed, mainly near the Honduras border. The highest daily precipitation values during this event were recorded on day 18. The highest accumulated precipitation corresponded to the Corinto (635 mm), León (530 mm), and Chinandega (368 mm) stations (INETER 1998).

### 4.1.2 Period 1981–1990

#### 4.1.2.1 Tropical Storm Alleta

Even though TS Alleta did not cross Nicaraguan territory, it indirectly affected the Pacific and Central regions of the country from May 22 to 28, 1982. The most intense precipitation occurred on days 23, 24, and 25. The highest totals accumulated during the event were recorded in the departments of Chinandega (1,457 mm), León (1,002 mm), and Corinto (896 mm) (INETER 1998).

This TS caused the death of 108 people, and at least 20,000 people were left homeless. It caused flooding in some cities such as Managua, León, and Masaya in the Pacific sector. In western Nicaragua, 90% of the banana and 60% of the corn crop were destroyed. In the North region, it affected the departments of Boaco, Matagalpa, and Chontales (La Prensa 1982). USD$465 million in losses were estimated (The Leader-Post 1982).

#### 4.1.2.2 Hurricane Joan

In 1988, the path of Hurricane Joan across the southern tip of the Caribbean was unusual. It is infrequent for a TS to transit the northern coast of South America, passing directly over Curacao in the Netherlands Antilles and the Guajira peninsula of Colombia. Earlier this century, only a 1933 TS did so, although the tracks of Edith and Irene in 1971 were only slightly north of that area (National Hurricane Center 1988).

Hurricane Joan reached the strength of a Category 4 hurricane on the Saffir-Simpson Scale on October 17 as it moved away from Colombia. On the 20th, Joan weakened, made a turn, and then resumed its westward motion and strengthened. It is estimated that the central pressure reached a minimum of 93,200 Pa at landfall on the Nicaraguan coast on October 22. Based on satellite imagery, Joan is calculated to have weakened to a TS before emerging over the Pacific Ocean on October 23. Joan was renamed Miriam upon entering the eastern Pacific Ocean basin and El Salvador and Guatemala coast. On October 28, it began to dissipate south of Acapulco, Mexico, to become a tropical depression and finally dissipated on November 2, 1988 (National Hurricane Center 1988) (Fig. 3B). The highest accumulated precipitation was recorded at the Managua (227 mm), Nandaime (215 mm), León (210 mm), Rivas (186 mm), and Juigalpa (182 mm) stations (INETER 1998).

According to press articles and reports from the Nicaraguan Embassy in Washington, D.C., Joan passed through Bluefields, causing many of the city's 6,000 houses to blow up or lose their roofs, and most of the main buildings were destroyed. There were 148 dead, 184 seriously injured, 100 missing, and 1missingshomeless throughout Nicaragua and the coastal island. Some 23,000 homes were destroyed, and another 9,000 were damaged. Approximately 15,700 cattle, 20,000 pigs, and 456,000 chickens died (El Nuevo Diario 1988a).

The rising waters destroyed 30 bridges and left another 36 seriously damaged. Some 404 miles of road sections were destroyed. In Nicaragua, approximately 120,000 people were evacuated. In addition, the most affected places in the rural sector were San Francisco Libre, Tipitapa, Ticuantepe, and El Crucero. In Bluefields, 100% of the power lines and telephone services were destroyed (El Nuevo Diario 1988b; 1988c). The Nicaraguan Embassy in Washington D.C. estimated the damage in Nicaragua at 840 million dollars (National Hurricane Center 1988).

A total of US$165.6 million in damages was estimated for transportation and communication. In the productive sector (agriculture, livestock, industry, and commerce), US$134.11 million in losses was estimated, US$161.75 million in natural resources, and US$347.21 million in the social sector (CEPAL 1988).

### 4.1.3 Period 1991–2000

#### 4.1.3.1 Tropical storm Bret

TS Bret was the second to receive a name in the 1993 Atlantic hurricane season. On August 1, a tropical wave moved off the west coast of Africa, the system that gave rise to Bret. On August 10, Bret strengthened into a TS. According to satellite estimates, Bret's maximum winds were close to 20 m/s and a pressure of 100,200 Pa when it crossed the coast of southern Nicaragua, near Punta Gorda Bay. After moving inland, Bret turned west-northwestward after moving inland, dissipating as a TS approached the Pacific coast on August 11. The system eventually regenerated into Tropical Depression 8, which later became Hurricane Greg (National Hurricane Center 1993b) (Fig. 4A).

The heavy rains associated with Bret caused ten deaths in Nicaragua; nine occurred on the high seas near the island of Maíz when a Spanish ship sank. Forty thousand people were also reportedly affected, and 25 isolated communities and seven bridges were destroyed in Nicaragua due to Bret. Almost all crops were lost on the North Atlantic coast and San Juan del Rio Coco. It is worth mentioning that the TS warning was only 8 hours in advance for the Nicaraguan coast (El Nuevo Diario 1993a; 1993b). TS Bret generated a maximum accumulated rainfall in Managua of 117 mm (INETER 1998).

#### 4.1.3.2 Hurricane Gert

Gert was the seventh named storm and the third Category 2 hurricane on the Saffir-Simpson Hurricane Scale of the 1993 Atlantic hurricane season, one month after TS Bret. Gert originated as a tropical depression over the southwestern Caribbean Sea. On September 14, it reached the strength of a TS before reaching the coast of Nicaragua (Puerto Cabezas) and passing through Honduras (Fig. 4A). The rains generated by Gert caused flooding (mainly near Bluefields, Tasbapauní, Rama, Rivas, Chontales,

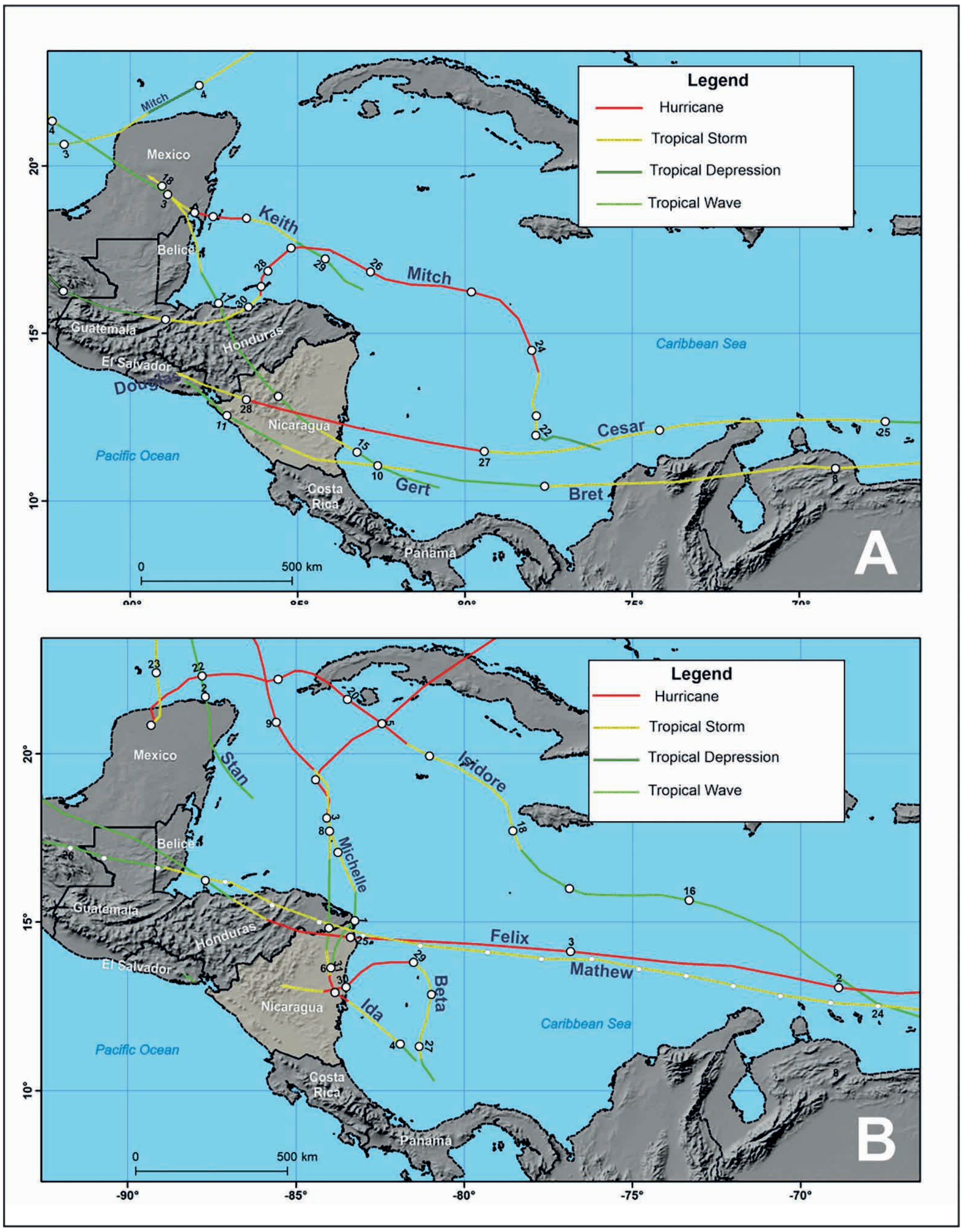


**Fig. 4** The trajectory of storms and hurricanes in Nicaragua in 1991–2000 (A) and 2001–2010 (B). Source: *HURDAT database*.

and Boaco), causing the evacuation of approximately 24,000 inhabitants. In addition, the floods caused slope instability (mudslides) and damage to roads, houses, and crops (National Hurricane Center 1993a).

