Big changes start with small talk: Twitter and climate change in times of Coronavirus pandemic.

Mariana Gaytan Camarillo[1*], Eamonn Ferguson[2], Vanja Ljevar[3], Alexa Spence[4]

[124]Department of Psychology, University of Nottingham, Nottingham, UK.

[3]Business School, University of Nottingham, Nottingham, UK.

*** Correspondence:**

Mariana Gaytan-Camarillo
mariana.gaytancamarillo@nottingham.ac.uk

Keywords: Environmental Psychology, Coronavirus, actions, climate change, public perceptions, Twitter.

This article has been formatted to British English

Abstract

Behavioural scientists have been studying public perceptions to understand how and why people behave the way they do towards climate change. In recent times, enormous changes to behaviour and people's interactions have been brought about by the worldwide coronavirus pandemic (covid-19), unexpectedly and indefinitely; some of which have environmental implications (e.g., travelling less). An innovative way to analyze public perceptions and behaviour is with the use of social media to understand the discourse around climate change. This paper focuses on assessing changes in social media discourse around actions for climate change mitigation over time during the global pandemic. Twitter data was collected at three different points during the pandemic: February (*time 1*), June (*time 2*), and October 2020 (*time 3*). By using machine learning techniques, including Recurrent Neural Networks (RNN) and unsupervised learning Latent Dirichlet Allocation (LDA) topic modelling, we identified tweets mentioning actions to mitigate climate change. The findings identified topics related to '*Government actions'*, *'Environmental behaviours', 'Sustainable production', and 'Awareness'*, among others. We found an increase in tweets identified as 'action tweets' relating to climate change for *time 2* and *time 3* compared to *time 1*. In addition, we found that the topic of energy seemed to be of relevance within the public's perceptions of actions for climate change mitigation; this did not seem to change over time. We found that the topic of '*Government actions'*, was present across all time points, and may have been influenced by political events at *time 1*, and by covid-19 discourse at *times 2* and *3*. Moreover, topic changes over time within Twitter indicated a pattern that may have reflected restrictions on mobility as these tended to focus on individual and private sphere, rather than group and public sphere, behaviours. Changes in topic patterns may also reflect an increase in salience of certain behaviours (e.g., shopping) which may have received increased attention due to lockdown restrictions. Considering restrictions and adaptability challenges people face in times of a global pandemic may help to identify how to support sustainable behaviour change, and the likely persistence of these changes.

1 Introduction

Climate change is one of the major global challenges for society. The study of how the public perceives climate change, and factors influencing mitigation and adaptation behaviours are important to respond effectively to this environmental issue. The use of big data and social media platforms such as Twitter to study climate change discourse is a relatively novel approach. Social media constitutes a vast pool of data available for the analysis and understanding of public opinions regarding climate change (Wu, Guo et al. 2016, Veltri and Atanasova 2017, Pearce, Niederer et al. 2019). With the emergence of the coronavirus pandemic (covid-19), individuals' behaviour has faced challenging changes in different domains (e.g. health, social interaction, travelling), some of these changes followed by both positive (e.g., emission reductions) and negative impacts (e.g., putting aside environmental priorities) (Helm 2020). Recent research on covid-19 has suggested that disruptive changes to people's behaviours have had an impact on the environment in the form of reduction of emissions, air pollution, and free movement of wildlife (Helm 2020, Rupani, Nilashi et al. 2020). In addition, the impact of coronavirus and the regulations to control it have had an effect on the public perceptions of regulations and policies needed for climate change (Bostrom, Böhm et al. 2020). However, to date, there is no evidence on how the discourse on actions undertaken intentionally to mitigate climate change has been impacted by covid-19.

In 2020, the World Health Organization declared a public health emergency as a consequence of covid-19 and warned that restrictions in mobility and confinements might negatively impact physical health and psychological wellbeing (World Health Organization 2020). The global pandemic and its impact on different aspects of individual's behaviour have been the focus of many researchers throughout the year studying the widespread anxiety and considerable uncertainty as the security of jobs is challenged by the pandemic (Statistics 2020) as well as the increase of domestic violence during lockdown (Bradbury-Jones and Isham 2020) amongst other things.

In terms of the impact of covid-19 on the environment, research showed some positive changes in the short term such as the drop in carbon emissions, a sharp decline in transport use and with it the burning of oil (Helm 2020); decrease of water pollution (Saadat, Rawtani et al. 2020); levels of air pollution falling as a result of countries efforts to combat the virus (Rupani, Nilashi et al. 2020), more wildlife movement in people-dominated areas, and a decrease in wildlife deaths on the streets (Shilling and Waetjen 2020). Among the negative impacts of covid-19 that have been identified are the increase in demand of plastic for healthcare usage (e.g., gloves, masks, disposable plastic items) (Klemeš, Van Fan et al. 2020); and an increase of domestic waste due to lockdowns (You, Sonne et al. 2020). In addition, the coronavirus has consumed a vast amount of political and administrative bandwidth, putting environmental priorities aside (Helm 2020).

Bostrom et al. (2020) evaluated public understanding of climate change and coronavirus threats, and how people's perceptions of each influenced their level of related concern and willingness to act to tackle these threats. The researchers found that individuals perceived these two risks to be very similar and that learning about the actions to control the pandemic may have a spillover effect on people's perception of climate change and the needs of implementation of environmental policies. However, the researchers' findings also suggested that the threat of climate change was also perceived as less worrying in comparison with the coronavirus pandemic (Bostrom, Böhm et al. 2020); these results may be due to the relative novelty of the consequences of the pandemic in comparison to the enduring concerns of climate change. The authors considered that an effect of a 'worry budget' may help explain their findings; the idea that people have a limited cognitive capability for worry which let them worry about one thing at the time (Achen and Bartels 2017, Bostrom, Böhm et al. 2020).

The experience of the pandemic has also raised the prominence of the debate of health issues and their link with climate change. As a result of the impact of the coronavirus on people's lives, researchers suggest that a change in individual's perceptions of actions for climate change mitigation could occur, reducing the enthusiasm for globalization (Helm 2020), and promoting the search for cleaner sources of energy. Researchers have suggested that the mortality rate associated with covid-19 could be linked to the poor quality of the air, ozone and nitrogen oxides (Travaglio, Yu et al. 2020). How peoples' perceptions of what needs to be done to mitigate climate change have varied in times of a global pandemic, has yet to be examined systematically.

Public perceptions of climate change are important in understanding how people engage with climate change mitigation. The Committee on the Human Dimensions of Global Change considers people's perceptions of global phenomena, such as climate change, a crucial contributor to the understanding of environmental problems and a determining factor for the development of possible solutions (Stern, Dietz et al. 1997). Individuals' perceptions of climate change and their willingness to support actions around climate change are dependent on: context, and individual experiences (Marshall, Picou et al. 2005, Weber 2006, Dessai and Sims 2010); availability heuristics (Tversky and Kahneman 1974); and political polarization (Weber 2010, Kahan, Jenkins-Smith et al. 2011, Poortinga, Whitmarsh et al. 2019). There is also evidence of differences in climate change perceptions between scientists and the public in general. In 2009, a Pew research centre poll reported that while 85% of scientists agreed that earth is getting warmer due to anthropogenic activity (e.g. burning fossil fuels), only 49% of the general public agreed with this statement (Center 2009). This demonstrates the importance of understanding public perceptions towards climate change mitigation in developing environmental communications and policies that are likely to be accepted and engaged with.

