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# Post-Disaster Recovery Assessment Using Sentiment Analysis of English-Language Tweets: A Tenth-Anniversary Case Study of the 2010 Haiti Earthquake

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Abstract: The 2010 Haiti earthquake stands as one of the most catastrophic events in terms of loss of life and destruction. Following an earthquake, there is an urgent demand for information. Regrettably, few studies have tracked the progress of the post-disaster recovery, leaving this phase poorly understood. In previous years, data were exclusively collected through on-site missions, but today, social media (SM) has enhanced earthquake reconnaissance teams' capacity to collect data beyond the emergency phase. However, text data from SM is unstructured, making it necessary to use natural language processing techniques to extract meaningful information. Sentiment analysis (SA), which classifies people's opinions into positive, negative, or neutral polarity, is a promising tool for understanding earthquake recovery. For the purposes of this paper, we conduct SA at the tweet level on data collected around the tenth anniversary of the earthquake using human expertise to fine-tune automatic classification methods. We conclude that the anniversary date is the best time to collect data. In our sample, 56.3% of the tweets in the sample were classified as negative, followed by positive (27.3%), neutral (8.2%), and unrelated (8.1%). In our study, we conclude that the assessment of the recovery progress based on data collected from Twitter is negative. The automatic method for SA with the highest accuracy is 'btweet'. The assessment result must be validated by stakeholders.

**Keywords:** Haiti; earthquakes; post-disaster recovery; social media (SM); Twitter; natural language processing (NLP); sentiment analysis (SA); reconstruction; vulnerability; funding mismanagement

# 1. Introduction

# 1.1. Background

Haiti, located on the western side of Hispaniola, was the first independent country in Latin America and the first black-led republic [1]. This country has beautiful landscapes with beaches visited by cruises and gorgeous mountains. Haiti has tasty traditional food [2] that can be accompanied by its national beer, and it is also the place where a brand of



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Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons. Attribution (CC BY) license (https://creativecommons.org/ licenses/by/4.0/). high-quality rum is produced and bottled. A national brand of beauty products focuses on creating sustainable jobs, protecting and conserving the island's environment and empowering Haitian women [3]. Unfortunately, this country, known as 'the pearl of the Antilles' [4], when the French colonised it, is now and for decades, the poorest country in the Western Hemisphere [5–9] and one of the poorest in the world. The debt that Haiti had to pay to France as indemnity for its independence [6,10,11], foreign interventions, poor governance and corruption [6,12], political instability [6,13–20], gang violence, organised crime [12], and disasters [18,19,21,22] have kept Haiti stuck in a downward spiral of poverty [12,19,23] since the last century. This is the reason why 80% of the basic services in the country are provided by non-governmental organisations (NGOs) [6,24].

#### 1.2. Earthquake Impact

The 2010 Haiti earthquake stands as one of the most catastrophic events in terms of human casualties and destruction [9,16,18,21,23,25,26]. At 16:53:10 EST/21:53:10 UTC on 12 January 2010, a 35 s duration quake [16,21] with a moment magnitude  $M_W = 7.0$  [8,12,14,15,17,24,27–33], depth of 13 km and an epicentre located at 18.443° N, 72.571° W approximately 25 km west and south of the capital city of Port-au-Prince [14,16,34,35] struck the city of Léogâne and the metropolitan region of Port-au-Prince [30,36,37]. The location of the case study area, along with the epicentre and the intensity of the earthquake in the Modified Mercalli scale, is presented in Figure 1.



**Figure 1.** Map showing the location of Haiti, epicentre, and intensity of the earthquake. Data source: ArcGIS Online.

The official death or missing toll was 316,000 [12,15,16,28,29,38–41], unlike the estimated death toll based on survey data, which ranged from 46,190 to 84,961 people [42]. 300,000 people became injured [8,15,21,31]. It was estimated that the injuries produced by the collapse of structures left 200 people with spinal cord injuries, 1500 with amputations, and hundreds of thousands with fractures [8,39]. Given the level of destruction, between 1.3 million (13%) [6,36,43] and 1.5 million (15%) [14,16,28,38,39,42,44] were displaced out of a population of 9.7 million [34,41]. This large displacement is explained by the destruction of 105,000 houses [18,41] and damaged 208,000 [14,16,42]. Three major sites were established [30]: Canaan, Jerusalem, and Onaville camps to host homeless people due to the earthquake. The earthquake affected around 3 million (30%) of the total population [14].

Eight hospitals were destroyed, 22 were severely damaged, and countless healthcare workers were affected [45]. Government buildings, the most remarkable being, the national palace [18], police stations, and the local headquarters of the United Nations (UN) peacekeeping team collapsed during the earthquake [17]. Around 5000 [22] (90%) schools were damaged or destroyed by the quake [15,18,46]. The Cathedral of Our Lady of the Assumption in Port-au-Prince [18] was severely damaged, and the Holy Trinity Cathedral, also in the capital of Haiti, collapsed [47]. Water and sanitation pipes were broken, and debris blocked roads [27,40]. Additionally, the port of the capital, Port-au-Prince, was also seriously affected [8]. Damages were estimated at \$8 billion [16], almost 100% of the gross domestic product (GDP) [48]; other sources estimate up to 120% of Haitians' GDP [22]; others report 113% [42]. In early March 2010, the amount of debris was estimated at 19 million m<sup>3</sup> [7].

#### 1.3. Literature Review

Camps for homeless people following the earthquake sprang up throughout Port-Au-Prince, coupled with a lack of access to clean water, healthcare experts had serious concerns about epidemic disease outbreaks [27,43]. Nine months later, between the 19 [42] and 20 October [43,49], the first case of cholera in Haiti was registered [22,23], but not within those internally displaced persons (IDP) camps, as had been anticipated by healthcare experts [49], but rather along the Artibonite River, an area unaffected by the earthquake. Weeks later, press reports pointed to the UN peacekeeping camp of Nepalese soldiers as the possible source of this epidemic [23]. It was found that a cholera outbreak had affected Kathmandu and its surroundings shortly before the Nepalese troops left for Haiti [27]. A total of 819,000 cases of cholera [23,46] were registered, with 9789 official deaths due to this illness. It took 2129 days for the UN to admit responsibility for introducing cholera to Haiti [42,50].

This devastating level of deaths, injury, destruction, displacement, and challenges was extremely traumatic for survivors [29,51]. This earthquake triggered exceptional response efforts [52]. It was the first time that the United States (U.S.) Government relied significantly on social media (SM) [53] to coordinate emergency response actions between the U.S. State Department, the U.S. armed forces and the Agency for International Development (USAID) [54]. International donors pledged between US\$9 billion to \$10.7 billion to aid Haiti's recovery [16,42,44]; other sources claim that this number was as high as \$13.3 billion [12]. NGOs raised US\$ 3.06 billion from private money [42]. The Clinton Foundation, which had previously contributed to the relief and recovery after the 2004 Indian Ocean tsunami and 2005 Hurricane Katrina, received more than US\$16 million in donations. Former President Bill Clinton himself served as the UN Special Envoy to Haiti and Co-Chair of the Interim Reconstruction Commission (IHRC) [7]. Foster children and orphans were notorious in international humanitarian aid efforts after the earthquake [15,55]. Initial reports during the emergency phase indicated that about one million orphans had become vulnerable to disease, food shortages, child traffickers, and prostitution rings [25]. 500,00 unpaid child domestic servants or "restaveks" [56,57] were the main concern.