#### *4.1.3.3 Hurricane Cesar-Douglas*

Hurricane Cesar was the third storm of the 1996 Atlantic hurricane season. It developed into a tropical depression on July 24 as its path moved along the north coast of Venezuela. On July 27, Cesar reached the Category of Hurricane. Cesar began to strengthen more rapidly before landfall just north of Bluefields, Nicaragua, reaching its maximum intensity (38 m/s and a minimum pressure of 98,500 Pa) on July 28. Cesar crossed Nicaragua and entered the eastern North Pacific, where it re-intensified and became Hurricane Douglas (National Hurricane Center 1996) (Fig. 4A).

Hurricane Cesar generated intense rainfall, especially in the Central Pacific sectors, registering the accumulated values in Masatepe (237 mm), Nandaime (203 mm), Managua (179 mm) (INETER 1998), Bluefields (271 mm) and Corinto (208 mm) (National Hurricane Center 1996).

In Nicaragua, six people were reported dead after the passage of Hurricane Cesar, in addition to leaving 100,000 affected, 10,000 refugees, and the destruction of hundreds of homes, roads, and significant extensions of hectares of crops affected by floods in different departments of the country (El Nuevo Diario 1996a; 1996b).

#### *4.1.3.4 Hurricane Mitch*

H urricane Mitch is known for being one of the three most destructive hurricanes in the Atlantic Ocean. On October 22, a tropical depression formed south of Kingston, Jamaica. On the 24th of the same month, it became a TS, and two days later, it was classified as a Category 5 hurricane on the Saffir-Simpson scale (Consorcio ERN America Latina n.d.) (Fig. 4A).

Hurricane Mitch was the third hurricane of the century, with wind speeds greater than 79 m/s. Its cloudy spirals covered 400 km$^2$, encompassing CA (Incer et al. 2000) and concentrating mainly on Costa Rica, El Salvador, Guatemala, and Honduras. The affected population was approximately 3.5 million, of which 20,000 died and disappeared (ECLAC 1999, cited in Alcántara-Ayala 2009). In Nicaragua, no meteorological phenomenon caused as much damage as Hurricane Mitch. The rainfall associated with Mitch exceeded the historical rainfall produced by other hurricanes that have affected the territory (INETER 1999).

Once Hurricane Mitch made landfall in Honduras, its movement was slow for a week, causing estimated rainfall of 889 mm, mainly in Honduras and Nicaragua (National Hurricane Center 1999). Floods, landslides (Fig. 5) and a high number of deaths, damage to infrastructure (roads, health, housing, education), agricultural production, and the environment occurred (ECLAC 1999). The most affected area was the country's west (León and Chinandega). Lake Xolotlán rose 3 m (from 36.41 m above sea level on October 22, 1998, to 40.12 m on October 30), receiving approximately 3,300 million m$^3$ of water (Source: ECLAC 1999; Incer et al. 2000).

**Fig. 5** The Casita volcano in western Nicaragua after a mudslide triggered by rainfall produced by Hurricane Mitch in October 1998. Source: USGS.

The damage generated by Hurricane Mitch on the Nicaraguan population was estimated at US$84 million in damage to facilities in the health sector, US$605.3 million in road infrastructure, US$471.1 million in housing, US$18 million in energy and electricity, US$12 million in communications, US$19.8 million in potable water and sewerage, US$51.3 million in education and US$1.1 million in the private sector. In addition, 867,752 people were affected (153,833 families); 254 were injured, 2,515 were dead, and 885 were missing (Álvarez et al. 1999).

#### *4.1.3.5 Hurricane Keith*

Hurricane Keith was the fifteenth tropical cyclone in the Atlantic. It formed on September 28, 2000, as a tropical depression, strengthening and becoming a TS the next day. Keith rapidly intensified over the northwestern Caribbean Sea and reached Category 4. In addition, the slow movement of Keith caused torrential rains in CA, mainly in Belize (National Hurricane Center, 2000) (Fig. 4A).

According to reports from the Meteorological Service and the media, the death toll was 12 in Nicaragua; in addition to hundreds of isolated communities, hundreds of families evacuated, and thousands of blocks of crops (corn, bananas, pastures) flooded (National Hurricane Center 2000; El Nuevo Diario 2000).

### 4.1.4 Period 2001–2010

#### *4.1.4.1 Hurricane Michelle*

The origin of Michelle was a tropical wave that moved west along the coast of Africa on October 16, 2001.

Squall activity increased on October 26 when it reached the Western Caribbean and a large area of low pressure near the coast of Nicaragua. On October 29, it became a tropical depression off the coast of Nicaragua, between Puerto Cabezas and Bluefields. On November 4, it became a Category 4 hurricane on the Saffir-Simpson scale, passing over Cuba (Fig. 4B). Michelle's slow initial movement caused widespread heavy rains in eastern Nicaragua. Press reports indicate that Nicaragua's deaths were 6, 12 missing people, more than a thousand affected, and almost 6,000 evacuees (National Hurricane Center 2001; El Nuevo Diario 2001).

#### 4.1.4.2 Hurricane Isidore

Hurricane Isidore was the second hurricane in the 2002 Atlantic hurricane season. Isidore peaked as a Category 3 hurricane causing damage in Jamaica, Cuba, Mexico, and the United States. Hurricane Isidore had a slow movement (National Hurricane Center 2002) (Fig. 4B). In Nicaragua, Hurricane Isidore generated floods, causing damage to the road network, incalculable losses in the agricultural sector, undermining bridges, and evacuating numerous families. The most affected departments were Rivas (municipality of Tola and Belén), Managua, León, and Chinandega, and the municipalities of Masatepe and Nandaime (El Nuevo Diario 2002a; 2002b; 2002c).

#### 4.1.4.3 Hurricane Stan

Category 1 Hurricane Stan generated flooding, landslides, and strong winds along its path in CA and Mexico. Stan quickly intensified into a hurricane on October 4, 2005, dissipating on October 5 over the terrain of the Mexican state of Oaxaca. It was the tenth hurricane of the Atlantic Ocean hurricane season (National Hurricane Center 2005) (Fig. 4B).

In Nicaragua, Hurricane Stan affected 2,470 people (467 families), of which 1,508 were evacuated. Homes affected included 14 destroyed, 50 semi-destroyed, and 359 flooded, in addition to 3 deaths. The departments most affected by Stan's rains were León, Chinandega, Managua, Granada, Matagalpa, and the municipality of Rosita in the North Atlantic Autonomous Region (RAAN) (SINAPRED 2005).

#### 4.1.4.4 Hurricane Beta

From October 27 to 31, 2005, Nicaragua was directly affected by Hurricane Beta. The Executive Secretariat of the National System for Disaster Prevention, Mitigation, and Response (SINAPRED) informed the Nicaraguan population that Tropical Depression No. 26 evolved into a TS. According to Law 337, a Yellow Alert is declared for the Autonomous Region of the North Atlantic (RAAN), the Autonomous Region of the South Atlantic (RAAS), and the Center-North of the Country.

On October 30, the hurricane's center made landfall near La Barra del Río Grande, north of Laguna de Perla, on the central coast of Nicaragua, and moving in a north-westerly direction, which is why it reached Hurricane Category 2 on the Saffir-Simpson hurricane scale. This is the seventh and last hurricane of the Atlantic season. Beta turned west and dissipated over western-central Nicaragua on October 31 (SINAPRED 2005) (National Hurricane Center 2006) (Fig. 4B).

SINAPRED, in coordination with the Civil Defense General Staff, reported that on October 27 from 4:00 p.m. and until November 1 at 4:00 p.m., a state of yellow alert was declared in the areas of the Autonomous Region of the North Atlantic, Autonomous Region of the South Atlantic, Center and North of the Country. In Puerto Cabezas, there was total precipitation of 162.306 mm, with 131.064 mm falling in 6 hours on October 29 (National Hurricane Center 2006).

In the South Atlantic region, 2,580 people (430 families) were evacuated, while 4,780 (637 families) were evacuated in the North Atlantic Autonomous Region. In addition, the total forestry potential area affected was estimated at 33,816 hectares and 250 hectares of lost crops (cassava, corn, beans, and plantains). Also reported were 76 destroyed homes and 430 semi-destroyed (roof, window, and door repairs), and three destroyed docks. International aid was received from countries such as Germany, Denmark, Japan, the United States, France, and organizations including WFP, UNDP, UNICEF, and FAO (SINAPRED 2005).