Public perceptions of climate change are typically measured through surveys such as the European Social Survey (ESS). Poortinga et al. (2019) used this survey on participant samples from 23 European countries to examine public perceptions of climate change and potential differences between countries. Findings indicated that socio-political and demographic factors had a clear impact on climate change beliefs, though this may be at least partially explained by differences in experiences people have with extreme weather events (e.g., flooding, droughts), and how vulnerable countries can be to the impacts of climate change (Brody, Zahran et al. 2008, Spence, Poortinga et al. 2011, Deryugina 2013, Demski, Capstick et al. 2017). In addition to cross-cultural differences that may shape public perceptions of climate change, the differences in ways that countries have experienced the global pandemic could influence perceptions of climate change and potential actions considered to mitigate it.

In contrast to examining public perceptions directly through surveys, there is now burgeoning research focusing on the analysis of public perceptions using naturalistic data freely available on social media. By 2019, of the 7.7 billion people in the world, 3.5 billion were reported to be online (Ortiz-Ospina 2019). The increase in the use of social media and the disruption of traditional hierarchical structures of communication has weakened large media companies, political parties and research organizations, while increasing individuals' power to reach a mass of people through microblogs (Pearce, Niederer et al. 2019). As a result, scientists have the availability of large amounts of data of people interacting in all sorts of ways, creating opportunities for the study of human behaviour.

The use of social media and big data tools have proved to make the gathering of large datasets more cost-effective contributing to areas such as gambling and sports (Schumaker, Jarmoszko et al. 2016, Bradley and James 2019); stock markets (Rao and Srivastava 2014); and public mood (Bollen, Mao

et al. 2011). Twitter is a platform structured as a microblogging website, due to its character restrictions – 280 characters per tweet – users are forced to communicate information through reduced messages, sometimes making use of keywords, also known as hashtags (#), used to highlight the topic of their messages (Kirilenko and Stepchenkova 2014).

Data from Twitter are theorised to have three main features (Veltri and Atanasova 2017). First, the information is selected and displayed according to the user's personal criteria and perceived relevance (instead of following journalistic criteria). Second, information is addressed to a particular audience made of network ties (rather than being broadcast to an unknown mass audience); and lastly, information is often displayed in a conversational way rather than unidirectional (Veltri and Atanasova 2017). This means that on Twitter, discussions around one topic are driven by what the users perceive as relevant for their audiences.

Social media can also shape public awareness on social matters such as climate change. By disrupting the hierarchies on mass communication, social media has enabled all individuals to share any kind of information to thousands of people, regardless of the nature or veracity of this information (Brossard 2013, Auer, Zhang et al. 2014). Pearce, Holmberg et al. (2014), used Twitter hashtags to assess the dynamics of tweets mentioning the 2013 IPCC report, examining the role played by influencers on reaching different types of public. Findings suggested that in general people are more likely to have conversational connections with those that share their views. However, within the UK community, despite the polarization in the climate change debate, data also indicated strong communications between people with opposing opinions about climate change (Pearce, Holmberg et al. 2014), suggesting the possibility of potentially building greater mutual understanding between groups with differing beliefs.

Social media has also previously been used to examine public perceptions about climate change (Segerberg and Bennett 2011, Auer, Zhang et al. 2014, Kirilenko and Stepchenkova 2014, Pearce, Holmberg et al. 2014, Pearce, Niederer et al. 2019). Satchwell (2013) explored children's understanding of climate change using Twitter conversations as an observational method, concluding that access to information about climate change does not necessarily translate to actions taken for climate change mitigation. Kirilenko et al (2014) collected a total of 1.8 million tweets in 2012 and 2013 to assess people's perceptions and impressions of climate change depending on their spatial location and potential exposure to news or events related to climate change. Kirilenko et al.(2014) found that the climate change discourse in Twitter showed high temporal variability, and intensified significantly with major new events, such as Hurricane Sandy that impacted the Atlantic in 2012.

Veltri and Atasanova (2017) introduced the use of semantic analysis and Natural Language Processing (NLP) tools to the analysis of Twitter data and climate change. The researchers' findings suggested that the most salient topics expressed along with 'climate change' were 'awareness', 'flood', 'action', and 'energy'. The researchers also found four main thematic clusters emerging from the discourse around climate change: i) calls for action and awareness, ii) causes and consequences, iii) policy debates, and iv) local events associated with climate change. These findings develop a broad understanding of public opinions of climate change by identifying the formation and evolution of themes and their frequency in the discourse of climate change. However, Veltri and Atasanova (2017) did not delve further into the nature of the discourse within each of the thematic clusters identified, to consider for example, the types of action called for. Indeed there is no current evidence, of which the authors are aware, of the assessment of Twitter users' discourse around the actions for climate change mitigation, or of how these may have changed over time during the global pandemic.

This paper reports the results from a longitudinal study examining public perceptions about actions for climate change mitigation through sets of tweets streamed at three different points in time during the covid-19 pandemic, contributing to the understanding of publics' perceptions of actions taken to mitigate climate change and the changes in these perceptions over time. We used Twitter data collected in February (*time 1*), June (*time 2*), and October (*time 3*) 2020, respectively. We hypothesized that the global pandemic may impact the frequency with which actions for climate change mitigation are mentioned within tweets. We also predicted that the topics emerging within tweets relating to actions for climate change mitigation may change over time, differing both in terms of the frequency with which they emerge and the nature of the topics.

2 Materials and Methods

2.1 Sampling Procedure

Latent Dirichlet Allocation (LDA) topic modelling is an NLP technique described as an unsupervised machine learning technique that analyses text data to determine clusters of words or topics for a set of documents. In the case of social media, topic models are used to analyse public reactions and conversations that happen online between people by extracting and identifying patterns in the popular topics shared on platforms such as Twitter (Sun, Luo et al. 2017, Xu, Liu et al. 2017). By topics we refer to the collection of dominant topic words that often work as representatives; the topic words can help us define the main topics of discussion. In the context of text modelling, the topic probabilities provide an explicit representation of the content of the documents (Blei, Ng et al. 2003).The researchers decided to use the LDA model based on previous literature using this method (Ostrowski 2015, Chen, Yao et al. 2016) and also due to its unsupervised classification features, not requiring for pre-defined topics was crucial for the evaluation of hidden patters or topics within the discussions of action tweets for climate change mitigation.

We used R software, to stream unique tweets written in English with the Rtweet package at three different points in time with the keywords "climate change", "sustainable", "environmental + action", "be green", "global warming" and "save the planet". We streamed all the available unique tweets with the relevant keywords daily, then compared them with tweets collected on previous days and removed duplicates, we kept on doing this process until we reached a minimum of 300,000 tweets streamed at each time point. On the first stream, *time 1*, we obtained 318,749 tweets (4^{th} – 13^{th} of February 2020), *time 2* 305,851 tweets (17^{th} June – 2^{nd} of July 2020) and *time 3* 303,636 (12^{th} – 23^{rd} of October 2020). A total of 928,236 tweets were streamed across the three points in time; all tweets were anonymized prior to any further analysis. The rationale behind the choosing of these time periods was based on the stages of the pandemic in the UK; the first set of Tweets streamed on February (time 1) was collected to gather data on the early stages of the pandemic, the second set of tweets (time 2) was collected after designing the study (four months later) to gather data just after the 1^{st} lockdown in the UK, and time 3 was collected four months after time 2 just as the UK was reconsidering their actions towards the 2^{nd} wave of the pandemic in the UK. Thus, the gaps between the streams also allowed an evaluation of the perception of climate change mitigation actions during the different stages of the pandemic. For tweets classification and analysis we used Python.