Following an earthquake, there is an urgent demand for information to estimate the amount of humanitarian aid needed. Most authors divide post-disaster recovery into three [58] or four phases [59,60] emergency response or relief, early recovery, recovery, and development. Data collection usually takes place during the emergency phase [60] and, in some cases, during the early recovery [61]. In the recovery and development phases, data are often sparse and often poorly documented. This absence of information has resulted in limited knowledge of the progress of the recovery process after earthquakes in the medium and long term [62,63], leaving the recovery and development phases poorly understood by

practitioners and the research community [62,64–66]. Disaster anniversaries dates, such as 12 January 2020, the tenth anniversary [33,47] of the Léogâne earthquake in Haiti, provide a window of opportunity to evaluate the progress of this recovery process [67].

In previous years, data were exclusively collected through on-site missions [64]. Today, satellite imagery [68], unmanned aerial vehicles (UAVs), light detection and ranging (LiDAR), high-resolution synthetic aperture radar (SAR), interferometric synthetic-aperture radar (InSAR), real aperture radar (RAR), SM, and crowdsourcing platform have enhanced earthquake reconnaissance teams' capacity to collect data [69,70] beyond the emergency response phase. Social media are online platforms designed to encourage users to share their opinions, thoughts, feelings, and activities that they observe or in which they are involved. Hence, the information extracted from SM can reflect what happens in society in real time, which is very useful for improving situational awareness [63] during the emergency phase or for assessing the progress of the recovery in the recovery and development phases.

There is a growing debate on the use of alternative data sources such as SM for impact, emergency response, and post-disaster recovery assessments [69]. However, SM has proven to be a valuable tool to quickly collect significant amounts of disaster data [53,71–73]. Image and text data extracted from Twitter, Instagram, and the LastQuake app [74] can support emergency response operations [75–79], earthquake reconnaissance missions [73,80], and long-term recovery assessments in L'Aquila (Italy) [67,81], Haiti [62], Chile [67], and New Zealand. Developing a big picture of disaster-stricken areas recovery using SM has the possibility of complementing traditional methods to evaluate recovery processes [82]. In the project "Learning from Earthquakes" (2016–2023) [83], we collected data from SM around the tenth anniversary of selected earthquakes because we identified this as an occasion when a greater number of posts addressed the event topic.

Recovery is defined as a multidimensional, long-term process of planning and implementing actions to restore sustainable living conditions in a community after a disaster [84]. Few research studies have explored post-disaster recovery in the long term and even less focus on socioeconomic recovery [82]. In Kobe, Japan, twelve workshops were conducted by the government, 4 and 8 years after the earthquake to make a comprehensive recovery assessment using the Citizen Happiness Index. This index covered the 16-point Plan of Action and consisted of 45 individual indicators. In the workshops, two questions were formulated: (1) What does life recovery mean for earthquake victims? and (2) What factors do citizens consider useful to promote recovery? The results identified seven elements in descending order: (1) housing; (2) social ties; (3) community rebuilding; (4) physical and mental health; (5) preparedness; (6) economy, livelihood, and economic and financial situations; and (7) relationship to the government [85]. The principal drawback of this methodology is its dependence on the researcher's personal network, limiting the scope to a select cohort of stakeholders. This disadvantage is overcome by extracting data from SM [86], because it provides volume, variety of data, and real-time insights [82]. Volunteer Geographic Information (VGI) through SM has been used to support the emergency phase but seldom the recovery phase [68,87]. Post-disaster tourist recovery was monitored and assessed in the Central Philippines island regions after the Bohol earthquake and super typhoon (Haiyan) in 2013 using geotagged Flickr photos. Researchers managed to determine the progress of the post-disaster recovery of the tourism industry in the spatial dimension, contributing to the tourism rehabilitation of the case study area with their findings [68]. A systematic literature review has identified the role of SM in post-disaster recovery involving financial support and donations, social cohesion and solidarity, reconstruction, socio-economic and physical well-being, information support, mental health and emotional support and business and economic activities. Based on these findings, researchers consider

that the understanding of the scope and effectiveness of information extracted from SM in the recovery phase is still limited but promising [87].

However, image and text data from SM is unstructured, making it necessary to use natural language processing (NLP) [76] to extract meaningful information. This NLP is a branch of artificial intelligence (AI) that enables machines to understand human language by analysing sentences and words, applying different approaches to extract information, and delivering outputs [88]. One specific NLP technique is sentiment analysis (SA), or 'opinion mining'. This NLP application classifies people's opinions, attitudes and emotions towards entities and their attributes, as expressed through written text, into a specific polarity (positive, negative, or neutral) [87,89]. Sentiment analysis can be done at document, sentence, entity, and aspect level [90]. Sentiment analysis is used in customer reviews of products and places. In this research, we decided to use this NLP to assess the progress of the post-disaster recovery in Haiti after the 2010 earthquake. We use SA because we believe that recovery can be considered to be a service that governments provide to the population affected by earthquakes. Therefore, the population has the right to express their satisfaction or dissatisfaction with the progress made after the earthquake. One means to express opinions is SM platforms such as Twitter, Instagram, TikTok, Facebook, Snapchat, Threads, Bluesky, and Reddit. This research aims to validate the use of SA on text data collected from SM around the anniversary of an earthquake to assess the progress of the recovery after an earthquake in the long term and test the accuracy (ACC) of automated methods for the SA. In this case, the recovery after the Léogâne earthquake will be evaluated on its tenth anniversary, and the ACC of three automated classification models will be tested.

Sentiments and perspectives regarding the post-disaster recovery process were explored using SA and topic modelling for mining a dataset of tweets about Bali and Lombok in Indonesia posted by nonlocal Twitter users after a series of earthquakes in both places in 2018 [72]. Researchers found that the negative polarity about the study areas decreased with time. Although frustration with the housing reconstruction progress, living conditions and tourism recovery in the areas affected in Lombok still existed in 2019 [72]. Researchers using AI-based methods to detect socio-economic recovery found multiple correlations between sentiment on SM and socio-economic recovery activities involved in restarting daily routines. A group of researchers used the demand for used cars to indicate socioeconomic recovery after the Tohoku earthquake and tsunami. The reason is that literature indicates that people living in areas struck by disasters buy used cars when restarting their daily routines, given economic hardship after a disaster that makes it difficult to purchase a new vehicle. Therefore, researchers purchased Twitter data containing hashtags such as 'earthquake', 'tsunami', 'recovery, restart', and 'car', among others. Researchers found a significant correlation between tweets among the local population and the used-car demand and a significant negative correlation between tweets among people outside of the affected area and used-car demand. They found that when the local population in the affected area expressed more complex emotions, containing positive and negative words, this indicated progress in socio-economic recovery. Curiously, fewer emotions among people outside of the area were also an indication of recovery in socio-economic terms [82]. The post-disaster recovery of L'Aquila was assessed using SA on tweets collected around the 10th anniversary of the earthquake [67,81].