#### 4.1.4.5 Hurricane Felix

Category 5 Hurricane Felix caused significant damage in the Northeast of Nicaragua. On September 4, 2007, at 04:45 local time, it impacted the Nicaraguan Caribbean Coast 51 km north of Bilwi, North Atlantic Autonomous Region (RAAN). Felix is estimated to have recovered to Category 5 just before landfall near Punta Gorda, Nicaragua (1200 UTC, 4 September). After landfall, Félix rapidly weakened to a TS over northern Nicaragua (Fig. 4B and Fig. 6) (National Hurricane Center 2007).

The total precipitation between August 31 and September 5 was 180.594 mm in Puerto Cabezas (National Hurricane Center 2007). The data on the impact of Hurricane Felix in Nicaragua were as follows: 198,069 people were affected, corresponding to 33,687 families; 300 dead, of which 102 were official, 67 were identified, and 35 were unidentified; 133 disappeared and 106 notarized; 20,344 homes affected; 102 schools, 84 public buildings, and 57 churches; the total affectation was 1,394,218 hectares destroyed; of these, 86,538 ha are for agricultural use. The affectation of the wetlands and the forest area was approximately 1,394,218 ha in the RAAN (Miranda 2010). The Government of Nicaragua decreed a state of disaster for the territory of the RAAN (Region Autónoma del Atlántico Norte), as several towns were destroyed (El Nuevo Diario 2007).

**Fig. 6** Citizens of Puerto Cabezas rush to get supplies and meals after Hurricane Felix. Source: U.S. Navy photo by Mass Communication Specialist 2nd Class Zachary Borden.

### *4.1.4.6 Tropical Storm Alma*

On May 30, 2008, originated in the Pacific Ocean, Tropical Depression 1 evolved into TS Alma, entering Nicaraguan territory near León. At this point, Alma's maximum winds were close to 27.5 m/s, and a pressure of 99,400 Pa. Alma mainly affected the departments of León, Chinandega, Managua, Masaya, Carazo, Granada, and Rivas (ReliefWeb 2008). After crossing the coast of Nicaragua, Alma began to weaken, but it maintained TS strength as it moved toward southern Honduras (National Hurricane Center 2008). Alma caused damage to the housing infrastructure, as well as damage to bridges and the suspension of essential water and energy services (Fig. 4B) (El Nuevo Diario 2008a; 2008b).

### *4.1.4.7 Hurricane Ida*

Ida was a late-season 2009 hurricane that significantly impacted the eastern coast of Nicaragua. It is estimated that the depression became a TS on November 4 while moving slowly toward the Northwest, toward the coast of Nicaragua. On November 5, additional intensification occurred, and Ida became a Category 2 hurricane on the Saffir-Simpson scale six hours after Ida made landfall on the eastern coast of Nicaraguan territory. Ida weakened as it moved north over the mountains between the Nicaraguan and Honduran border. Then it moved over the water to the north-eastern part of Honduras and strengthened again (Fig. 4B) (National Hurricane Center 2009).

More than 21,000 people were affected, and between 6,000 and 8,000 people evacuated reported. In addition to 530 homes destroyed, 80% of the power lines collapsed, lack of drinking water service, partial problems in telephone service, 1,408.8 hectares of crops were damaged, and 140 wells were contaminated due to Hurricane Ida passing through the Nicaraguan Caribbean coast (National Hurricane Center 2009; El Nuevo Diario 2009).

Between November 4 and 10 in the municipalities of Puerto Cabezas, there was a rainfall of 231 mm, Bluefields 63.5 mm, Corn Island 187.96 mm, Bonanza 215.9 mm, and San Juan del Sur 76 mm (National Hurricane Center 2009).

### *4.1.4.8 Tropical Storm Matthew*

Matthew was a TS that formed on September 20, 2010. It began while it was approaching the Atlantic coast of CA and made landfall on September 24 in the extreme north of Nicaragua (east of Cape Gracias a Dios, the border between Nicaragua and Honduras). Mathew's maximum winds were close to 25 m/s and a pressure of 99,800 Pa when it crossed the North of Nicaragua on the border with Honduras. After landfall, Matthew moved west-northwestward across Honduras but did not weaken in the first 6 hours. Matthew weakened to a tropical depression as it moved across

Belize and into northern Guatemala. Its main impact was the rainfall (Fig. 4B). In Nicaragua, 65 fatalities and more than 70,000 people were affected, including the corn and bean crops (National Hurricane Center 2010).

### 4.1.5 Period 2011–2020

#### *4.1.5.1 Hurricane Otto*

Otto was the sixteenth tropical cyclone and seventh hurricane of the 2016 Atlantic hurricane season. Otto formed in the southwestern Caribbean Sea, best defined between November 17 and 18. However, in the early morning of November 20, a tropical depression began north of Colón Panama. The tropical depression became a TS on the 21st, and Otto moved slowly to the west-northwest. On the 23rd, it became a hurricane and, after intensifying, a Category 3 hurricane before landfall in southern Nicaragua.

Hurricane Otto weakened to a TS on November 25, just before leaving the Pacific coast of North-western Costa Rica, weakening on the 26th of the same month and becoming a tropical depression (Fig. 7). Otto caused winds that affected the Indio Maíz Biological Reserve (Southeast of the country), where extensive defoliation of the low forest canopy was reported. In addition, 76.2 to 152.4 mm of rainfall was recorded in the South and Southwest, the highest rainfall total being 161.29 mm in El Castillo, Nicaragua, causing flooding (National Hurricane Center 2017). Otto is one of the few TCs from the Atlantic to the eastern North Pacific basin to maintain tropical cyclone status. The last tropical cyclone to do so was Cesar, which landed in Nicaragua as a hurricane in July 1996 (National Hurricane Center 2017). The passage of this phenomenon left material damage. However, no deaths were reported due to this event (Baltodano 2016).

#### *4.1.5.2 Hurricane Nate*

Nate was the fourteenth named storm and ninth hurricane of the 2017 Atlantic hurricane season. This depression generally moved north-westward following its genesis, led by a weak subtropical ridge to the northeast, gradually strengthening. It is estimated to have become a TS shortly before landfall in north-eastern Nicaragua on October 5. Nate's strength changed little as it moved north-northwest through north-eastern Nicaragua (Puerto Cabezas) and eastern Honduras. On October 7, the TS reached hurricane intensity (Category 1) over the southeastern Gulf of Mexico (National Hurricane Center 2018) (Fig. 7).

Rains generated by Nate in Nicaragua caused flooding, and 16 deaths were reported (National Hurricane Center 2018). Likewise, SINAPRED estimated that 10,000 people were affected by the floods, seven were reported missing, 729 people evacuated, and damage to roads and houses in 31 municipalities in Nicaragua (CCRIF 2017).

#### *4.1.5.3 Hurricane Eta*

Eta constituted the 28th storm and the twelfth hurricane of the 2020 season (SINAPRED 2020). Eta's origin was a tropical wave estimated to have moved off the west coast of Africa on October 22. This system moved westward across the Atlantic for about a week, strengthening from a tropical depression into a TS on November 1. On November 2, Eta became a Category 4 hurricane on the Saffir-Simpson scale and, on November 3, made landfall in Nicaragua, about 27.78 km south-southwest of Puerto Cabezas. After crossing the coast, the hurricane moved slowly to the

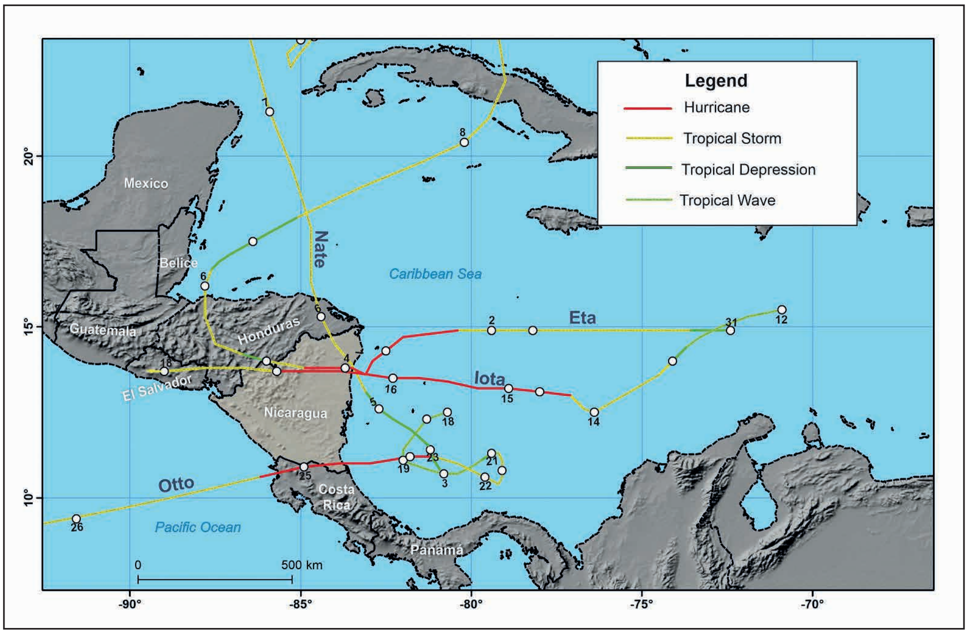


**Fig. 7** The trajectory of hurricanes in Nicaragua in 2011-2020. Source: *HURDAT database*).

west over northern Nicaragua, steadily weakening until it became a TS on November 4 (Fig. 7) (National Hurricane Center 2021a).