Since we were interested in actions for climate change mitigation, we selected 'action' tweets from the tweets dataset at each time point. In order to identify the 'action' tweets, one researcher independently classified a total of 3949 tweets from the first data set (Pitsilis, Ramampiaro et al. 2018, Ljevar, Goulding et al. (in press)). A second rater then classified a random sample of 750 tweets from the same sample of tweets using criteria identified by the first researcher to discuss and

validate the tweet's classification. The inter-rater reliability Cohen's kappa test showed a good level of agreement between the raters (2 raters), $\kappa = 0.64$ (95% CCI, 0.588 to 0.700) $p \leq 0.05$.

An 'action' tweet was considered as any tweet that would describe a behaviour aiming to mitigate climate change, see Table 1. For example, a tweet was considered an 'action' tweet if they identified the actions that others ought to do to mitigate climate change (e.g., *"…If you lecture about climate change sell your private jets use mass transit and bike or walk when possible go vegan …"*); reported the start of a particular behaviour intended to mitigate climate change, in either in individual or collective form (e.g.,*" Jane Fonda recycled a 2014 gown …to make a statement about climate change", or "From banning pesticides to growing green roofs on bus stops … communities are trying to save the bees"*). Action tweets also included the development of policies to tackle climate change (e.g., *"The government has announced funding to support 13 projects that will plant 50000 trees in total across England to support the fight against climate change"*); pointed out others' perceptions about environmental actions that, in their opinion, do not help to mitigate climate change (e.g.,*"…Being vegan will not save the planet…"*); and highlighted or condemned other people's actions around climate change (e.g., *"You are using a lithium battery to operate your phone climate change HYPOCRITE"*).

Detecting 'action tweets' was considered a classification task with a 2-class variable. Data was split into training (80%) and test (20%) sets. We used neural network architecture in this task, as it has previously been shown to be successful when trained on language properties (Cocos, Fiks et al. 2017). A Bi-Directional Long Term Memory (BiLSTM) was used to classify climate change tweets as 'action' or 'non-action' tweets. Recent literature have shown that neural network models, such as BiLSTM, performs better in cases beyond sequence prediction problems and in the field of text classification (Cocos, Fiks et al. 2017, Ljevar, Goulding et al. (in press)). BiLSTM transforms words in sequences of vectors to process them across the different documents and examine the temporal dependencies of words within the data. Thus, the input features for the BiLSTM model were word-embedded vectors that were created from the manually labelled Twitter data (see Figure 1) Performances were then tested on the remaining set of tweets and the quality of performance was assessed using the classification prediction. Prediction accuracy of 88.3% was obtained along with satisfactory recall (0.74) and precision (0.93) scores. This classification prediction was deemed as successful and the model was used on all the three sets of tweets to automatically classify the tweets into 'action' and 'non action'. As a result, a total of 165,872 'action' tweets was obtained across the three-time points of datasets.

2.2 Procedure unsupervised machine learning analysis.

For the identification of the topics for each set of tweets, we selected the 'action' tweets only, since we were interested in public perceptions regarding actions for climate change mitigation. For this task, unsupervised machine learning was used, specifically, Latent Dirichlet Allocation (LDA) model, with the Gensim package from the programming software Python. LDA is an unsupervised machine learning technique indicating that there is no predefined list of tags. Topic modelling scans a dataset of text, detecting words and phrase patterns within the text and clusters the word groups and similar expressions that characterize the dataset. We analysed each set of tweets separately to identify relevant topics discussed for each of the three datasets of tweets.

After analyzing the text content of all the tweets within one dataset, LDA calculates the percentage of each topic present within each set of tweets. The output of the LDA model thus lists all the topics

along with the frequency of how often a topic was used within the text of the tweets. It is important to highlight that there can be more than one topic within a tweet.

For all three data sets of action tweets we filter out stop words (e.g., *"a", "the")* and the keywords that were used to stream the tweets (e.g., *"climate change", "save the planet").* We then lemmatized the remaining words; this process transforms the word to its root *(e.g., walking to walk), then created* a dictionary from the lemmatized data and convert this to a bag of words corpus; this was the main input for the LDA model. Then, we identified the optimal number of topics that best fitted the data by running many simulations of the model and adjusting the number of topics in order to find the number that optimized the objective metric, in this case, the objective metric was the coherence score (Kapadia 2019). For topics optimization we used coherence score rather than perplexity score sometimes used, since it has been shown to correlate better with human interpretability (Kapadia 2019). The number of topics that held a coherence score of 0.54 for time 1 was 9 topics, for time 2 we obtained a model with 12 topics and a coherence score of 0.55, and for time 3 we obtained a model with 11 topics and a coherence score of 0.5. After setting the number of topics for each set of 'action' tweets we assessed the differences in the Twitter data between time points in terms of number of topics, frequency, nature of topics, relevant topic words, and the emergence of new topics. Table 2 provides an overview of the process of tweets collection and the final number of action tweets used in the topic modelling analysis.

In order to define the outcomes from the topic modelling analysis we will develop topics from the clusters of words that the model defines (henceforth referred to as 'topic words') along with the percentage of tweets that relate to each topic (Table 4). The interpretation of the topics was carried out by evaluating the collection of dominant topic words within each topic; this was supported with the manual examination of tweets to understand the context where the topic words were used. Two researchers oversaw the assessment of the collection of dominant topic words for each topic to define all topics in the three datasets.

3 Results and Discussion

The following data shows the results of the topic modelling analyses of the 'action' tweets streamed at the three different points in time during the covid-19 pandemic (February, June, and October 2020). Table 2 shows the total number of 'action' tweets identified for all three sets of data. Findings show an increase of more than double the number of action tweets found at *time 1* (33,659), for *time 2* (72,798), and similar high amounts at *time 3* (59,415). Table 3 shows the brief statistics of total number of words, number of unique words and average of relevant words per tweet for the 'action' tweets.

Overall, the most salient topic words across the three sets of tweets were: energy, food, people, and help. The topic words 'tax', 'money', and 'funding' were observed at *time 1* and then became less frequent within the *time 2* and *time 3* datasets. Among the most frequent topic words observed in *time 1* tweets were: 'carbon', 'money', 'energy', 'tax', 'fuel', 'customer', 'fund', 'fossil', 'emission', 'trade', 'coal', 'address', and 'clean'. For *time 2* the most frequent topic words were: 'energy', 'food', 'development', 'future', 'production', 'waste', 'farmer', 'recovery', 'people', 'solution', and 'agriculture'. And for *time 3* the most frequent words were: 'energy', 'food', 'future', 'development', 'people', 'industry', 'farmer', 'plastic', 'fashion', and 'packaging'. The topic words 'farmer', 'plastic', 'food', 'packaging', 'waste', and 'agriculture' seemed to be more frequent across the tweets from *time 2* and *time 3*, but not in *time 1*.

The analyses of the topic modelling included the interpretation of the topics found by the model. In order to interpret these topics, we examined the most relevant topic words for each topic, detected sections of tweets that presented these topic words and used this as the basis for naming the topics for each of the three-time points. Table 4 compares the frequency of topics identified in datasets between timepoints.

While tweets on climate change mitigation are predominantly focused on the topic of '*Government actions'* in *time 1* (52.9%), we found its relevance decreased for *time 2* (21.6%) and *time 3* (2.8%). The drop in relevance of the topic of '*Government actions'* for *time 2* and *time 3* could be due to governments' actions focusing primarily on the pandemic at *times 2* and *3*, resulting in users talking more about the government and covid-19 than the government and climate change. Table 5, Table 6, and Table 7 provide further information on each topic identified, along with examples of tweets that mentioned the topic. By comparing the topics that were present at different time points, we can see that some topics, labelled as the same, differ with regards to the relevant topic words within the topic. For example, the topic of '*Government actions'* in *time 1* was represented with the topic words 'money', 'fund', 'fuel', 'fossil', 'tax', and 'investment', whereas for *time 2* representative topic words for this topic were: 'development', 'recovery', 'covid', 'resilient', and 'report'; and for *time 3* representative topic words for the same topic were: 'plan', 'healthcare', 'act', 'insurance', 'data', 'police', 'socially', and 'council'. These results suggest that the discussions encompassed by the topic of '*Government actions'* differed over time. One possible explanation is that *time 1* could have been influenced by the early voting for presidential elections in the US occurring in February 2020; we considered that this event may have politicized the tweets relating to climate change mitigation at *time 1*, driving comments around climate change mitigation to be focused more on the candidates and not on the problem itself.