After highlighting the aspects that can contribute to Haiti's recovery and sustainability, the root causes of its problems, and the impacts of the 2010 earthquake explained in this introduction the importance of data collection and the limited availability of data to develop knowledge of the progress of the recovery process after earthquakes in the medium and long term. The following section lists the steps to collect and process the data, extract the information for the post-disaster recovery assessment, and conduct the preliminary

validation. The amount of data collected, the assessment of the post-disaster recovery, and the preliminary validation are presented in the Section 3. The Section 4 recognises limitations in the sampling considering the data source but explains how those limitations are overcome. Afterwards, the discussion focused on the topics in tweets classified into positive and negative polarity. The Section 5 indicates the best time to harvest data related to the anniversary and the assessment of the recovery process based on manual and automatic classification methods. This paper ends with recommendations for those who want to contribute to the post-disaster recovery assessment, what is needed in Haiti to strengthen its resilience, the problems observed in the recovery process, and suggestions for further research on this topic and case study area.

# 2. Materials and Methods

# 2.1. Data Collection

Text data related to the tenth anniversary of the earthquake were collected from Twitter and occasionally from Instagram and Facebook when a link to these SM platforms was embedded in the tweet. Although we are aware of the change in the name of this SM platform to X from 23 July 2023, we prefer to use the previous name, considering that the data were collected in 2020, when the name of this platform was still Twitter.

We tested two automated methods to evaluate the recovery of Haiti based on text data posted in English on Twitter from January 6th to 15th, 2020, days before and after the earthquake's anniversary date. This period was selected based on monitoring SM activity. The methodology comprises of seven steps, as described in Figure 2.



Figure 2. Methodology. Source: adapted from [62].

#### 2.2. Data Processing and Analysis

In the first step, we identified the hashtags related to the anniversary of the 2010 Haiti earthquake. In the second step, we purchased Twitter data posted during the observation period from a third-party vendor, using the identified hashtags as filters to collect data about the anniversary. In the third step, we selected a sample composed of original tweets posted in English about the earthquake's tenth anniversary and those that indicated economic activity at that time. We want to clarify that some of those tweets, mainly written in English, also contained words or sentences in French, Haitian Creole, Creole, Spanish, and Finnish. In the fourth step, text data were processed. Tweets and posts containing spelling mistakes were corrected; uniform resource locators (URLs), retweet characters (RT), hashtags (#), symbols (e.g., @), links, and repeated characters in word [91] were removed for the analysis. Emoticons are graphical emotional expressions essential for the SA [92], therefore we replaced them with the words, expressions, and actions they represent to ensure comprehensive and standardised data for analysis. Emoticons express the emotional signal in an independent form that does not have a grammatical function [92]; therefore, it is necessary to transform them into word vectors [93].

In the fifth step, we used SA to extract information from unstructured data. For this paper, we conduct SA at the tweet level, treating each microblog post as a document. The classification into polarities for SA was undertaken manually through expert judgment. The lead author, based on her disaster management expertise, manually classified the tweets in the document into three polarities: positive, negative, and neutral. Sarcasm [67] contained in some of the tweets was identified and considered for their classification. Some tweets were instead classified as 'unrelated' when they did not address the topic of the tenth anniversary of the earthquake in Haiti or economic activities that could indicate recovery. The classification was based on pre-defined rules to determine each polarity. These rules were adapted to Haiti from the classification rules formulated to classify the tweets related to the tenth anniversary of the earthquake in L'Aquila [67]. The first and fourth authors initially articulated these classification rules based on their experience in disaster management, monitoring recovery processes after earthquakes, and earthquake reconnaissance, and later refined them based on their experience analysing the text data related to the tenth anniversary of other earthquakes [67].

Tweets posted around the tenth anniversary of the earthquake in Haiti were classified as positive if they related to life returning to normality. Conversely, tweets were classified as negative if they highlighted failures in the recovery process [67]. In line with these rules, for the case of Haiti, we classified tweets reporting progress in the recovery and economic activities as positive. Conversely, tweets highlighting problems that arose during the post-disaster phase after the 2010 earthquake in Haiti, such as delays in the reconstruction activities [94], the cholera epidemic [43], human trafficking [95], sexual abuse [96], and events such as hurricanes [97], were classified as negative as the hinder the recovery process. Tweets mentioning seismic information or invitations to commemoration ceremonies or activities were classified as neutral. While developing our set of classification rules, we acknowledge that not everyone will agree with our classification, and not every tweet will fall neatly into a unique category. Nevertheless, we maintain that most of our rules would not be controversial, that the associated tweets are aligned with the designated polarity [67], and that they are sufficient for assessing the recovery progress for this case study. The rules applied for the SA in this paper addressing the post-disaster recovery in Haiti after the 2010 earthquake are listed in alphabetical order in Table 1.

Polarity	Rules
Positive	<ul> <li>Commercial announcements</li> <li>Improvement of living conditions</li> <li>Indications of industrial activity</li> <li>Job announcements</li> <li>Lessons learnt</li> <li>Promotion of tourist attractions and Haitian products</li> <li>Reconstruction/Retrofitting actions</li> <li>Social and artistic initiatives</li> <li>Solidarity messages</li> </ul>
Negative	<ul> <li>Cholera epidemy</li> <li>Delay in reconstruction activities</li> <li>Depopulation, internal displacement, and migration</li> <li>Expressions of inability to forget the impact of the earthquake</li> <li>Food insecurity</li> <li>Human trafficking</li> <li>Hurricanes</li> <li>Lack of preparedness</li> <li>Mismanagement of the funds for reconstruction</li> <li>Political instability</li> <li>Sexual abuse</li> <li>Unfulfilled reconstruction goals</li> </ul>
Neutral	<ul><li>Seismic information</li><li>Commemoration ceremonies/actions</li></ul>

Table 1. Polarity classification rule set for SA. Adapted from [62].

The unrelated tweets detected by the lead author were eliminated from the sample used to train the machine learning (ML) algorithm and the transformer-based language models for automatic classification. The ML algorithm used was developed by MonkeyLearn [98]. It is a user-friendly no-code ML platform for text analysis that uses pre-trained models or allows users to build customised classification models [99]. We build a customised classification model for Haiti using this platform and the text data already classified by authors for the anniversary. To evaluate the model's ACC, we conducted tests using 1%, 5%, and 10% of the English-language sample to train the algorithm, excluding those tweets that were used to train the algorithm. It was expected that by increasing the percentage of classified tweets to train the algorithm, the classification ACC would be higher. The training process of the algorithm is depicted in Figure 3.

In addition to MonkeyLearn, we also tested two advanced transformer-based language models [100], which were further fine-tuned for SA: Twitter-RoBERTa, referred to in this paper as 'troberta' [101], and BERTweet, referred to as 'btweet' [102]. Both models were built upon the RoBERTa architecture [103] and have been pre-trained on extensive tweet datasets. These transformer-based language models [104] consistently outperform previous SA approaches and adapt well to different domains, including SM text data. For these experiments, we used the models' implementations found in the Hugging Face platform [100]. The models are fine-tuned on a subset of the human-annotated dataset to perform the SA and extract information about the perception related to the progress of the recovery during the 10th anniversary of the earthquake. The sixth step in the methodology is the recovery assessment based on each classification model's highest polarity reported in the SA. The results of the SA analysis based on the classification done by humans are always considered the benchmark [105]. The seventh step is validating classification rules and assessment results, which must be ideally done by stakeholders of the case study area or experts who have engaged with Haiti's context. However, in this case, given the security conditions in the case study area [106], we consulted the sixth co-author, who visited the case study area in December 2014, and academics present at the co-production workshop at Cardiff University on 24 July 2024. After reading the classification rules presented in Table 1, these academics classified the most retweeted tweet of the entire dataset of tweets related to the tenth anniversary of the 2010 Haiti earthquake.