The intensity of Eta when touching Nicaragua was 67 m/s (maximum intensity). The Nicaraguan weather service reported a storm surge 8 to 10 m above normal near Eta's landfall. Hurricane Eta's impact was compared to Hurricane Joan in 1988 in Bluefields. The highest precipitation reported by Eta was 733 mm in Puerto Corinto and Chinandega (National Hurricane Center 2021a).

After its landfall, it headed towards the city of Rosita in the mining triangle, arriving at dawn as a Category 1 hurricane heading towards San José de Bocay in the North of Jinotega, where it reached as a TS Category, passing through the North of Wiwilí from Jinotega and left the country between the night of November 4 and the early hours of November 5 (SINAPRED 2020).

Hurricane Eta caused flooding. Three million people were affected, 30,000 were sheltered, and infrastructure was damaged in 56 municipalities. Approximately 43,000 damaged/destroyed homes were reported. In addition, there were uprooted trees, power cuts, affected bridges, and road blockades. In addition, two people died from a landslide in the Bonanza mining area (National Hurricane Center 2021a) (Fig. 8).

**Fig. 8** Effects of Hurricane Eta in Nicaragua: Children in Puerto Cabezas after Hurricane Eta (upper photo). Source: UNICEF); Debris of destroyed houses after the passage of Eta (lower image). Source: ONU News.

### *4.1.5.4 Hurricane Iota*

Iota was the 30th storm of the 2020 Atlantic hurricane season (National Hurricane Center 2021b). It was a low-latitude tropical wave that moved off the coast of Africa on October 30. It was classified as a tropical depression formed over the Central-South Caribbean Sea on November 13; the depression continued to strengthen, becoming a TS 6 hours later. From November 14 to November 16, Iota strengthened into a Category 5 hurricane on the Saffir-Simpson Hurricane Scale, with winds of 68 m/s (National Hurricane Center 2021b) (Fig. 7 and Fig. 9).

On November 17, Hurricane Iota landed on the easternmost of Nicaragua near However Lagoon and the mouth of the Wawa, becoming a TS that same day while over western Nicaragua. It left the territory through Nueva Segovia (on the border between Nicaragua and Honduras) (SINAPRED 2020). There was little information on land wind associated with Hurricane Iota due to the passage of Hurricane Eta through the same area almost two weeks before Iota's arrival, causing damage or destruction of meteorological observation systems in the West of the Caribbean Sea and parts of CA (National Hurricane Center 2021b). The maximum precipitation reported was 250 mm in Puerto Cabezas and 200 mm in San Marcos. The Nicaraguan Institute of Territorial Studies (INETER) estimated a storm surge of about 8 m, north and south from the town of Haulover and further north on the coast near Wawa Bar of the Nicaraguan coast where Iota impacted (National Hurricane Center 2021b).

**Fig. 9** Hurricane Iota and its passage through Nicaragua: Hurricane Iota's winds affected the infrastructure (upper photo) and housing (lower image) in Puerto Cabezas. Source: BBC News.

In Nicaragua, the damage was US$564–741 million dollars (EM-DAT n.d.; National Hurricane Center 2021b), almost more than half the estimated total damages for the Central American territory

(1.4 billion USD dollars). This damage estimate is less than expected for a Category 4 hurricane because Iota made landfall where Hurricane Eta caused extensive damage two weeks earlier. Additionally, 900,000 people were affected (EM-DAT n.d.), 39 died, and 29 were missing; 160,233 homes were left without electricity, 47,638 families lacked water service, and 35 communities had no telephone service (Fig. 9). Rains triggered by Iota caused flooding and landslides. The independent evaluation of the damage caused by the two hurricanes was quite difficult for local emergency managers (National Hurricane Center 2021b).

### 4.2 Most damaging hurricanes that have affected Nicaragua

The most significant losses of human life in Nicaragua are related to disasters triggered by seismic activity. However, the effects of TSs between 1971 and 2020 are in second place. The areas most affected in the territory are the Atlantic and Pacific Coasts (Incer et al. 2000) (Tab. 7). The meteorological phenomenon that had the most significant impact on the region was Hurricane Mitch in October 1998. Estimates indicate that 3,332 people died during this disaster (EM-DAT n.d.). Most deaths were associated with the lahar on the Casita volcano, which destroyed two villages and killed more than 2,500 people see Fig. 5 (Kerle and van Wyk de Vries 2003).

Total losses in production and capital goods were estimated at US$987.7 million, equivalent to 48.8% of GDP, 114% of exports of goods and services, 154.8% of gross fixed investment, and 16.5% of external debt. Furthermore, the impact of Hurricane Mitch had transcendental macroeconomic repercussions for the Central American region. The damaged infrastructure was to be reconstructed, opening a new opportunity to strengthen the Central American economic integration process (ECLAC 1999).

In the second place, there is Hurricane Felix in 2007, Category 5, which impacted the Nicaraguan Caribbean Coast, leaving 198,069 people affected, corresponding to 33,687 families; more than 300 dead, of which 102 were official (67 identified and 35 unidentified; 133 disappeared and 106 notarized) (Miranda 2010). The areas most affected by this hurricane were those with extreme poverty and marginalization. These were converted into one of the country's poorest areas with the lowest human development index. The passage of Hurricane Felix over the RAAN caused losses of approximately $716.31 million, equivalent to more than 14.4% of the 2006 GDP (PNUD 2008).

The third most damaging event was Category 4, Hurricane Joan, which in 1988 hit the city of Bluefields (Ruiz et al. 2013), causing 300,000 affected people and 130 deaths (EM-DAT n.d.). Approximately 300,000 to 500,000 hectares of rainforest were also affected between Bluefields and Rama, extending some 50 km from the coast (Vandermeer et al. 1990).

The hurricane occurred when the country was in a precarious economic situation, and the effects of the hurricane on gross domestic product showed its full impact in 1989. At that time, it was estimated that the agricultural sector would experience a contraction of 17% more pronounced than expected (initially more than 8%). The only economic sector where a more considerable expansion was estimated was the construction sector due to the anticipated effect of rehabilitation programs. In the medium term, the central government's financial situation was expected to worsen due to rehabilitation and reconstruction, which will pressure domestic financing unless foreign resources become available. The population settled in the regions directly affected by the hurricane were those food insecure and had limited access to nutrition, health, education, social security, and services such as water and sewage (CEPAL 1988).

The 2020 Atlantic hurricane season has been the most intense ever recorded and the only one in which two hurricanes have affected the territory. Eta and Iota occurred in November and had practically the same trajectory, contributing 37% of the total precipitation of the rainy season (May- November) in just 18 days (ONU-SINAPRED 2021).

Both hurricanes impacted the RAAN and part of the RAAS, Jinotega, Chinandega, Matagalpa, Madriz, Esteli, and Nueva Segovia. About 100,000 hectares of annual crops were exposed, including basic grains, roots, tubers, musaceaes, and vegetables. In the fishing sector, total losses were estimated at $19.6 million. The hurricanes affected 3,152,356 hectares of forests (palm, pine, broadleaf, and gallery forests) (ONU-SINAPRED 2021).

Additionally, 44 natural areas were affected, and total economic losses in environmental resources were estimated at $41 million. At the national level, the damage was reported in 16 of the 19 Local Integral Health Care Systems (SILAIS). The evolution of the COVID pandemic in Nicaragua was in a community transition stage, which increased the risk in the populations that had been evacuated and sheltered from the areas affected by hurricanes and vector diseases such as malaria and dengue. Concerning school infrastructure, 261 schools and six delegations reported destruction to their infrastructure. Damage to water, sanitation, and hygiene infrastructure was also reported, including wells and rainwater collection systems. According to data provided by the government of Nicaragua, more than 98,000 families at the urban level and more than 15,000 families at the rural level were affected (ONU-SINAPRED 2021).

Within the strategic responses in the early recovery and livelihoods sector, actions were proposed that would contribute to overcoming the diverse needs of the rural and indigenous populations directly affected. This included food assistance but was accompanied by comprehensive solutions aimed at guaranteeing the reintegration of the people into their productive activities (seed and tool supply programs, small livestock, the establishment of various crops, etc.). Government institutions coordinated these programs, maintaining coordination with the indigenous and Afro-descendant peoples of the Caribbean Coast through the Regional, Municipal, and Territorial Indigenous Governments. Other sectors were also strengthened, including food security, water and sanitation, and health (ONU-SINAPRED 2021; FAO 2021).