The *'Environmental behaviour*' topic commenting on actions for the mitigation of climate change seemed to be the most prominent topic for *time 2* (46.9%) and *time 3* (69.9%), in comparison to *time 1* (33.6%). One plausible reason for the increase in the relevance of the topic is that people may have started to reflect on their behaviour over the course of the pandemic that were incidentally more pro-environment due to restrictions, perhaps partly due to increased time that some had available for this. Indeed, research indicates that individuals reflecting on their actions towards climate change and the implications of climate change on their lives, may have an impact on their behavioural intentions for climate change mitigation (Rickard, Yang et al. 2014). Another explanation of why the topic *'Environmental behaviour*' had an increase in the amount it was mentioned may be due to the increase in non-environmental behaviour individuals had to undertake due to covid-19 (e.g., wear face masks, use disposables, use hand gel) having a compensatory effect on other environmental behaviour (Hope, Jones et al. 2018, Capstick, Whitmarsh et al. 2019). So, individuals may have mentioned actions to mitigate climate change more to make up for other less climate friendly actions they were undertaking.

The topics of '*Social network initiation'* and *'Awareness and fairness'* found at *time 1* were not present at *time 2* and *time 3* and we consider that these topics could have been attached to events. In the case of '*Awareness and fairness'*, we consider that the US campaign may have had an impact on the nature of this topic since the relevant topic words of this topic suggest users pointing out unconformity about individuals showing non-environmental behaviour (e.g., *"Like lecturing on climate change while having multiple homes private jets helicopters Private armed security you think rules dont apply to you"*). In addition, in *times 2* and *3* when the pandemic was more spread across the globe, more restrictions were reducing the visibility of the non-environmental actions (e.g., travel on private planes). As for *'Social network initiation'* we consider that these were primarily calls for individuals to act on a particular event or to support a particular campaign or business; the lack of presence of this

topic in *time 2* and *time 3* could also be due to the restrictions that governments enforced to achieve social distancing.

The topic '*Awareness'*, which is present at all three-time points, relates to the promotion of awareness around climate change. This topic seemed to change over time as well. At *time 1* (3.7%), topic words included 'award', 'elite', 'mention'. On further examination of tweets containing this topic, we found that the text of climate change mitigation was followed by the names of different international events, most of them related to climate change (e.g., *"… Prize in Food and Agriculture Sciences ... and aims to improve crop production and hardiness helping to address challenges of global population growth and climate change…", "Im sure many stars will use the Oscars to raise awareness for climate change"*). As for *time 2* (2.3%) and *time 3* (1.3%) the topic of *"Awareness"* seemed to relate more to types of actions for climate change mitigation, topic encompassing topic words such as 'packaging', 'bag', 'fair', 'env_conscious', 'raise_awareness', 'fundraising' (e.g., "*Young people all over the world are working hard to raise awareness about ClimateChange …Climate change is real and we need to dramatically reduce greenhouse gas emissions", "…environmentally conscious teen …who believes we can all continue to help the environment and remain sustainable even when we are stuck at home…"*). The change in this topic with the reduction in references to international events as a forum for raising awareness about climate change again may be attributed to the pandemic restrictions banning mass gatherings.

Our analysis also indicated a topic discussing what organisations do to combat climate change, we titled *'Organisation's actions'*. At *time 1* (1.8%) we found the discourse around this topic focused on environmental actions taken, or to be taken in the future by organisations, with relevant topic words: 'reduce_passenger', 'greeneconomy',and 'wildlife' (e.g., *"…Airlines may need to reduce passengers to take off due to climate change…"; "changing aircraft altitude could cut flights climate impact in half…", "…how going digital and eradicating paper receipts sets companies on a sustainable path in the green economy…*"). For *time 2* (0.9%) and *time 3* (1.5%) other topic words emerged such as: 'bank', 'powerful', 'museum', 'amazon_pledge', 'cost_effective', 'airline' ,and 'hotel' (e.g., *" FYI systemic barriers to energy efficiency low zero carbon world banks funding of high carbon polluting investments" ; "Amazon pledges 2bn investment to fight climate change…", " Alaska Airlines and Microsoft sign partnership to reduce carbon emissions with flights";" Beer company… in Colombia introducing an Airbnb style platform showcasing Colombian ecohotels that…sustainable tourism…", …"redesign the museum to help bring about more equitable and sustainable futures in the climate change era Then check out the design competition Reimagining Museums for Climate Action…")* . The differences of the topic words between time points suggest that while in *time 1* people call for organisational actions, *times 2* and *3* discussions were focused on reporting organisational actions. This may reflect an increase in the importance placed upon corporate social responsibilities (Kolk and Van Tulder 2010, Rosen-Zvi 2011).

In addition, we found that the topic of *'Collective actions'*, though present at all three-time points, reduced its prevalence at *time 2* (1.4%) and *time 3* (1.4%) in comparison to its presence in *time 1* (3%). One possible explanation for the low presence of this topic within the climate change mitigation discussion is the reduction of social behaviours due to the fear of the contagiousness of covid-19. Moreover, as time passed, more restrictions were happening across the globe and with it the reductions in social and cooperative behaviour.

The topic of '*Collective actions'* also appeared different in nature between times, with differences in relevant topic words evident. At the beginning of the year, at *time 1*, this topic included topic words such as: 'city', 'ready', 'milk', 'bee', 'collective', 'mobility', and 'network'; suggesting group

behaviours (e.g., *"From banning pesticides to growing green roofs on bus stops here are 5 ways communities are trying to save the bees..."*, *It is a collective action to reduce the impact of climate change we are making agriculture more efficient through AI an important effort to make farming more sustainable"*, *"Sharing is caring If we own less and use more things collectively ...Sharing cars exchanging clothes lending and borrowing tools"*). Relevant topic words within the same topic in *time 2* were: 'threat', 'regulation', 'adapt', 'corona', 'cooperative', and 'electric_car' suggesting a focus on individual behaviour that may benefit the community (e.g., *"...celebrates 26 years of unique hospitality…. the pioneer of eco initiatives ... lighting the path for a sustainable hospitality industry*", *"Cooperatives for climate action…Heating cooling planning for greener cities Sustainable transport…", "build low income housing for working families and or a non profit worker cooperative that gives back to the community through the arts sustainable farming…")*. For *time 3*, the most relevant terms of the topic *'Collective actions'* were: 'chemical', 'bag', 'bond', 'solid', 'wealthy', 'attention', 'consume', 'tea', 'ewaste', 'evolution', 'socialism', and 'nitrogen'; suggesting cooperative behaviour to perform individually, e.g., (*"Cut the chemicals and learn how to create natural sustainable cleaning tools from things youll have in your cupboards",* "*Sustainable behavior begins at home kick starts the International EwasteDay caign [sic] by pledging to dispose off [sic] old electronics responsibly*…").