Figure 3. Training process of the MonkeyLearn classification algorithm. Source: [62].

# 3. Results

#### 3.1. Data Collection

The hashtags included in tweets associated with the tenth anniversary of the 2010 Haiti earthquake were #Haiti, #Haiti10, #HaitiEarthquake, #Haiti10YearsOn, #10AnsAprès, #12Janvjer2010, and #Ayiti. Twitter activity using these hashtags during the designated observation period is plotted in Figure 4. This graph reveals a pronounced spike in activity on the anniversary day itself, followed by a gradual decline over the subsequent five days.

Text data provided by the third-party vendor comprised 47,200 tweets, of which 8157 were original tweets (accounting for 17%), and 39,043 were retweets (constituting 83%). The most retweeted tweets about the tenth anniversary of the 2010 Haiti earthquake can be observed in Figure 5a, and one of the most liked tweets is presented in Figure 5b.



Figure 4. Twitter activity from the 6-15 January 2020. Adapted from: [62].



**Figure 5.** Selected tweets related to the 10th anniversary of the 2020 earthquake in Haiti. (**a**) The most retweeted tweet. (**b**) The most liked tweet in the dataset. Source: [62].

#### 3.2. Data Analysis

Applying the rules defined in Table 1, a sample of 4265 original tweets posted in English discussing the recovery of Haiti during the tenth anniversary of the 2010 earthquake were manually classified. This number of original tweets corresponds to 31,003 retweets, from which 17,467 (56.3%) were classified as negative, 8470 (27.3%) as positive, 2548 (8.2%) as neutral, and 2518 (8.1%) as unrelated to the tenth anniversary of the earthquake. These SA results can be observed in Figure 6a, and retweets in Figure 6b.

The outcome of the SA of original tweets and retweets exhibits disparities in the difference between polarities. Still, in both cases, the predominant polarity is negative, followed by positive polarity in the case of the original tweets (Figure 6a) and, widely far in the case of retweets (Figure 6b). In the case of the dataset with the original tweets, the number of unrelated tweets is almost double the number of tweets classified into the neutral polarity, as plotted in Figure 6a. Instead, the number of retweets classified with neutral polarity and unrelated are almost the same with a slight difference, as depicted in Figure 6b.



**Figure 6.** SA results. (**a**) Polarity identified in original tweets. (**b**) Polarity identified considering retweets. Source: [62].

The highest number of tweets related to the tenth anniversary were posted on the exact day. The next day, the number of these tweets of interest for us dropped to almost half (54.2%) and to 17% on 14 January 2020. The other significant tweets related to this event were posted two days before the tenth anniversary. In the first two days of the observation period, the number of unrelated tweets exceeded the number of tweets related to the anniversary of the earthquake, as shown in Figure 7.



Figure 7. SA per day including retweets during the observation period.

However, on 8 January 2020, tweets with negative polarity first exceeded tweets that were classified into the other categories. Nevertheless, the previous tendency continued the next day, but from 10 January until the end of the observation period the predominant

polarity in the tweets was negative. Consistent with the aggregated SA result depicted in Figure 6, the positive polarity is the second most frequent per day throughout the observation period.

After the manual classification that serves as a benchmark for the automatic classification, we use the dataset with the original tweets, excluding 400 tweets utilized to train the MonkeyLearn algorithm, to eventually end with a corpus of 3865 tweets. The tweets manually classified by the primary author for training the ML algorithm were omitted to assess the algorithm's classification ACC, as they were already accurately categorised, and their inclusion will not help to test the ACC of the model. The comparative results of the SA for English-language tweets associated with the tenth anniversary of the 2010 Haiti earthquake have been made publicly available in a dataset [107]. A synopsis of these findings is presented in Table 2.

Across the three automatic classification models, negative polarity emerged as the most prevalent (as in the manual classification), except for the MonkeyLearn model trained on 1% of the sample, which showed a predominance of positive sentiment. However, this finding is not given weight due to the relatively small training dataset, especially when contrasted with the 5% and 10% outcomes from the other training sets. Notably, within the MonkeyLearn framework, there is a discernible trend of increasing average confidence in sentiment classification as the size of the training sample expands. Nevertheless, the average confidence levels for 'troberta' and 'btweet' surpass those of the MonkeyLearn model, as evidenced in the column detailing average confidence for each classification model. The outcome of the validation exercise trial during the co-production workshop classifying the most retweeted tweet in the dataset was negative, matching the result of the manual classification, but not the polarity allocated by the automatic methods: positive. In this exercise, 15 academics participated. The result can be observed in Figure 8.

Join at menticom | use code 5737 7143

SA Comment level: Never forget the tragedy that occurred on January 12, 2010, which claimed thousands of lives in Haiti due to the catastrophic ... 10
2
2
0
Positive Negative Negative Neutral

f lives in Haiti due to the catastrophic earthqua 's take this time to remember all of our fellow br lost due to this tragedy. #HaltiEarthquake

the tragedy that occurred in January 12,2010



s 150 Quotes 9,995 Likes 49 Bookmarks

Figure 8. Validation exercise trial outcome.

nce Fan account demondelus

		Table 2. Compa	red results of SA	A classification m	nodels. Adapted	from [62].					
Polarity	Authors	MonkeyLearn		MonkeyLearn		MonkeyLearn					Average Confidence
	Manual Classification	Sample Trained 1%	Average Confidence	Sample trained 5%	- Average Confidence	Sample Trained 10%	<ul> <li>Average</li> <li>Confidence</li> </ul>	troberta	Average Confidence	btweet	
Positive	1229	1797	0.39	1440	0.56	1422	0.64	1556	0.89	1651	0.92
Negative	1546	1726	0.39	2031	0.56	1709	0.64	1878	0.89	1820	0.92
Neutral	380	91	0.39	135	0.56	389	0.64	431	0.89	394	0.92
Unrelated	710	251	0.39	259	0.56	345	0.64	0	0	0	0.92
	Accuracy (ACC)	)	58.6	ACC	60.8	ACC	62.4	ACC	63.5	ACC	63.4

models Adapted from [6] T-1-1- 0 C rad regults of SA classification

# 4. Discussion

#### 4.1. Data Collection

We are aware that Twitter users may not be representative of the entire population affected by the earthquake and experiencing the recovery process. However, as in every survey, it is impossible to reach the entire population to collect data. Considering that we were exploring SM as a data source to assess the recovery progress, our data sample was initially limited to Twitter users. This platform was selected as a data source, given the facility to extract and analyse the text data for SA. Although this analysis was based on the text data of the tweets, the content from links embedded in those tweets took us not only to other SM platforms but also to news articles written by journalists and reports from NGOs. The content in those other SM platforms and documents was considered in classifying the tweets into a specific polarity, overcoming the limitation of extracting information only from tweets.

Observing the data collection period, it is visible how the number of tweets containing hashtags related to the tenth anniversary of the earthquake peaked between 12 January 2020, started decreasing on the next day, and continued to decline until 15 January 2020. The hashtags included in the tweets for this SA were identified by monitoring Twitter two weeks before and two weeks after the tenth anniversary of the 2010 earthquake in Haiti. After that period, we could not find any other hashtags related to the tenth anniversary.