Historically, only a similar example to what happened in 2020, when two hurricanes were spinning toward Nicaragua, has been reported. It occurred in 1971, with Category 5 Hurricane Edith and Category 1 Hurricane Irene impacting the Caribbean Coast (RAAN and RAAS) one week apart.

### 4.3 Some insights derived from the historical account of Tropical Cyclones that have affected Nicaragua

The affectation of hurricanes and TSs in Nicaragua has historically occurred in the months included in the cyclonic season, from June to November. This chronology establishes that between 1971 and 2020, 18 hurricanes (Fig. 10A) and four TSs (Fig. 10B) affected Nicaragua. Fifty percent of the hurricanes were Category 4 or 5, while three were Category 1 and 2.

Only two hurricanes were Category 3, and the remaining one had no associated Category due to a lack of information (Tab. 5). Mitch (1998), Felix (2007), and Joan (1988) were the most damaging hurricanes that affected the country in the last five decades.

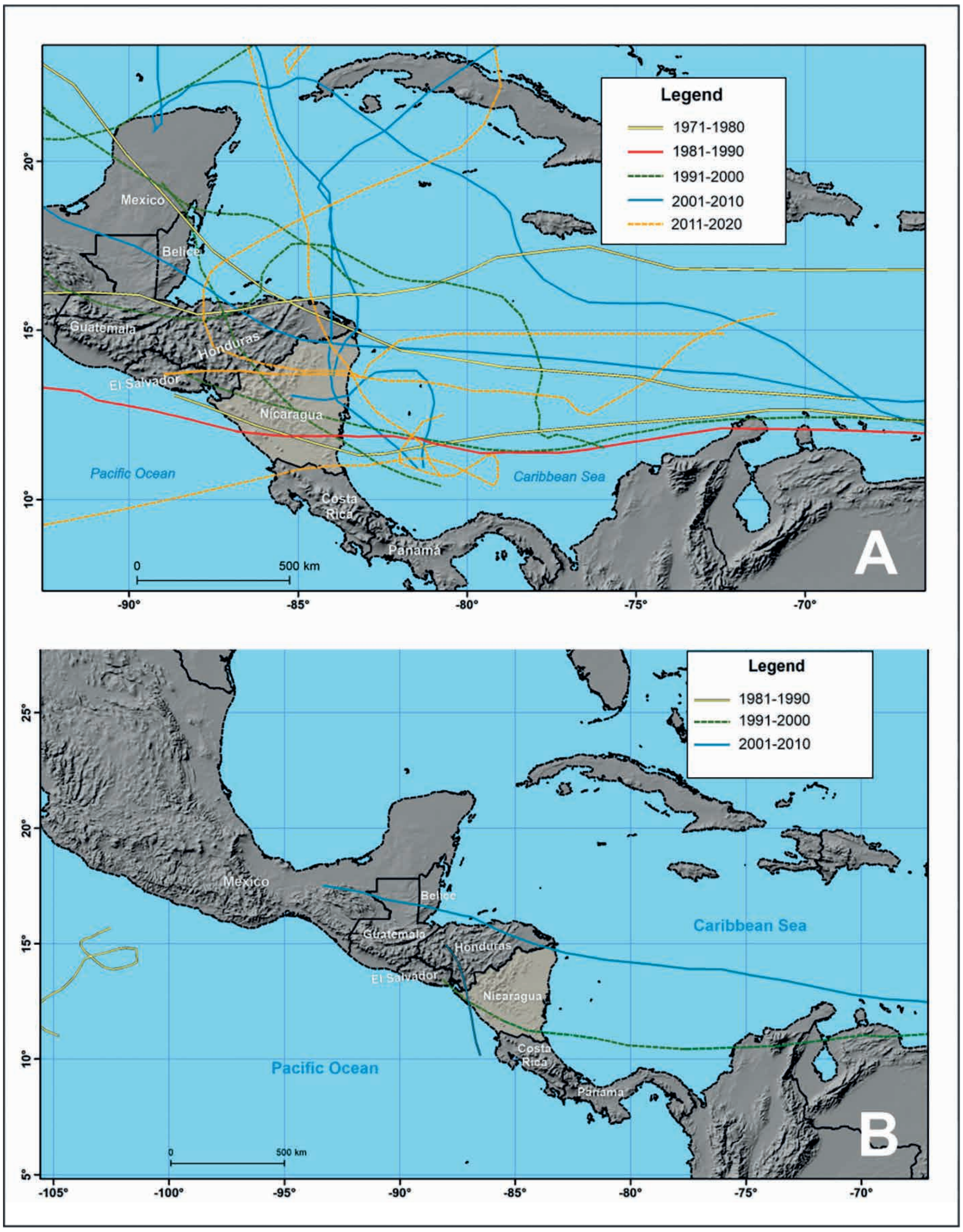


**Fig. 10** The trajectory of hurricanes (A) and tropical storms (B) in 1971–2020. Source: HURDAT database.

**Tab. 5** The frequency of Nicaragua's hurricanes ranked according to the Saffir-Simpson Scale (1971-2020).

| Category | Maximum wind speeds (m/s) | Pressure (Pa) | Number | % |
|---|---|---|---|---|
| 1 | 36–41 | 97,700–98,500 | 4 | 22.2 |
| 2 | 44–51 | 96,200–97,100 | 3 | 16.6 |
| 3 | 51–56 | 93,400–97,500 | 2 | 11.1 |
| 4 | 38–67 | 93,200–98,500 | 5 | 27.7 |
| 5 | 69–80 | 90,500–93,400 | 4 | 22.2 |
| | | Total | 18 | 100 |

These events, which originated mainly in the Atlantic Ocean, are correlated with oceanographic oscillations and physical variables such as AMO, VWS, and ENSO, particularly with the La Niña phase (Martinez et al. 2023).

Of the 22 TCs, 15 occurred during Cold ENSO, whereas only 3 in Warm ENSO and four TCs between the ENSO-neutral periods (Fig. 11 and Tab. 6).

TSs Alleta and Alma occurred in May and July, and Hurricane Cesar-Douglas. In August, one TS (Bret) and a major hurricane (Felix). In September, TS Matthew and six hurricanes were recorded (Edith, Irene,

**Tab. 6** Distribution of storms in Nicaragua in ENSO Warm, Cold, and Neutral Phases in 1971–2020.

| Event | Total number of years associated with the event | Number of Atlantic-originated storms during the event | Number of Pacific-originated storms during the event | Total number of storms that occurred during the event | Rate of Nicaragua storms occurrence per event |
|---|---|---|---|---|---|
| Warm ENSO | 23 | 2 | 1 | 3 | 0.13 |
| Cold ENSO | 22 | 14 | 1 | 15 | 0.68 |
| Neutral | 5 | 4 | 0 | 4 | 0.8 |