We observed the emergence of new topics, at *time 2: 'Food', 'Nature conservation'*, and at *time 3: 'Support farmers',* and *'Consequences of climate change solutions'*. For both *times 2* and *3* we also observed the emergence of topics: *'Eco-friendly products'*, *'Sustainable production'*, *'Innovative solutions'*, and *'Third party actions'*. The topic '*Support farmers*' at *time 3* contained topic words related to the common agricultural policy (CAP) which suggest that the topic was based on opinions around the negotiations that happened in October at the European council regarding the common agricultural policy reform package. This same event may have also influenced the discussion of other related topics such as *'Eco-friendly products', 'Sustainable production', and 'Food'*.

The topic '*Eco-friendly products'*, had similar topic words at both *times 2* and *3* including: 'plastic', 'product', 'clothing', 'fashion', 'packaging', and 'sustainably'; and the topic *'Sustainable production'* also presented similar topic words between *times 2* and *3* such as: 'Coffee', 'palm_oil', 'chocolate', 'manufacture', 'rainforest', 'dairy', 'bottle', 'beef', 'trading', and 'locally'. The topic modelling indicated these topics as different and we interpreted them as such based on the conceptual differences between eco-friendly and sustainable products and the relevant topic words found for each topic. Notably a product is eco-friendly when it has been designed to do the least possible damage to the environment (e.g., biodegradable plastic, bamboo toothbrush), whereas sustainable products should recognize and minimize the social, ethical, and environmental impact of the product; while sustainability may include eco-friendly activities, eco-friendly does not always translates to sustainable. It is unknown why these topics became more prevalent over time but shopping, and the nature of shopping may become more salient during the pandemic given store closures, restrictions on purchasing, and inability of many to visit shops due to shielding. The salience of purchasing behaviour may have been accompanied by an increased reflection on what kinds of products people were buying.

In addition, the topic of *'Protests to government'* emerged in *time 1* (1.5%) and *time 2* (1.2%) only, with the promotion of active protesting to governments and organisations on climate change, for example, 'dc_weekly' was a bigram found on tweets encouraging people to go every week to protest about climate change at Washington DC. By *time 3* this topic disappears; this again could be attributed

with the restrictions on gatherings taking place in more countries or being out staged by other types of protests that happened at the time (e.g., protest anti-lockdown, or against facemasks).

4 Conclusions

According to the results of this study, public discourse around actions for climate change mitigation changed over time during the coronavirus pandemic on Twitter. We also observed an increase in the number of tweets that talk about actions to combat climate change at *times 2* and *3* in comparison with *time 1*. With the use of Twitter data and machine learning techniques, we examined the public perceptions of actions for climate change mitigation during the coronavirus pandemic in 2020. Data indicates changes in perceptions over time, a pattern that appears to relate to restrictions in behaviour and social activity, and the increased salience of, and potential reflection, on certain behaviours. These changes support the idea that the pandemic impacted discourse around actions to tackle climate change. The development of sustainable communications and behavioural strategies could benefit from the findings of this paper in order to help support and promote those environmental behaviours that are likely to endure over time.

We observed changes in topics within tweets relating to climate change actions over time which may reflect a pattern of change relating to restrictions on mobility and public gatherings due to covid-19. We note a decrease in the prevalence of the *'Awareness and fairness'* topic, possibly an incidental result of restrictions on mobility and people shielding to avoid covid-19. In addition, the reduction of *'Social network initiation'* along with the change in nature of *'Collective actions'*, and *'Awareness'* may be attributed to the same restrictions of mobility and gatherings. Over time these appear to focus more on individual behaviour rather than group behaviour. These behaviours may change again once restrictions are lifted and individuals can travel, and meet socially etc., without covid-19 being a threat to their health. Changes here may therefore not persist long term.

Changes in topics observed within tweets also indicated the possibility of an increased salience of certain behaviour due to covid-19. The increase of the prevalence of the *'Environmental behaviour'* topic within tweets over time may be explained partially by an increased focus on certain environmental behaviour. It is possible that people had more time to reflect on their behaviour, particularly behaviour that given restrictions, was also incidentally more environmentally friendly. On the other hand, this could be explained by people observing increases of non-environmental behaviour relating to measures to contain covid-19 (e.g., face masks, single use plastic) may also contribute to a drive to balance this by doing more for the environment (a compensatory effect). We may have observed a similar pattern in the increase in the prevalence of the topic of *'Sustainable production'*. We suggest this may be the result of people's reflection on their shopping habits. If changes in discourse we have observed are indeed due to increased salience of certain behaviours, and increased reflection on environmental behaviour (cf. (Rickard, Yang et al. 2014), then associated behavioural changes are likely to continue in the longer term. We note that information processing models (e.g., the Elaboration likelihood model (Petty and Cacioppo 1986, Manca, Altoè et al. 2020) and the Heuristic systematic model (Chen and Chaiken 1999, Kim, Lee et al. 2015, Shi, Gong et al. 2020)) indicate that systematic consideration and elaboration of behaviour is likely to lead to more permanent behaviour changes. Manca et al (2020) suggested that reflection on the consequences of unsustainable behaviour may be one main predictor of rational-intentional proenvironmental choice.

One of the most common themes observed around peoples' perceptions of actions to mitigate climate change is 'energy', this did not change during the different time points, and it is consistent with previous findings in the literature (Kirilenko and Stepchenkova 2014). This indicates that considering

energy is the most discussed aspect of how to take action on climate change and may be the most salient to people.

While coronavirus seemed to have an impact on the perceptions of actions for climate change mitigation, we observed that other unrelated events (e.g., general elections in the US, agricultural policies in the EU) also had an impact on the topics that emerged in the discussions of climate change mitigation. The topic of '*Government actions'*, was particularly frequently noted in the tweets around climate change mitigation for *time 1*, this is consistent with the literature that suggests climate change is a politicised issue (Weber 2010, Clayton, Devine-Wright et al. 2015, Poortinga, Whitmarsh et al. 2019). However, these discussions seemed to be subdued at further time points, perhaps due to the presence of other issues, such as coronavirus; this seems to be consistent with findings in the literature suggesting a "worry budget" and the coronavirus pandemic taking over political and administrative agendas (Bostrom, Böhm et al. 2020, Helm 2020).

The analysis performed here for the study of public perceptions of actions for climate change mitigation allowed us to evaluate the topics people talked about without predefined topics, contributing to the identification of topics that may not be considered in scientific reports of climate change mitigation (e.g., protests, nature conservation, collective action). It is important to note that while this research identified the topics people talked about when talking about climate change mitigation, we cannot define whether the discussions were positive or negative around a topic, for example, when we see terms like 'carbon', 'emission', 'tax', on a topic we can infer they talk about taxing carbon emissions, but we cannot define whether they are in favor or against of taxing carbon emissions. We also highlight that the classifications of action tweets for climate change mitigation were based on word coding from the researchers, and it is possible that words identified and therefore the related dataset could be slightly different if different researchers were to identify actions on climate change within tweets. Similarly, topics identified within topic analysis were interpreted and named by the researchers, and while we validated the topic interpretation with two different researchers this is still open to subjective bias; notably differences observed in themes over time, are also dependent on the themes being identified as the same predominant types between time points, e.g., different types of tweet being identified as relating to *'Collective action'* between time points may partly explain differences observed in this topic. We attempted to minimize subjective bias with second coding by additional researchers.

Whilst Twitter can be used to gather information about people's perceptions of a topic, we acknowledge that the information found in the tweets does not necessarily define the user's views. On Twitter, users' self-present to a "networked audience"; an audience thought to consist of real and imaginary or potential viewers (Papacharissi 2002). Moreover, it has been suggested that users write different tweets to different audiences; these tweets are typically influenced by the tweets, or re-tweets, within the user's feed (Marwick and Boyd 2011). The implications of this for our data are that they may not represent people's perceptions but may reflect of what the user is exposed on their news feed or virtual context and what they may perceive as 'socially accepted' by other users.