Our data sample for this analysis is based on tweets posted in English because it is the common language among the co-authors. We are aware of this limitation, which can bias the outcome. Nonetheless, this sample already represents 65% of the complete dataset. The rigour of the polarity classification can be improved by relying on the input of local stakeholders for the classification of the text data; however, some of the current co-authors of this paper are French speakers and have visited the case study area after the earthquake. Although the predominant polarity of tweets is negative, it is noticeable that the second most frequent polarity is positive and not neutral; therefore, this section will focus on the tweets classified into negative and positive polarity.

#### 4.2. Data Analysis

Most tweets with negative polarity address the mismanagement of funds donated for reconstruction and point to the Haitian governmental authorities [14] and the Clinton Foundation as responsible. Most Twitter accounts that supported the allegations against the Clinton Foundation were suspended. A significant number of these tweets also propagated conspiracy theories, notably QAnon [108], and echoed slogans from Donald Trump's campaign, such as 'Make America Great Again (MAGA)' and 'where we go one, we go all (wwg1wga)'.

Other tweets with negative polarity report the continued closure of institutions like the National Art Museum and the lack of reconstruction of the Government Palace [16]. Other tweets report projects such as the industrial park in Caracol [109], which was constructed in an area not affected by the 2010 earthquake and for which USD 202 million was used to provide electricity, transportation [46], and housing to this urban facility and its surroundings rather than to rebuild infrastructure in Port-au-Prince and other hard-hit areas [110]. Unfortunately, the 13,000 or 10,214 [42] jobs generated and the USD 5.25 per day, which is three times less than Haiti's estimated cost of living [110], do not compensate for the loss of productive land and the increase in food insecurity in the country [19,24,33].

Negative polarity also comes from Twitter users who remember the ravages of the cholera epidemic that started nine months after the earthquake [27,42,43]. It is understandable that tweets still report this fact, considering that the last cholera case in Haiti was recorded in January 2019. It was only in February 2022, twelve years after the earth-

quake and the beginning of the outbreak, that the country declared to have eliminated this illness [111].

Other tweets with negative polarity are those reporting the hunger crisis [17] that the country was facing precisely at the time of the 10th anniversary. By 12 January 2020, almost four million people in Haiti were facing severe hunger; many of them belonged to the thousands displaced by the earthquake.

It was not related to the 2010 earthquake and even started before, but the dataset contains tweets also classified into negative polarity that comment on the sexual abuse and exploitation perpetrated by UN peacekeepers in Haiti. Research has indicated that children fathered by personnel from the UN Stabilisation Mission in Haiti (MINUSTAH) have been typically raised in extreme economic deprivation without access to education and other basic services while living with the stigma [112] regarding their identity [113]. The MINUSTAH remained in Haiti for 13 years. The minimum number of allegations of sexual abuse and exploitation by UN troops or other personnel in Haiti, from 2004 to 2016, was 150 [42,112].

The difficulty of forgetting the 2010 earthquake was expressed in tweets classified into negative polarity. According to academic research, this level of distress was more prevalent among adolescents and young adults even six years after the earthquake [51]. Other tweets with negative polarity are those that tackle the topic of housing. The American Red Cross for Haiti raised US \$486,000,000, but by June 2015, only six houses had been built by this institution after the earthquake [50]. Something similar happened with USAID; this agency planned to build 15,000 houses for US\$59 million; however, only 900 houses were built in the end. Additionally, 150 houses were built 12 Km from Port-au-Prince, and the other 750 houses were 209 km from this city. Each house cost US \$8000, and none of the 750 houses followed seismic regulations [42]. By January 2020, most of the displaced population had officially returned to their place of origin [14,16]. However, according to the International Organisation for Migration (IOM), 32,788 people remained in 22 displacement sites across the country [16]. The reasons for continuing to live in these places were either the living conditions in their places of origin or the delays in the reconstruction of their housing [14,94]. These low figures are explained by the fact that three major sites were removed from the official camp list in 2013, but by the time of the tenth anniversary of the earthquake, at least three news portals reported that 300,000 people were still living in the Cannan camp. Some camps have become permanent settlements without essential services [12].

Other tweets with negative polarity highlight the impact of ending the temporary protected status (TPS) granted by the Homeland Security Secretary of the USA to Haitians who were already living in the country as of 12 January 2010 and those evacuated to the USA after the earthquake [114]. This TPS was granted as part of the efforts of this Department to assist Haiti after the earthquake and allowed Haitians covered by this status to legally stay and work in the country [115]. However, this benefit has an expiration date that was originally fixed by January 2020, postponed to March of the same year [114], then to 4 January 2021 [116], and currently to 3 August 2025 [117,118]. When this TPS expires, those Haitians who have not been naturalized will become undocumented [116].

The cases of human trafficking after the 2010 earthquake were reported in tweets classified into negative polarity. Transnational adoption requirements were relaxed by the Obama administration, resulting in the adoption of 100 children by families in the U.S. alone [25]. Organisations and individuals worldwide focused their efforts and resources on the cause of vulnerable children [119]. However, 10 Baptist missionaries with the New Life Children's Refuge, who were on a mission to rescue earthquake orphans and take them to an orphanage in the Dominican Republic for eventual placement with Christian families,

were apprehended. The Haitian authorities arrested this group on child kidnapping charges because they attempted to cross the border with 33 children without the permission of the Haitian Government. Later, it was discovered that these children were not orphans, and their parents had been told they could visit them and take them back [25].

Expressions of despair are also classified into negative polarity. These tweets refer to the situation of Haitians who lost loved ones [57] and those who were disabled due to the 2010 earthquake [120]. The quick emergency response by local and international non-governmental organisations resulted in people surviving their terrible injuries, but at the same time, increased the proportion of Haitians living afterwards with permanent impairments and therefore needing rehabilitation services, which did not meet the needs of the country even before the earthquake [8].

Instead, tweets classified into positive polarity mention survival stories [28–30,50,121], successful stories from NGOs working during the emergency response phase [9,23,24,31,37,41,46,57,122], distributing humanitarian aid such as blankets, tents [57], and cooking materials [30]. These tweets also report rescue operations [32,40], provision of temporary homes [37] for children [46], children reunited with their families, implementation of recovery programmes for them, construction of community centres [32,123], and villages to provide long-term care for children [123]. Tweets with positive polarity mention support from donors [16,124] and the establishment of food distribution points [32,37,57] for children [15,46] and adults.

Other tweets classified into positive polarity include links in which NGOs mention partnerships with churches to support children and youth, the opening of disaster response offices [30] and the training of vulnerable communities and authorities [9] to respond to disasters [31,41,57,125]. The closure of the camps and the training of young people as community intervention teams [37] were mentioned in links included in tweets classified into positive polarity. Tweets reporting the organisation of marathons to support Haitian children [126] were also classified into positive polarity. One link included in a tweet classified as positive reported how Haitians found strength in singing on the night after the earthquake. Hundreds of thousands sang Haitian anthems and hymns that rallied their spirits.

One tweet classified into positive polarity contained a link that explained the role of the BBC's Caribbean Service as the primary outlet for getting out on-the-ground information for Haiti after the earthquake. This service contributed to reuniting a Haitian American mother in the U.S. with her son, whom she had thought dead in Port-au-Prince. *Koneksyon Ayiti*, a tiny department funded and technically supported by the BBC, was in charge of broadcasting vital information for Haitians seeking water supplies, food drops, the location of a temporary hospital, and other key information [17].