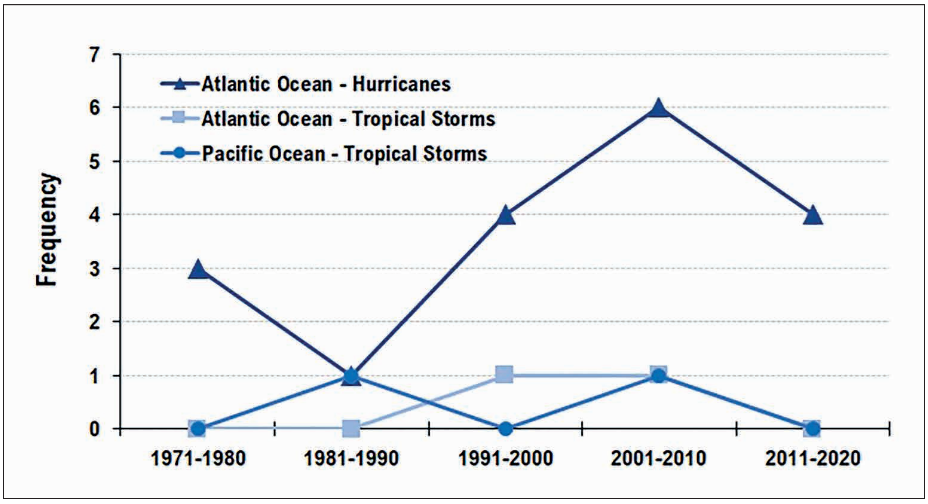


**Fig. 11** Frequency of hurricanes and tropical storms in 10-year periods in Nicaragua in 1971–2020.

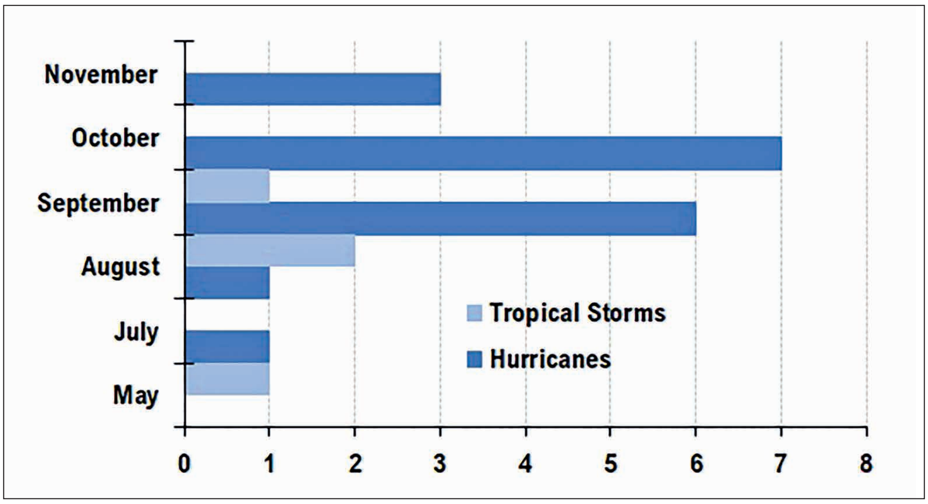


**Fig. 12** Monthly distribution of hurricanes and tropical storms in Nicaragua in 1971–2020.

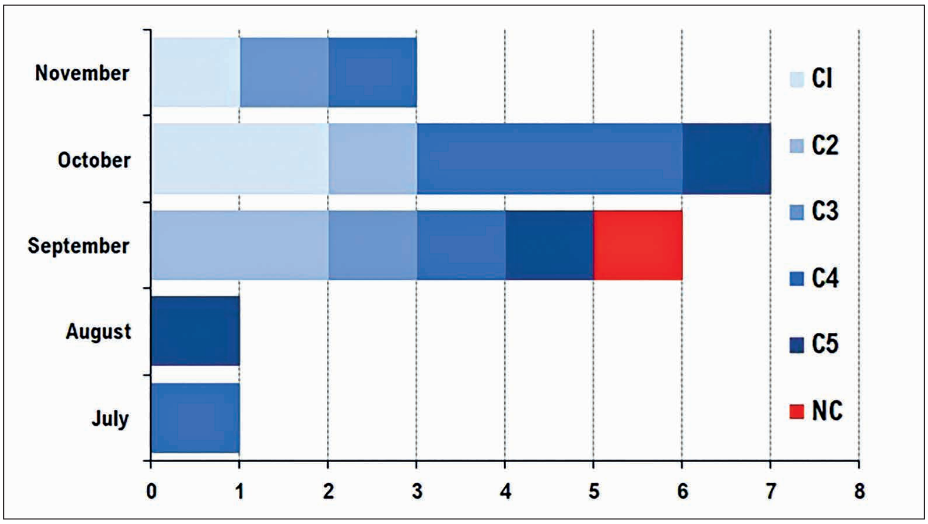


Fig. 13 Monthly distribution of significant hurricanes in Nicaragua according to the Saffir-Simpson Category scale in 1971–2020 (NC: no Category included due to lack of information).

Fifi, Gert, Keith, and Isidore), while in October, there were seven (Joan, Mitch, Mitchelle, Beta, Stan, Nate, and Eta), and in November, three (Ida, Otto, and Iota). The period was established as the Atlantic cyclone season except for May. The affected month is October and September. July is the month with the minor impacts (Fig. 12 and Fig. 13).

## 5. Discussion

The analysis of TSs and hurricanes through the bibliographic review of various sources allowed the elaboration of the chronology of TCs in Nicaragua, with specific information on the date, the intensity of landfall, and the main affectations (Tab. 4 and Tab. 7). This was

| No. | Year | Month | Event | Maximum intensity (Saffir-Simpson scale) | Intensity at landfall | Deaths | Affected population | Total damage (millions of dollars) |
|---|---|---|---|---|---|---|---|---|
| 1 | 1971 | September | Edith | 5 | 5 | 28–35 | 4,650 | 380 |
| 2 | 1971 | September | Irene | 1 | 1 | 2 | 1,500 | n.dat. |
| 3 | 1974 | September | Fifí | 2 | 2 | 0 | n.dat. | n.dat. |
| 4 | 1982 | May | Alleta | TS | TS | 71*–80 | 52,000*–70,000 | 356*–599 |
| 5 | 1988 | October | Joan | 4 | 4 | 130*–148 | 550,000 | 1,160 |
| 6 | 1993 | August | Bret | TS | TS | 37* | 123,000* | 5.1 |
| 7 | 1993 | September | Gert | 2 | TS | 8 | >24,000 | 5.6 |
| 8 | 1996 | July | Cesar–Douglas | 4 | 4 | 9–42* | 10,724*–29,500 | 10*–53 |
| 9 | 1998 | October | Mitch | 5 | NLF | 3,045–3,332* | 368,261–868,228* | 987.7*–988 |
| 10 | 2000 | September | Keith | 4 | NLF | 1* | 2,300* | 1* |
| 11 | 2001 | October | Michelle | 4 | n.dat. | 16* | 24,866* | 1* |
| 12 | 2002 | September | Isidore | 3 | NLF | 2* | 300* | 1* |
| 13 | 2005 | October | Stan | 1 | NLF | 3 | 7,780 | n.dat. |
| 14 | 2005 | October | Beta | 2 | 2 | 4* | 5,763* | n.dat. |
| 15 | 2007 | August | Félix | 5 | 5 | 188* | 188,726* | 293.3 |
| 16 | 2008 | May | Alma | TS | TS | 13* | 25,000* | n.dat. |
| 17 | 2009 | November | Ida | 1 | 1 | n.dat. | 19,897* | n.dat. |
| 18 | 2010 | September | Matthew | TS | TS | 65 | 70,000 | 10.2 |
| 19 | 2016 | November | Otto | 3 | 3 | 0 | 10,570* | 360 |
| 20 | 2017 | October | Nate | 1 | TS | 16 | 10,000 | n.dat. |
| 21 | 2020 | November | Eta | 4 | 4 | 2* | 30,000* | 178* |
| 22 | 2020 | November | Iota | 5 | 5 | 18* | 900,000* | 741* |

Tab. 7 Chronological list of all hurricanes and tropical storms and associated economic losses and human impact in Nicaragua in 1970–2020. Sources: * EM-DAT (n.d.); Consorcio ERN America Latina (n.d.); Incer et al. (2000); HURDAT2 (1971–2020); Defensa Civil (2010); SINAPRED (2008, 2016); Abate et al. (2014); UNOCHA (2010; 2017). NLF means no landfall, and n.dat. means no data is available.

quantified as an insight to analyze the lessons learned from past events and contribute to future effective mitigation strategies.

The historical account of TCs in Nicaragua presented here does not refer to any meteorological analysis or specific links to the dynamics of long-term climate change. Nonetheless, as far as it is known, previous research has yet to provide a detailed account of the occurrence and impact of tropical cyclones in Nicaragua, which can be of value to future research on disaster risk reduction.

The knowledge provided by the IPCC (2007; 2012; 2022; 2023) and other studies for CA (see Martínez et al. 2023), together with the effects of TS and hurricanes described here, suggest that knowledge of these historical records could increase sensitivity to the need to develop systematized information not only at the regional level but at the national level. This is critical for the population in the most vulnerable and exposed regions to compound and cascading risks, as they urgently need to strengthen adaptive capacity (IPCC 2022). Lacking information and knowledge is a significant obstacle to implementing integrated disaster risk management and capacity for climate change adaptation.

Moreover, the goal concerning the compromise that "Early warning systems must protect all people on Earth within five years," recently committed by the UN Secretary-General Antonio Guterres, cannot be achieved without fundamental information of past events, especially in countries where communities are highly vulnerable and exposed to hydrometeorological events such as TSs and the development of science is not as optimal as needed.

Nonetheless, it must be recognized that a few questions regarding the dynamics of TSs in CA and the Caribbean remain to be addressed. A closer look at the literature on the interlinkages between climate change and hydrometeorological hazards, especially floods and landslides, reflect significant progress on this matter at the global and regional level. However, it also reveals several gaps and shortcomings at national and subnational scales, easily reflected in the weak interface between science and policymaking.

## 6. Conclusion

In the 50 years compiled in this research, seven hurricanes of Category 4 to 5 affected the territory of Nicaragua, which caused direct and indirect harmful effects on the population and the economy, often not visible such as the social disruption that is not counted.

The information collected has made it possible to identify the sectors and services historically vulnerable to hydrometeorological phenomena, such as housing, agriculture, electrical networks, telephone service, drinking water service, roads, bridges, forestry systems, and coastal ecosystems.

Despite the effects of disasters such as those caused by hurricanes Eta and Iota, the environmental consciousness of the state and citizens remain underdeveloped, and the government not often engages in climate change adaptation measures, even though the nation depends mainly on its agricultural exportations (Bertelsmann Stiftung 2022).

This research provides a timely and necessary chronological account of the occurrence and impact of TCs in Nicaragua, which can be of value to future research on disaster risk reduction. Therefore, given the potential effect of TCs on the population, systematic efforts should be developed to ensure preparedness and integrated disaster risk management.

As reflected in the Mid-term review of the Sendai Framework for Disaster Risk Reduction 2015–2030, developing better multi-hazard early warning systems (MHEWS) is essential to reduce disaster risk and future disasters. Among other aspects, MHEWS must address how hazards interact temporally and spatially and include reliable and updated disaster risk information, including vulnerability and exposure conditions of at-risk populations (International Science Council 2023). This should be, without doubt, one of the priorities of Nicaragua and other countries in Central America and the Caribbean, particularly regarding hydrometeorological hazards.