Further research should focus on the evaluation of whether the topics we found on this study will still appear within public perceptions of climate change mitigation when the governments' restrictions are lifted, and covid-19 becomes less of a threat to public health. We also consider it relevant to explore if the presence of one topic co-occurs with another topic, indicating whether specific discussions around actions for climate change mitigation prepare the ground for others, this could add to the study of behavioural spillover effects between environmental behaviours (Lanzini and Thøgersen 2014, Thomas, Poortinga et al. 2016, Margetts and Kashima 2017).

Overall, this paper highlights the importance of studying public perceptions of actions for climate change mitigation, and how these are likely to change due to social context and events that may not be directly related to climate change such as covid-19. Previous literature suggests climate change and covid-19 are similar global threats (Bostrom, Böhm et al. 2020). This paper supports the idea that the coronavirus pandemic has impacted the nature of comments relating to actions for climate change mitigation on Twitter. We observed an increased number of tweets relating to actions to combat climate change over the course of the coronavirus pandemic as well as changes in the prevalence and types of topics emergent within tweets relating to action on climate change. Understanding perceptual and behavioural changes towards the environment due to covid-19 and which of these are likely to persist in the long term could help in structuring environmental communications and behavioural interventions to support long term sustainable behaviour change.

5 Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

6 Data Availability Statement

The data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

7 Author Contributions

MG, AS and EF contributed the conception and design of the study. MG wrote the first draft of the manuscript. VL and MG contributed to the programming of the RNN and LDA models. MG, AS performed the qualitative analysis. MG, AS, and EF contributed with iterations of manuscript revision. All authors read and approved the submitted version.

8 Funding

This work was supported by the doctoral scholarships granted by CONACYT- Mexico grant number: 614574, and partly supported by the EPSRC through the Trusted Autonomous Systems Hub [EP/V00784X/1] and Horizon Digital Economy Research [EP/T022493/1 and EP/M02315X/1].

9 Acknowledgments

We would like to thank Mairi Houlgreave for their contributions as a second rater of the Tweets. And James Goulding for their contribution on clarifying technical queries.

10 References

Achen, C. H. and L. M. Bartels (2017). Democracy for realists: Why elections do not produce responsive government, Princeton University Press.

Auer, M. R., et al. (2014). "The potential of microblogs for the study of public perceptions of climate change." Wiley Interdisciplinary Reviews: Climate Change **5**(3): 291-296.

Blei, D. M., et al. (2003). "Latent dirichlet allocation." Journal of machine Learning research **3**(Jan): 993-1022.

Bollen, J., et al. (2011). "Twitter mood predicts the stock market." Journal of computational science **2**(1): 1-8.

Bostrom, A., et al. (2020). "Credible Threat: Perceptions of Pandemic Coronavirus, Climate Change and the Morality and Management of Global Risks." Frontiers in psychology **11**.

Bradbury-Jones, C. and L. Isham (2020). "The pandemic paradox: The consequences of COVID-19 on domestic violence." Journal of clinical nursing.

Bradley, A. and R. J. James (2019). "How are major gambling brands using Twitter?" International Gambling Studies: 1-20.

Brody, S. D., et al. (2008). "Examining the relationship between physical vulnerability and public perceptions of global climate change in the United States." Environment and Behavior **40**(1): 72-95.

Brossard, D. (2013). "New media landscapes and the science information consumer." Proceedings of the national academy of sciences **110**(Supplement 3): 14096-14101.

Capstick, S., et al. (2019). "Compensatory and catalyzing beliefs: Their relationship to pro-environmental behavior and behavioral spillover in seven countries." Frontiers in psychology **10**: 963.

Center, P. R. (2009). "Public praises science; scientists fault public, media." Washington, DC.

Chen, Q., et al. (2016). Short text classification based on LDA topic model. 2016 International Conference on Audio, Language and Image Processing (ICALIP), IEEE.

Chen, S. and S. Chaiken (1999). "The heuristic-systematic model in its broader context."

591 Clayton, S., et al. (2015). "Psychological research and global climate change." Nature climate change
592 **5**(7): 640-646.

593

594 Cocos, A., et al. (2017). "Deep learning for pharmacovigilance: recurrent neural network
595 architectures for labeling adverse drug reactions in Twitter posts." Journal of the American Medical
596 Informatics Association **24**(4): 813-821.

597

598 Demski, C., et al. (2017). "Experience of extreme weather affects climate change mitigation and
599 adaptation responses." Climatic change **140**(2): 149-164.

600

601 Deryugina, T. (2013). "How do people update? The effects of local weather fluctuations on beliefs
602 about global warming." Climatic change **118**(2): 397-416.

603

604 Dessai, S. and C. Sims (2010). "Public perception of drought and climate change in southeast
605 England." Environmental hazards **9**(4): 340-357.

606

607 Helm, D. (2020). "The environmental impacts of the coronavirus." Environmental & Resource
608 Economics: 1.

609

610 Hope, A. L., et al. (2018). "The role of compensatory beliefs in rationalizing environmentally
611 detrimental behaviors." Environment and Behavior **50**(4): 401-425.

612

613 Kahan, D. M., et al. (2011). "Cultural cognition of scientific consensus." Journal of risk research
614 **14**(2): 147-174.

615

616 Kapadia, S. (2019). "Evaluate Topic Models: Latent Dirichlet Allocation (LDA)." Onlineresource)
617 Availableat https://towardsdatascience. com/evaluate-topic-model-in-python-latent-dirichlet-
618 allocation-lda-7 d57484bb5d0.

619

620 Kim, H., et al. (2015). "The heuristic-systemic model of sustainability stewardship: Facilitating
621 sustainability values, beliefs and practices with corporate social responsibility drives and eco-
622 labels/indices." International Journal of Consumer Studies **39**(3): 249-260.

623

624 Kirilenko, A. P. and S. O. Stepchenkova (2014). "Public microblogging on climate change: One year
625 of Twitter worldwide." Global environmental change **26**: 171-182.

Klemeš, J. J., et al. (2020). "Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19." Renewable and Sustainable Energy Reviews **127**: 109883.

Kolk, A. and R. Van Tulder (2010). "International business, corporate social responsibility and sustainable development." International business review **19**(2): 119-125.

Lanzini, P. and J. Thøgersen (2014). "Behavioural spillover in the environmental domain: an intervention study." Journal of Environmental Psychology **40**: 381-390.

Ljevar, V., et al. ((in press)). "Perception detection using Twitter." Proceedings of the IEEE BigData 2020.

Manca, S., et al. (2020). "The persuasive route to sustainable mobility: elaboration likelihood model and emotions predict implicit attitudes." Environment and Behavior **52**(8): 830-860.

Margetts, E. A. and Y. Kashima (2017). "Spillover between pro-environmental behaviours: The role of resources and perceived similarity." Journal of Environmental Psychology **49**: 30-42.

Marshall, B. K., et al. (2005). "Ecological disaster as contextual transformation: Environmental values in a renewable resource community." Environment and Behavior **37**(5): 706-728.

Marwick, A. E. and D. Boyd (2011). "I tweet honestly, I tweet passionately: Twitter users, context collapse, and the imagined audience." New media & society **13**(1): 114-133.

Ortiz-Ospina, E. (2019). "The Rise of social media." from https://ourworldindata.org/rise-of-social-media.

Ostrowski, D. A. (2015). Using latent dirichlet allocation for topic modelling in twitter. Proceedings of the 2015 IEEE 9th International Conference on Semantic Computing (IEEE ICSC 2015), IEEE.