Removal of debris was done with the support of the population deprived of livelihood [37], like the rural population of Artibonite (including women) [9], who were paid for that; this was reported in links in tweets classified into positive polarity. Other tweets classified into positive polarity reported another livelihood assistance [41], providing tools to clear rubble to make space for transitional shelters [24,46,127]. Slope stabilisation [9], return of the displaced population to their houses, relocation of families through the provision of rental assistance [37], resettlement of population, road repairs [9], and community centres repaired were actions also listed in tweets with positive polarity. Other tweets classified into the same polarity informed about the population benefiting from a new safe house to live in [41,128], the supply of medicines, medical supplies, school and dormitory furniture, tiles, shoes, hygiene items, household items, cleaning supplies and construction supplies [32]. The repair of destroyed springs and the rebuilding of the water reservoir in Petit-Goâve [9] were also announced in tweets classified into positive polarity. Messages to raise awareness of seismic risks [129], reconstruction [16,24], retrofitting of houses [130], and financial assistance for repairing those with minor damage [37,41] were actions mentioned in tweets with positive polarity. The construction of seismic and hurricane-resistant houses with local materials [32,57], schools rebuilt, and construction of seismic-resistant schools [32,37,39,41,46,131,132], as well as the installation of playgrounds and provision of toys and puzzles on school campuses, were considered positive. The installation of solar panels at Marialapa School in Hinche also turned this facility into a community centre, and now the school is a point of pride for the community, which was also considered to be classified as positive.

The reconstruction of the Supreme Court building, the ongoing reconstruction of the Parliament complex [16], and the graduation of builders, including women, who were trained to build houses with seismic considerations in mind [37], are included in tweets classified into positive polarity. Another aspect mentioned in links in tweets classified into positive polarity is the signing of memorandum of understanding between the UN Development Programme (UNDP), the State University of Haiti, and the National Geospatial Information Centre to support the capacity of the Haitian government to prevent and manage future disasters by assessing the vulnerability of buildings and simulating socio-economic losses in the event of an earthquake in three major cities in the North and 50 public establishments. The tweets that contain the architectural proposals participating in the international competition for the reconstruction of the Haitian National Palace and the tweets with the winning proposal [133,134] are included in the tweets classified as positive. The post about the rehabilitation of the Haitian Meteorological Service headquarters was also classified as a tweet with positive polarity [135]. The announcement of the opening of the National Bank for Agricultural Development (BNDA) in Haiti on 1 May 2020 [136] was included in a tweet also classified as positive, as well as the intention to reactivate the deal with the International Monetary Fund (IMF) to revive the weak Haitian economy [137].

The provision of a mobile phone app to the Board of National Haitian Engineers and Architects (CNIAH) to assess structural damage in buildings after earthquakes and the certification of 117 engineers in rapid damage assessment (RDA) methodology are included in one of the links in the tweets classified into positive polarity. The announcement of the publication of a digital archive that documents the emergency response after the earthquake and detailed information about community planning initiatives undertaken in the years following [138], included in a link in a tweet, led us to classify this post into positive polarity.

The participatory construction of Ravine Pintade, a sustainable neighbourhood, was reported in a tweet classified as positive polarity. This neighbourhood was constructed with pedestrian paths and paved roads, seismic-resistant houses, solar-powered night lighting, rainwater harvesting for washing, and a five-point drinking water supply. The profit from the water purchase is invested in neighbourhood maintenance [139]. The construction of villages for homeless people due to the earthquake [26] reported on tweets, was classified into positive polarity. It is reported on a tweet classified into positive polarity, the partnership between the Government of Haiti, USAID Haiti, the World Bank (WB), and the National Renewable Energy Laboratory (NREL) to provide training and technical assistance for constructing 54 mini solar grids in Haiti [140].

The shift of NGOs work from a humanitarian response to long-term development [9] to tackle the root causes of poverty [30] by establishing self-sustaining school gardens to provide meals for students, teaching them effective farming methods, as well as the invitation to volunteers to join mission trips to Haiti through posts on Twitter were also classified as positive [141]. Other links in tweets classified into positive polarity mention

the provision of farm equipment [57], subsidies [41], and rental grants; the creation of job opportunities and the improvement of infrastructure; and the offering of micro-loans [37] to affected families so they could feed themselves, establish small businesses [41], or reconstruct their homes [30]. Support for enterprises and micro-enterprises creation [37] to contribute to the recovery of the local economy was also mentioned in links in tweets classified into positive polarity [21]. Also, the support to people with disabilities to access employment or start business activities was reported in links included in these tweets with positive polarity [31]. Other tweets classified into positive polarity contained links to announcements of investments in building institutions, leadership capacity, multisectoral partnerships, and elements of sustainable economic growth in rural regions of Haiti [18], as well as initiatives to innovate the agricultural sector using technology [142].

Promotions of hotels in Haiti and recommendations of tourist guides [143] or to visit Labadee [144], with posts on Twitter and links to Instagram, are classified into positive polarity [145]. Innovative fundraising actions based on songs to help displaced Haitians still living in camps [146], the announcement of successfully harvesting rice to feed school children, auctions of quilts by the Sarasota Amish community [147] and donations from sportsmen [132] promoted in tweets are also considered positive. The announcements of USAID's Office of Food for Peace (FFP) partnership with the UN WFP to provide cash transfers for food, the maintenance of a stockpile contingency food supplies and the provision of food and seed vouchers an conditional cash transfers were announced in a link in a tweet with positive polarity [19]. Shoemaking skills training for local artisans and the creation of 'The Love-Haiti Sandals' to provide local jobs and support the local communities [148] were reported in a tweet that we classified into positive polarity. Implementation of goat-raising opportunity programmes, carnival announcements [149], the announcement of apps to send money to Haiti [150], and an increase in remittances are also classified as positive [151].

Hiring and training teachers [46,132], schools back in operation and fully operational [57], donation of school buses, reconstruction of youth centres [46], construction of warehouses to store survival kits [46] and the purchase of a delivery truck were also reported in links embedded in tweets with positive polarity [46]. Integration of school gardens, kitchens and harvest storage systems in designing new school campuses was also listed on links in tweets with positive polarity. The posts indicating that children are returning to school [46] and tweets with images of children were also classified as positive [152] because children are the country's future. Tweets that include images of children practising sports are also classified as positive because sports are considered a tool for development and education [153]. Increased access to safe water [57] in schools and communities, using water filtration units or drilling water wells and installing pumps [32], provision of chlorine tablets [49] and reforestation of watersheds were also reported in tweets classified into positive polarity. Reforestation projects offered fishermen and smallholder families an additional income and raised their awareness of the environment [9].