## Acknowledgements

Thanks to the National Council of Humanities, Sciences, and Technologies (CONAHCYT) who provided a student fellowship for Gema Velásquez Espinoza and Ricardo J. Garnica-Peña for helping elaborate the maps in the article. Our sincere gratitude to the anonymous reviewers whose comments and suggestions helped improve the manuscript's final version.

## References

Abate, B., Agnesi, V., Cappadonia, C., Caprai, A., Conoscenti, C., Esposito, E., Giusseppe, G., Hernandez, M., Lopez, R., Maselli, G., Orioli, S., Porfido, S., Rodriguez, D., Rotigliano, E., Rotolo, S., Sulli, A., Marvin, M., Violante, C., Castellón, R., Elvir, O. (2014): Experiencia en análisis de la peligrosidad natural en Centroamérica Guatemala, El salvador y Nicaragua. In G. Giunta, G. Maselli (Eds.), repositorio.csuca.org. Consejo Superior Universitario Centroamericano. Available online https://repositorio.csuca.org/47.

ALADI (2009): Examen de las políticas comerciales: informe de la Secretaría de la Organización Mundial del Comercio: Nicaragua. In OMC (Ed.), Library Catalog (Koha). ALADI. Secretaría General. In Spanish. https://biblio.aladi.org/cgi-bin/koha/opac-detail.pl?biblionumber=46338&shelfbrowse_itemnumber=46397.

Alcántara-Ayala, I. (2009): Disasters in Mexico and Central America: A Little Bit More than a Century of Natural

Hazards, 75 – 97. In Natural Hazards and Human-Exacerbated Disasters in Latin America 13. Elsevier, https://doi.org/10.1016/S0928-2025(08)10004-9.
Álvarez, A., Valle, A., Morales, C. (1999): El huracán Mitch en Nicaragua. In Spanish. Available online http://cidbimena.desastres.hn/ri-hn/pdf/spa/doc12141/doc12141-contenido.pdf.
Baltodano, I. (2016). Otto golpeó poco en Nicaragua. La Prensa. In Spanish. Available online https://www.laprensani.com/2016/11/25/nacionales/2140403-otto-golpeo-poco-en.
Bender, M. A., Knutson, T. R., Tuleya, R. E., Sirutis, J. J., Vecchi, G. A., Garner, S. T., Held, I. M. (2010): Modeled impact of anthropogenic warming on the frequency of intense Atlantic hurricanes. Science 5964(327), 454–458, https://doi.org/10.1126/science.1180568.
Bertelsmann Stiftung. (2022): BTI 2022 Country Report – Nicaragua. Gütersloh: Bertelsmann Stiftung.
CCKP-World Bank. (n.d.): Climate Change Knowledge Portal for Development Practitioners and Policy Makers, World Bank, Available online https://climateknowledgeportal.worldbank.org/country/nicaragua.
CEPAL (1988). Daños ocasionados por el huracán Joan en Nicaragua: Sus efectos sobre el desarrollo económico y las condiciones de vida y requerimiento para la rehabilitación y reconstrucción. Repositorio. CEPAL. In Spanish. Available online https://repositorio.cepal.org/bitstream/handle/11362/29387/S8811198_es.pdf?sequence=1&isAllowed=y.
CEPAL (2002): La sostenibilidad del desarrollo en América Latina y el Caribe: desafíos y oportunidades, Naciones Unidas, Santiago de Chile. In Spanish.
Consorcio ERN América Latina. (n.d.). Análisis probabilista de Amenazas y Riesgos Naturales. Informe técnico ERN-CAPRA-T2-1. Revisión de Eventos Históricos Importantes. In Spanish. Available online https://ecapra.org/sites/default/files/documents/ERN-CAPRA-R7-T2-1%20-%20Eventos%20Hist%C3%B3ricos%20Importantes%20NIC.pdf.
CCRIF – The Caribbean Catastrophe Risk Insurance Facility (2017): Ciclón Tropical Nate (AL162017) Viento e Incremento de Marea Reporte Preliminar del Evento Nicaragua 8 de octubre de 2017. Available online https://www.ccrif.org/sites/default/files/publications/eventreports/20171005_CCRIF_EventBriefing_TC-Nate_20171007_NIC_Final_Spanish.pdf.
Done, J. M., Holland, G. J., Bruyère, C. L., Leung, L. R., Suzuki-Parker, A. (2012): Modeling high-impact weather and climate: lessons from a tropical cyclone perspective. NCAR/TN-490 + STR, p 28. Available online http://nldr.library.ucar.edu/repository/collections/TECH-NOTE-000-000-000-854.
ECLAC (1999): Nicaragua: Assessment of the Damage caused by Hurricane Mitch, 1998, Implications for economic and social development and for the environment. Repositorio.cepal.org. Available online https://repositorio.cepal.org/handle/11362/25356.
El Nuevo Diario (1988a): Recuento en las regiones: Pérdidas agrícolas y daños materiales. El Nuevo Diario, 2. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (1988b): Reportero narra el Apocalipsis de Bluefields. El Nuevo Diario, 12. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (1988c): Segunda avalancha de refugiados: Seis mil costeños entran a Managua. El Nuevo Diario, 14. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (1993a): Bret es depresión tropical, pero el peligro persiste. El Nuevo Diario, 12. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (1993b): Cuatro muertos y 40 mil damnificados. El Nuevo Diario, 16. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (1996a): Huracán golpeó Costa Atlántica. El Nuevo Diario, 16. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (1996b): Seis muertos por causa de huracán. El Nuevo Diario, 16. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2000): Aguas arrasan con cultivos en el municipio de Villanueva. El Nuevo Diario, 2. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2001): Desastre en el Atlántico. El Nuevo Diario, 26. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2002a) Diluvio y Estragos. El Nuevo Diario, 30. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2002b): Refugiados y daños viales. Alertas continúan. El Nuevo Diario, 32. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2002c): Rivas reporta muchos daños. Huracán se aleja, pero las lluvias continuarán. El Nuevo Diario, 18. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2005): Expediente de huracanes. El Nuevo Diario, 7(A). Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2007): Decretan Estado de Desastre en la RAAN. El Nuevo Diario, 52. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2008a): Alma nos tempraneó. El Nuevo Diario, 40. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2008b): Colapsa puente. El Nuevo Diario, 16. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
El Nuevo Diario (2009): Ida causo desastres. El Nuevo Diario, 10. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
EM-DAT (n.d.) Available online http://emdat.be/human_cost_natdis.
FAO (Organización de las Naciones Unidas para la Alimentación y la Agricultura). (2021). La república de Nicaragua 2020, huracanes Eta e Iota. Llamado urgente de asistencia. In Spanish. FAO. Available online https://www.fao.org/3/cb2821es/cb2821es.pdf.
GFDRR (2010): Disaster Risk Management in Latin America and the Caribbean Region: GFDRR Country Notes Nicaragua, World Bank.
Incer, J., Wheelock, J., Cardenal, L., Rodríguez, A. (2000): Desastres naturales de Nicaragua. Guía para conocerlos y prevenirlos. Hispamer. In Spanish
INETER (1998): Las lluvias del siglo en Nicaragua. Instituto Nicaragüense de Estudios Territoriales. Edición INETER, Managua, diciembre de 1998. Derechos Reservados Conforme a la Ley. In Spanish.
INETER (1999): Características e impactos meteorológicos del Huracán Mitch en Nicaragua. Dirección de