Papacharissi, Z. (2002). "The presentation of self in virtual life: Characteristics of personal home pages." Journalism & Mass Communication Quarterly **79**(3): 643-660.

Pearce, W., et al. (2014). "Climate change on Twitter: Topics, communities and conversations about the 2013 IPCC Working Group 1 report." PloS one **9**(4): e94785.

Pearce, W., et al. (2019). "The social media life of climate change: Platforms, publics, and future imaginaries." Wiley Interdisciplinary Reviews: Climate Change **10**(2): e569.

Petty, R. E. and J. T. Cacioppo (1986). The elaboration likelihood model of persuasion. Communication and persuasion, Springer**:** 1-24.

Pitsilis, G. K., et al. (2018). "Detecting offensive language in tweets using deep learning." arXiv preprint arXiv:1801.04433.

Poortinga, W., et al. (2019). "Climate change perceptions and their individual-level determinants: A cross-European analysis." Global environmental change **55**: 25-35.

Rao, T. and S. Srivastava (2014). Twitter sentiment analysis: How to hedge your bets in the stock markets. State of the art applications of social network analysis, Springer**:** 227-247.

Rickard, L. N., et al. (2014). "The "I" in climate: the role of individual responsibility in systematic processing of climate change information." Global environmental change **26**: 39-52.

Rosen-Zvi, I. (2011). "You are too soft: What can corporate social responsibility do for climate change." Minn. JL Sci. & Tech. **12**: 527.

Rupani, P., et al. (2020). "Coronavirus pandemic (COVID-19) and its natural environmental impacts." International Journal of Environmental Science and Technology: 1-12.

Saadat, S., et al. (2020). "Environmental perspective of COVID-19." Science of The Total Environment: 138870.

Satchwell, C. (2013). ""Carbon literacy practices": textual footprints between school and home in children's construction of knowledge about climate change." Local environment **18**(3): 289-304.

694 Schumaker, R. P., et al. (2016). "Predicting wins and spread in the Premier League using a sentiment
695 analysis of twitter." Decision Support Systems **88**: 76-84.

696

697 Segerberg, A. and W. L. Bennett (2011). "Social media and the organization of collective action:
698 Using Twitter to explore the ecologies of two climate change protests." The Communication Review
699 **14**(3): 197-215.

700

701 Shi, S., et al. (2020). "Antecedents of Trust and Adoption Intention toward Artificially Intelligent
702 Recommendation Systems in Travel Planning: A Heuristic–Systematic Model." Journal of Travel
703 Research: 0047287520966395.

704

705 Shilling, F. and D. Waetjen (2020). "Special Report (Update): Impact of COVID19 Mitigation on
706 Numbers and Costs of California Traffic Crashes."

707

708 Spence, A., et al. (2011). "Perceptions of climate change and willingness to save energy related to
709 flood experience." Nature climate change **1**(1): 46-49.

710

711 Statistics, O. o. N. (2020). "Coronavirus and the social impacts on Great Britain, 16 April." Retrieved
712 5/01/2020, 2020, from
713 https://www.ons.gov.uk/releases/coronavirusandthesocialimpactsongreatbritain16april2020.

714

715 Stern, P. C., et al. (1997). "Consumption as a problem for environmental science." Environmentally
716 significant consumption: Research directions: 1-11.

717

718 Sun, S., et al. (2017). "A review of natural language processing techniques for opinion mining
719 systems." Information fusion **36**: 10-25.

720

721 Thomas, G. O., et al. (2016). "The Welsh single-use carrier bag charge and behavioural spillover."
722 Journal of Environmental Psychology **47**: 126-135.

723

724 Travaglio, M., et al. (2020). "Links between air pollution and COVID-19 in England." medRxiv.

725

726 Tversky, A. and D. Kahneman (1974). "Judgment under uncertainty: Heuristics and biases." Science
727 **185**(4157): 1124-1131.

728

729 Veltri, G. A. and D. Atanasova (2017). "Climate change on Twitter: Content, media ecology and
730 information sharing behaviour." Public understanding of science **26**(6): 721-737.

731

732 Weber, E. U. (2006). "Experience-based and description-based perceptions of long-term risk: Why
733 global warming does not scare us (yet)." Climatic change **77**(1-2): 103-120.

734

735 Weber, E. U. (2010). "What shapes perceptions of climate change?" Wiley Interdisciplinary
736 Reviews: Climate Change **1**(3): 332-342.

737

738 World Health Organization (2020). "Statement on the second meeting of the International Health
739 Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019-
740 nCoV)." Retrieved 30/10/2020, 2020, from https://www.who.int/news/item/30-01-2020-statement-
741 on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-
742 regarding-the-outbreak-of-novel-coronavirus-(2019-ncov).

743

744 Wu, J., et al. (2016). "Big data meet green challenges: Big data toward green applications." IEEE
745 Systems Journal **10**(3): 888-900.

746

747 Xu, Z., et al. (2017). "Crowdsourcing based social media data analysis of urban emergency events."
748 Multimedia Tools and Applications **76**(9): 11567-11584.

749

750 You, S., et al. (2020). "COVID-19's unsustainable waste management." Science **368**(6498): 1438.

751

752 11 Data Availability Statement

753 The datasets [GENERATED/ANALYZED] for this study can be found in the [NAME OF
754 REPOSITORY] [LINK]. Please see the Data Availability section of the Author guidelines for more
755 details.

756 12 Tables

757 **Table 1. Description of the types of actions considered for the classification of 'action tweets'**

Type of action	*Description*	*Tweet Examples*
The initiation of a behaviour	Reporting the start of a particular behaviour with the intentions to mitigate climate	- ”Jane Fonda recycled a 2014 gown at the Oscars Sunday night to make a statement about climate change”

	change. This can either be individual or collective.	- ”From banning pesticides to growing green roofs on bus stops here are 5 ways communities are trying to save the bees”
Behaviour to adopt for climate change mitigation	Identifying the actions that others ought to do to mitigate climate change.	- “If you lecture about climate change sell your private jets use mass transit and bike or walk when possible go vegan etc …” - “Does Eating Less Meat Fight Climate Change CA Study Says Yes” - “Let’s end capitalism and save the planet Green revolution”
Behaviour that should be stopped to tackle climate change	Identifying behaviour that contribute to climate change and a call to individuals to stop this behaviour.	- “Our attitudes to flying need to change before its too late” - “Southeastern trains please turn off the heating on your unbearable trains Thought your supposed to be green Its not free energy”
Monetary options for climate change mitigation	Investment on initiatives focused on tackling climate change.	- “Amazon founder Jeff Bezos commits 10bn to fight climate change”
Political actions for climate change mitigation	Calling on leaders and heads of organizations to act to mitigate climate change.	- “Sign and send the petition Urge your governor and state legislators to urge state pension fund divestment from fossil fuels We cannot continue to fund climate change Write one here”
Government actions for climate change mitigation	Development of policies devoted to a particular action to tackle climate change.	- “Netherlands 515 billion pension fund to accelerate cuts to fossil fuel investments Article AMP Reuters” - “…Bipartisan Climate legislation to put a Price On Pollution is key to addressing climate change…” - “The government has announced funding to support 13 projects that will plant 50000 trees in total across England to support the fight against climate change.
Actions that do not help climate change mitigation	Users’ perceptions about environmental actions that do not help to mitigate climate change.	- “So to save the planet with electric cars and mars bases Elon is chopping down 225 acres of forest for his new European factory and chucking tons of carbon into the atmosphere for escape velocity Sounds like a plan”

		- "Being vegan will not save the planet …"
Goals on climate change mitigation	No clear actions or behaviour reported but describe a desired end goal (reducing carbon footprint).	- "For years now Pacific Island governments have been pleading with more developed countries to phase out the use of fossil fuels and rapidly transition to cleaner sources of energy"

758

759 **Table 2 Overview of total tweets, 'action' tweets and topic modelling analyses**

Times	*Total of tweets streamed*	*# of action tweets*	*# of Topics*	*Coherence Score*
Time 1 *(February 2020)*	318,749	33,659	9	0.54
Time 2 *(June 2020)*	305,851	72,798	12	0.55
Time 3 *(October 2020)*	303,636	59,415	11	0.50

760 NOTE: Number of total tweets streamed for each time-point along with the action tweets identified by
761 the BiLSTM model for each of the three sets of tweets. Coherence score were obtained from topic
762 modelling analysis of the number of action tweets reported to be acceptable at levels ≥0.50.