The reconstruction of the Haitian Red Cross blood bank [41] was reported in a tweet classified as positive. Additional funding for mobile clinics [38], medical aid [46], medical shipments to equip urban and rural clinics, cholera prevention [49] and outbreak response services and other community health services [41] were reported in tweets classified as positive. The construction of cholera treatment units, medical incinerators, laboratories and storage facilities for hospitals [30], epidemiologic monitoring [49] and equipping of hospitals and clinics [41] and the establishment of prevention strategies in the communities against cholera [37] were reported in tweets classified as positive. The presence of personnel trained in orthopaedic and physical rehabilitation and the development of the knowledge of local rehabilitation specialists [31], the investment in psycho-social care [57], the training in

psychological first aid and the provision of one-on-one counselling [154] were informed in tweets classified into positive polarity. The announcement in a tweet of the opening of the Mirebalais University hospital, a solar-powered hospital, as a contribution to rebuilding the health care system and the country's environmental sustainability was counted in the tweets with positive polarity. This healthcare facility is also a training centre for Haitian healthcare workers [23]. The existence and growth thanks to donations and grants of healthcare centres such as St. Boniface Hospital, the only facility in Haiti with an emergency C-section and the only place with a neonatal intensive care unit [155] was reported in a tweet with positive polarity. The announcement of newborn babies [156] around the anniversary in tweets is also classified as positive polarity because we consider it a sign of improvements in the healthcare system. The local production of prostheses for Haitians [157] and the tweet, including a video of the Haitian Women's Amputee Soccer Team celebrating [158] were classified into positive polarity. Additional funding to improve access to quality healthcare [23], medication and dental services in Southern Haiti [159] was mentioned in a tweet classified into positive polarity.

To ensure the sustainability of water-borne disease prevention, one NGO undertook market research to determine how much Haitians would be willing to pay for water treatment products [49]. A water and sanitation project called WatSan was implemented in Jeremie to build staff capacity, rehabilitate infrastructure, and improve the operations of municipal water utilities [160]. The construction and safe use of latrines [37,57], other hygiene promotion activities and the funding for constructing the country's first wastewater treatment plant [41] were considered positive.

Artists and grassroots cultural heritage workers rescued books and artefacts and pulled paintings out from the rubble after the earthquake [35], and the role of the Digital Library of the Caribbean in Protecting Haitian patrimony [161] was reported in links included in tweets classified into positive polarity. It was reported in a tweet that the earthquake in Haiti prompted a worldwide effort to safeguard cultural heritage worldwide. The tweet that includes a link to the article that reports about the Youth Choir and Chamber Ensemble tour from Haiti's Holy Trinity Music School in Main, Manhattan, Washington, Kentucky and Ohio in the USA [47] was classified into the positive polarity. The tweet inviting to stop by the Mupanah Museum in Port-Au-Prince for Museum Selfie Day [162] was also classified as positive polarity. One post classified also into positive polarity contains a link to the work of an artist oriented to address the tragedy of the earthquake [163]. The 14th edition of the Port-au-Prince International Jazz Festival (PAPJAZZ) was scheduled between the 18 and the 25 January 2020, after the tenth anniversary of the earthquake. Countries including Germany, Belgium, the U.S., and the Netherlands were invited to participate. This invitation is interpreted by us as a sign of recovery and, therefore, classified as positive [134].

One important tweet with positive polarity contains a link to the ground-breaking deal reached by Haitian farmers. Only in 2018 did evict farmers agree with the IDB and the Haitian government on corrective measures, such as access to new land [42]. Finally, the IDB offered land titles for 100 of the most vulnerable families, irrigation schemes or money to invest in personal businesses or employment at the industrial park [109].

Other tweets classified into positive polarities are those that mention the support of Haitian ex-pat living in the U.S. and Canada [164], those which ask to remember and pray for those affected by the earthquake [165], who request honouring the memory of those who perished [24], as well as those who exalt the resilience of Haitian citizens [17]. Those tweets posted by users who thanked God for saving their families and messages of solidarity were classified as positive. Tweets of people proud of contributing to the emergency response after the earthquake were also classified into positive polarity. Messages of hope based on pictures of meteorological phenomena such as rainbows in the sky of Port-au-

Prince [166,167] were considered positive. Tweets with images of hardworking Haitian women [168] are also classified as positive. The tweet with the link reporting the debut of Haiti at the Winter Youth Olympic Games at Lausanne 2020 with Mackenson Florindo was classified as positive given that it projected another image of Haiti to the world and can function as an inspiration to young sport Haitians [169]. Pictures of the Haitian team appeared on SM [170]. Another inspiring role model for young Haitians is the Haitian actor and film producer Jimmy Jean-Louis [171].

Tweets promoting Haitian products such as T-shirts [172], caps [173,174], travel bags, handicrafts, cosmetic items, beer [175] and rhum [176,177] produced in Haiti as well as job opportunities in the country [178] were classified as positive. Although these tweets do not discuss the post-earthquake recovery, they were deemed positive. This classification was based on the rationale that such promotions signal the presence of active local enterprises, which are pivotal in providing employment and income in Haiti, thereby contributing to the recovery.

A series of tweets indicated the location of factories of industrial goods in proximity to Haitian communes [179] Determining the existence of the factories in these locations is crucial to confirm the classification of these tweets as positive polarity or as unrelated. Expertise from individuals familiar with the case study area or those with on-ground experience would be invaluable in verifying this data. Regrettably, the prevailing security conditions in Haiti [106] pose significant obstacles to conducting on-site verification of these details.

Regarding the automated classification process, it is crucial to note that tweets utilized to train MonkeyLearn's algorithm should be excluded when calculating the algorithm's ACC. The initial inclusion of manually classified tweets by the lead author inadvertently inflated the ACC. This oversight was rectified with the assistance of coauthors, leading to the realisation that the apparent increase in ACC was not indicative of the algorithm's enhanced performance. Consequently, the manually classified tweets were removed to ascertain the true ACC of the MonkeyLearn model. Scholars concur that a minimum ACC of 50% is required for SA to be deemed effective, while an ACC of approximately 65% is regarded as proficient [180]. The ACC of MonkeyLearn, when trained with 5% of the sample, stands at 60%, and at 62% when trained with 10% of the sample, both of which are within acceptable bounds. These findings indicate that augmenting the proportion of classified tweets for training the algorithm on the MonkeyLearn platform yields a modest enhancement in classification ACC. In contrast, the ACC rates for troberta and btweet surpass those of MonkeyLearn, which may be attributable to the latter's commercial orientation. The disadvantage of using these transformation-based language models is that unrelated tweets are not identified.

# 5. Conclusions

#### 5.1. Data Collection and Information Extraction

In this research, we collected Twitter data related to the tenth anniversary of the earthquake in Haiti for ten days in January 2020 to test whether we can use the text data contained in those posts to assess the recovery progress after the earthquake using SA at the tweet level. We can conclude that the anniversary date is the best time to collect data related to this event. We are aware that analysing tweets from the tenth anniversary may not capture the full dynamic nature of public sentiment over time therefore, we believe it would be beneficial to monitor SM around 12 January 2030, the twentieth anniversary of this earthquake, to check if there is enough data to compare polarities and check the evolution of the assessment of the progress of the recovery process.

Mining data from SM to extract meaningful information goes beyond tweets and checking links. We found that links embedded in tweets contained essential information for the comprehensive assessment of the recovery progress after an earthquake. Positive aspects of the recovery process in Haiti would not have been identified without using SM. We found that data from SM is also perishable because, at this time (five years after the tenth anniversary), some posts do not exist anymore, or the Twitter accounts were suspended. In some cases, tweets still exist, but the embedded links are no longer available. There are also cases in which we could not view some posts because the user limited who can view them.