Meteorología y Recursos Hídricos. Revista Internacional de Ciencias de la Tierra. In Spanish.
Inter-Agency Standing Committee and the European Commission (2021): INFORM REPORT 2021 Shared evidence for managing crises and disasters, EUR 30754 EN, Publications Office of the European Union, Luxembourg, 2021, https://doi.org/10.2760/238523. Available online https://drmkc.jrc.ec.europa.eu/inform-index/Portals/0/InfoRM/2021/INFORM%20Annual%20Report%202021.pdf.
International Science Council (2023). Report for the Mid-Term Review of the Sendai Framework for Disaster Risk Reduction. Paris, France. International Science Council, https://doi.org/10.24948/2023.01.
IPCC (2007): Fourth Assessment Report, www.ipcc.ch/ipccreports/ar4-wg1.htm.
IPCC (2012): Managing the risks of extreme events and disasters to advance climate change adaptation. Available online http://ipcc-wg2.gov/SREX.
IPCC (2022): Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, https://doi.org/10.1017/9781009325844.
IPCC (2023): AR6 Synthesis Report Climate Change 2023. IPCC, Switzerland.
Kerle, N., van Wyk de Vries, B., Oppenheimer, C. (2003): New insight into the factors leading to the 1998 flank collapse and lahar disaster at Casita volcano, Nicaragua. Bulletin of Volcanology 65(5), 331–345, https://doi.org/10.1007/s00445-002-0263-9
La Prensa (1982): Evacuan a damnificados. La Prensa, 13–14. Hemeroteca UNAN-Managua, Nicaragua. In Spanish.
Matinez, L.-C., Romero, D., Alfaro, E. J. (2023): Assessment of the Spatial Variation in the Occurrence and Intensity of Mayor Hurricanes in the Western Hemisphere. Climate 2023, 11(1), 15, https://doi.org/10.3390/cli11010015.
Miranda, M. (2010): Memoria del Impacto Social y Ambiental del Huracán Félix. Wani 58, 16–21, https://doi.org/10.5377/wani.v58i0.201 In Spanish.
National Hurricane Center (1988): Preliminary Report Hurricane Joan, 10–23 October 1988. National Hurricane Center. Available online https://www.nhc.noaa.gov/archive/storm_wallets/atlantic/atl1988-prelim/joan.
National Hurricane Center (1993a): Preliminary Report. Hurricane Gert, 14–21 September 1993. Available online www.nhc.noaa.gov, https://www.nhc.noaa.gov/archive/storm_wallets/atlantic/atl1993prelim/gert/prelim01.gif.
National Hurricane Center (1993b): Preliminary Report. Tropical Storm Bret. 4-11 August 1993. Available online https://www.nhc.noaa.gov/archive/storm_wallets/atlantic/atl1993/bret.
National Hurricane Center (1996): Preliminary report Hurricane Cesar 24–29 July 1996. Available online https://www.nhc.noaa.gov/data/tcr/AL031996_Cesar.pdf.
National Hurricane Center (1997a). Preliminary report. Hurricane Edith. September 5–17, 1971. Available online www.nhc.noaa.gov, https://www.nhc.noaa.gov/archive/storm_wallets/atlantic/atl1971-prelim/edith.
National Hurricane Center (1997b): Preliminary Report. Hurricane Fifi. September 14–22, 1974. Available online www.nhc.noaa.gov, https://www.nhc.noaa.gov/archive/storm_wallets/atlantic/atl1974-prelim/fifi.
National Hurricane Center (1999): Preliminary Report. Hurricane Mitch. 22 October – 05 November 1998. Available online www.nhc.noaa.gov, https://www.nhc.noaa.gov/data/tcr/AL131998_Mitch.pdf.
National Hurricane Center (2000): Tropical Cyclone Report Hurricane Keith. Available online https://www.nhc.noaa.gov/data/tcr/AL152000_Keith.pdf.
National Hurricane Center (2001): Tropical Cyclone Report Hurricane Michelle. Available online https://www.nhc.noaa.gov/data/tcr/AL152001_Michelle.pdf.
National Hurricane Center (2002): Tropical Cyclone Report Hurricane Isidore 14–27 September 2002. Available online https://www.nhc.noaa.gov/data/tcr/AL102002_Isidore.pdf.
National Hurricane Center (2005): Tropical Cyclone Report Hurricane Stan 1–5 October 2005. Available online https://www.nhc.noaa.gov/data/tcr/AL202005_Stan.pdf.
National Hurricane Center (2006): Tropical Cyclone Report Hurricane Beta 26–31 October 2005. Available online https://www.nhc.noaa.gov/data/tcr/AL272005_Beta.pdf.
National Hurricane Center (2007): Tropical Cyclone Report Hurricane Felix. https://www.nhc.noaa.gov/data/tcr/AL062007_Felix.pdf.
National Hurricane Center (2008): Tropical Cyclone Report Tropical Storm Alma. Available online https://www.nhc.noaa.gov/data/tcr/EP012008_Alma.pdf.
National Hurricane Center (2009): Tropical Cyclone Report Hurricane Ida (AL112009) 4–10 November 2009. Available online https://www.nhc.noaa.gov/data/tcr/AL112009_Ida.pdf.
National Huricane Center (2010): Tropical Cyclone Report. Tropical Storm Matthew (AL152010). Available online https://www.nhc.noaa.gov/data/tcr/AL152010_Matthew.pdf.
National Hurricane Center (2017): Hurricane Otto 20–26 de November 2016 (AL162016, EP22016). Available online https://www.nhc.noaa.gov/data/tcr/AL162016_Otto.pdf.
National Hurricane Center (2018): Hurricane Nate, 4–8 October 2017. Available online https://www.nhc.noaa.gov/data/tcr/AL162017_Nate.pdf.
National Hurricane Center (2021a): Tropical cyclone report hurricane Eta (AL292020). Available online https://www.nhc.noaa.gov/data/tcr/AL292020_Eta.pdf.
National Hurricane Center (2021b). Tropical Cyclone Report. Hurricane Iota (AL312020). Available online https://www.nhc.noaa.gov/data/tcr/AL312020_Iota.pdf.
NOAA (2014): HURDAT Re-analysis of various data tables. Available online www.aoml.noaa.gov, https://www.aoml.noaa.gov/hrd/hurdat/Data_Storm.html.
NOAA (n.d): Available online https://www.nhc.noaa.gov/data/.
ONU-SINAPRED (2021): Hurricane Iota–Nov 2020. (2020). Reliefweb.int. Available online https://reliefweb.int/disaster/tc-2020-000227-nic.

PNUD – Programa de las Naciones Unidas para el Desarrollo (2008): Impacto del Huracán Félix en la Región Autónoma del Atlántico Norte y de las lluvias torrenciales en el Noroeste de Nicaragua. CEPAL. In Spanish. Available online https://repositorio.cepal.org/bitstream/handle/11362/25868/.LCmexL860rev1_es.pdf?sequence=1&isAllowed=y.
ReliefWeb (2008): Nicaragua: Tormenta ALMA afecta la zona del occidente – Nicaragua. In Spanish. Reliefweb.int. Available online https://reliefweb.int/report/nicaragua/nicaragua-tormenta-alma-afecta-la-zona-del-occidente.
Ruiz, J., Vandermeer J., Granzow I., Perfecto I. (2013): Regeneración de Bosques huracanados de Nicaragua (1988–2007). Wani 52, 6–16. Available online https://revistasnicaragua.cnu.edu.ni/index.php/wani/article/view/1335.
Riehl, H. (1979): Climate and weather in the tropics. London: Academic Press. Available online https://journals.sagepub.com/doi/10.1177/030913338100500322.
Defensa Civil (2010): Sistema Nacional de Defensa Civil, Nicaragua. Ministerio de Integración Nacional. In Spanish. Available online http://cidbimena.desastres.hn/pdf/spa/doc6778/doc6778-1.pdf.
SINAPRED (2005): Nicaragua: Beta convertida ya en huracán–Nicaragua. In Spanish. ReliefWeb. Available online https://reliefweb.int/report/nicaragua/nicaragua-beta-convertida-ya-en-hurac%C3%A1n.
SINAPRED (2008): Informe ejecutivo: Administración del desastre provocado por el huracán Felix 2007. In Spanish.
SINAPRED (2016): Informe de pérdidas y daños ocasionados por el huracán Otto. Diciembre 2016. In Spanish.
SINAPRED (2020): Informe final de misión. Huracán Eta e Iota. Managua, Nicaragua. Centro de documentación del SINAPRED. In Spanish.
SINAPRED (2023): Available online https://www.sinapred.gob.ni.
The Leader-Post. (1982): The Leader-Post–Google News Archive Search. News.google.com. Available online https://news.google.com/newspapers?nid=w9EjUEod0xMC&dat=19820610&printsec=frontpage&hl=en.
UNISDR – United Nations International Strategy for Disaster Reduction (2015): Sendai framework for disaster risk reduction 2015–2030. UNISDR.
UNOCHA – Oficinas de las Naciones Unidas para la Coordinación de Asunto Humanitarios (2010): Paso de huracán Matthew por Nicaragua deja al menos cinco muertos y millas de evacuados. In Spanish. Available online https://reliefweb.int/report/nicaragua/paso-de-hurac%C3%A1n-matthew-por-nicaragua-deja-al-menos-cinco-muertos-y-miles-de.
UNOCHA – Oficinas de las Naciones Unidas para la Coordinación de Asunto Humanitarios (2017): Caribe: Tormenta Tropical Nate-Flash Update No. 2 (al 6 de octubre 2017). In Spanish. Available online https://reliefweb.int/report/nicaragua/caribe-tormenta-tropical-nate-flash-update-no-2-al-6-de-oct-2017.
Vandenneer, J., Zamora, N., Yih, K., Boucher, D. (1990): Regeneración inicial en una selva tropical en la costa caribeña de Nicaragua después del huracán Juana. Re. Biol. Trop, 38(2B), 347–359. Available online https://tropicalstudies.org/rbt/attachments/volumes/vol382B/02_Vandermeer_Regeneracion_selva.pdf.
World Bank (2021): Pooling Catastrophe Risk to Protect against Natural Hazards: Nicaragua's Experience in Disaster Risk Management and Finance, Results Briefs, November 1, 2021. Available online: https://www.worldbank.org/en/results/2021/11/01/pooling-catastrophe-risk-to-protect-against-natural-hazards-nicaragua-s-experience-in-disaster-risk-management-and-finan.