#### 5.2. Post-Disaster Recovery Assessment

The statement that highly vulnerable countries have more prolonged and difficult post-disaster recovery phases is demonstrated with the situation of Haiti, tenth years after the earthquake. Although billions of dollars in aid were promised, this Caribbean country has seen little progress one decade after the earthquake [12,16,17,20,39] and continues to struggle to survive [12,18]. It is essential to keep in mind that Haiti was impacted in 2010 by an earthquake of a high magnitude and intensity, also low deep and that this happened in an already highly vulnerable country, which is a difficult starting point for the recovery [20].

Five years after the earthquake, there was still debris in the streets [20]. It was necessary to wait seven years to reopen the major Hospital in Haiti [11,17]. The \$100 million public hospital, promised by the U.S. and France, was an empty shell six years after construction began due to a dispute over money [12]. Two iconic buildings in Haiti that represent the state of governance, the Cathedral of Our Lady of the Assumption and the Presidential Palace, were not rebuilt by the time of the tenth anniversary [12]. Looking at satellite images, it seems to continue in this state today. A fact that prevented not only the recovery but also the progress to the development phase in Haiti is the lack of approval of the country for a third time in months in 2019, at least one of the new hotels built with seismic considerations [23] has closed. In contrast, others have quietly laid off staff [12]. Later, the impact of the 2021 earthquake [22] would slow down the recovery efforts in Haiti started in 2020.

The assessment of the progress of the recovery process based on data collected from Twitter is mainly negative. The negative polarity of tweets reports the role of the Clinton Foundation, the construction of the industrial park in Caracol [109], the food shortages [11], the cholera epidemic, child trafficking [57], hurricane Mathew [22,46], and the low number of houses constructed [18], the poor execution of financial resources raised, the decamped of international development programs [12,16,20] and the political chaos [11]. The Cholera epidemic implied that healthcare resources that could have been allocated to support people with injuries related to the earthquake [2,29] needed to be reallocated to care for infected people.

The UN Children's Fund (UNICEF), Haiti's Brigade de Protection des Mineurs (BPM), and the Heartland Alliance formed a coalition to establish checkpoints at key bordercrossing points to ensure nobody else took Haitian children to the Dominican Republic without the informed authorisation of the parents and the Haitian government [25]. Again, these efforts could have been focused on improving the living conditions of children after the earthquake. These problems delayed the post-disaster recovery and compromised the country's sustainability to the point that some academics consider Haiti a failed state [6,181].

Tweets classified into positive polarity list actions to encourage recovery and to reach Haiti development phase [60] after the earthquake. The problem is that most of those actions are isolated, punctual interventions implemented independently by NGOs [6] without being part of a coordinated plan between them and the government. This lack of coordination and governmental involvement jeopardizes the sustainability of these actions in the long term. It could be another reason for the little progress in the recovery in Haiti,

Considering the ACC rates observed, it would be advantageous to persist with 'troberta' and 'btweet' for the automated classification of such textual data and for analysing other post-earthquake recovery scenarios in English and additional languages. However, finding a mechanism for identifying unrelated tweets related to the topic of interest is necessary.

The recovery assessment of this case allowed the identification of a comprehensive list of emergency response and re-development actions applicable for recovery after earthquakes in global southern Countries. This case also allowed the authors to test and validate the usefulness of SA of data extracted from Twitter and occasionally from Instagram and Facebook around the tenth anniversary to assess the recovery progress after earthquakes. Finally, we would like to praise the resilience of Haitians [50] and highlight that the tenth anniversary of the 2020 earthquake in Haiti triggered a reflection among Twitter users of the seismic hazard in neighbouring Puerto Rico [182,183] which had an earthquake on 7 January 2020, five days before the tenth anniversary of the 2010 Haiti earthquake.

# 6. Recommendations

as some authors suggest [20].

We recommend that other researchers do not discard tweets that only contain the hashtag with the name of the case study area during the observation period, even more so when that hashtag is combined with others specifically related to the anniversary of the earthquake. Thanks to this we still considered, for the analysis, the hashtags: #Haiti, we realised the tourist potential, the existence of gastronomy products inspired by Haitian food, accessories and cosmetic products developed for and by Haitian women, Haitian handcrafts, Haitian beer and rum, and even that there was a Haitian ski team. All of this contributes not only to the country's visibility, hence recovery, but also to the country's sustainability.

It is important that Twitter/X users include the word: anniversary in the hashtags because other users thought that another earthquake in Haiti was happening again on the 12 January 2020. According to the UN Office for Disaster Risk Reduction (UNDRR) early warning systems need to be strengthened along with safety and services management at evacuation shelters in Haiti. Adequate shelter coverage needs to be extended to the entire 41 municipalities in the country. It is urgent to invest in urban resilience and critical infrastructure [22].

The number of NGOs working in this country is remarkable, some of them religious [30], others secular. Still, of those thousands of NGOs working in the country, only 300 were officially recognized by the Haitian Ministry of Planning and External Cooperation (MPCE). The government may want to consider coordinating NGOs as this may increase the impact of their actions and their sustainability. A couple of NGOs focused their work on rural areas, which is a good approach considering the possibility of implementing agricultural programmes to reduce food insecurity in the country.

The proposed SA classification rules should be reviewed and endorsed by the stakeholders and/or experts who have engaged with Haiti's context. The ambiguity surrounding the tweets' classification also highlights the need for sentence-level analysis to diminish classification errors. The topic analysis combined with SA can determine the aspects that influenced the negative assessment of the recovery. Future research will extend the analysis to include tweets in French and Creole, the official languages in Haiti [184], and any other languages detected on the posts. Those results will be integrated with the results presented in this research to have a comprehensive assessment of the progress of the recovery from the 2010 earthquake in Haiti by the tenth anniversary.

The validation exercise trial was beneficial in validating the classification of the most retweeted tweet, and it shows the need to classify at the sentence level because there are sentences on this tweet that can be classified into positive polarity, which could be why the automatic classification allocated a positive polarity.

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# Abbreviations

The following abbreviations are used in this manuscript:

NLP	natural language processing
SA	sentiment analysis
NGO	non-governmental organisation
GDP	gross domestic product
U.S.	United States
USAID	United States Agency for International Development
UN	United Nations
IHRC	Interim Reconstruction Commission
UAV	unmanned aerial vehicle
LiDAR	light detection and ranging
SAR	high-resolution synthetic aperture radar
InSAR	interferometric synthetic-aperture radar
RAR	real aperture radar
VGI	volunteer geographic information
AI	artificial intelligence
URL	uniform resource locator
RT	retweet characters
ML	machine learning
ACC	accuracy
MAGA	Make America Great Again

wwg1wga	Where we go one, we go all
IDB	Inter-American Development Bank
WFP	World Food Programme
SEA	sexual exploitation and abuse
MINUSTAH	United Nations Stabilisation Mission in Haiti
IOM	International Organisation for Migration
TPS	temporary protected status
UNDP	United Nations Development Programme
BNDA	National Bank for Agricultural Development
IMF	International Monetary Fund
CNIAH	Board of National Haitian Engineers and Architects
RDA	rapid damage assessment
NREL	National Renewable Energy Laboratory
FFP	Food for Peace
PIH	Partners In Health
MUPANAH	National History Museum of Haiti
PAPJAZZ	Port-au-Prince International Jazz Festival
UNICEF	United Nations Children's Fund
BPM	Haiti's Brigade de Protection des Mineurs
UNDRR	United Nations Office for Disaster Risk Reduction
MPCE	Ministry of Planning and External Cooperation

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