763

764

765 **Table 3 Brief statistics of words for action tweets.**

TIME	TOTAL NUMBER OF WORDS	UNIQUE WORDS	AVERAGE WORDS PER TWEET
TIME 1	225,503	24,365	6.7
TIME 2	606,128	36,659	8.3

TIME 3	536,703	29,564	9

NOTE: The number of words was calculated after the removal of stopwords (e.g., “a”, “the”, “and”), and keywords used for streamed tweets. Considering only the words that were used for the topic modelling analysis.

Table 4 Salience of topics for each set of tweets

Topic	% of data Time 1	% of data Time 2	% of data Time 3
Government actions	52.9	21.6	2.8
Environmental behaviours	33.6	46.9	69.9
Awareness	3.7	2.3	1.3
Collective actions	3	1.4	1.4
Organisation’s actions	1.8	0.8	1.5
Protest to government	1.5	1.5	-
Social Network initiations	1.3	-	-
Awareness and Fairness	1.2	-	-
Third party actions	1	1.6	1.3
Eco-friendly products	-	11.8	10.2
Food	-	7.3	-
Nature conservation	-	2.9	-
Sustainable production	-	1.1	3.6
Innovative solutions	-	0.8	1.8
Support farmers	-	-	4.4

Consequences of climate change solutions	-	-	1.8

770

771

772 **Table 5 Time 1. Labelled topics and topic words within tweets from February 2020**

Topic's Label	Description	Examples of tweets	Number of Tweets and % of data	Topic words
T1. Government Actions	Government actions to mitigate climate change, from funding initiatives to imposing taxes.	"...A carbon tax can incentivise corporations eg UKs Climate Change..." "…Our current national policy is to spend billions in taxpayer money increasing climate risk."; "…A Republican plan to address climate change fails to address carbon pollution…"	17,803 (52.9%)	Carbon, emission, money, fuel, fund, fossil, tax, address, company, way, government, people, industry, dollar, taxis, oil, investment.
T2. Environmental behaviours	Observing the different industries or types of behaviour that may help with climate change mitigation.	"...mistakenly believe that forest bioenergy and long lived wood products are solutions..." "..providing eco energy product solution to leading a more sustainable lifestyle";"… you can cut the risk to yourself and the planet by eating more plant based foods like this spicy jackfruit crispy taco…" "..Investing in agriculture can address not only hunger and malnutrition but also other challenges including poverty climate change and unsustainable production and consumption…"	11,309 (33.6%)	Energy, people, food, renewable, car, clean, coal, tree, sustainable, waste, air, power, solar
T3. Awareness	Promoting awareness about climate change around international events.	"… Prize in Food and Agriculture Sciences ... and aims to improve crop production and hardiness helping to address challenges of global population growth and climate change…"; "…Awards…support in biodiversity conservation fisheries management combating wildlife trafficking and climate change mitigation…."	1,246 (3.7%)	Award, liberal, trade, mention, direct, third, essential, diversity (div), pocket, video, great, elite, evil, reusable, know, pension, airport.
T4. Collective actions	Collective behaviour, noting behaviour undertaken, or that could be undertaken, as part of a community or a group to combat climate change.	"…Imagine how much we could reduce that if there was public demand for alternative milk protein sources…"; "… We can save Earth Its going to take collective action from big companies small companies nation states global organizations and individuals…"; "From banning pesticides to growing green roofs	1,011 (3%)	City, ready, milk, bee, collective, combat, customer, capital, open, burn, teacher, baby, network, corrupt, mobility, college, ways_communities

		on bus stops here are 5 ways communities are trying to save the bees..."		
T5. Organisation's actions	Describing what organisations are doing to combat climate change.	"…Airlines may need to reduce passengers to take off due to climate change…"; "changing aircraft altitude could cut flights climate impact in half…"; "…how going digital and eradicating paper receipts sets companies on a sustainable path in the green economy…"	605 (1.8%)	Wildlife, decade, skill, degree, reduce_passenger, scientist, block, extraction, takeoff_due, aircraft, ditch, greeneconomy, illegal,
T6. Protests to governments	Protesting to authorities about climate change.	"Just like us Jane Fonda who flies to DC weekly to get arrested protesting climate change…"; "…hear about an Extinction Rebellion protest to try and get Tom DiNapoli to divest from fossil fuels from and questions from town hall Sat about impeachment climate change…"	504 (1.5%)	Town, run, bullshit, saving, gold, hypocrisy, dc_weekly, metal, show, radical, toward_solving, change trump,
T7. Social network initiatives	A call to the public to show support for climate change campaigns.	"…Tomorrow is one more chance to catch them this season We need your photos to create a record of changes to our coast to raise awareness about climate change and to help California plan…"; "Thurs Feb 6 is SweaterDay This is an opportunity to raise awareness about climate change energy conservation and show how together we can be a part of the solution…"	438 (1.3%)	Tomorrow, platform, generate, photo, actor, show, solid, burning, sweater, positively, thermostat, generate_value, laundry,
T8. Awareness and fairness	Expressions of inconsistency within other people's actions to mitigate climate change	"…Oscar nominees get a 225000 gift bag arrive in private jets and limos but they want to lecture you on income inequality and climate change…."; "Like lecturing on climate change while having multiple homes private jets helicopters Private armed security you think rules dont apply to U"; "…explain how you said youre fighting for climate change but then you fly on a personal jet Then you have the nerve to try to hide behind your staff when you were spotted…"	405 (1.2%)	Twitter, crazy, hot, decent, push, find, bicycle, technew, helicopter, limo, tv, equity, hide_behind.
T9. Third party actions	Observing what third parties and public figures do about climate change mitigation.	"David Gilmour sold his guitars for 215 million and donated everything to fight climate change…"; "Orsted one of the worlds biggest developers of offshore wind farms wants to decarbonize heavy	338 (1%)	Hydrogen, climateactnow_auspol, global warming, utility, visit, guitar, court, persuade, art,

	industries using Hydrogen to achieve climate change goals…".		mansion, flight_shaming, mansion, utility.

Note: Description column is based on the interpretation of the topic based on the relevant terms and analysis of the tweets for further context. Example of tweets show fragments of the tweets where the topic was present.

Table 6 Time 2. Labelled topics and topic words within tweets from June 2020.

Topic's label	Description	Examples of tweets	Number of Tweets and % of data	Topic words
T1. Environmental behaviour	Observing the different industries or types of behaviour that may help with climate change mitigation.	"…Transitioning away from coal to sustainable biomass is essential in the fight against climate change…"; "… the focus will be on a green future investing in sustainable transport the focus will be on a green future investing in sustainable transport…"; "….we need is to stop buying new cars share the ones we have walk and cycle work ….."	34,142 (46.9%)	Way, energy, people, year, emission, money, time, company, new, carbon, industry, infrastructure, solution., transport, car, plan, community

T2. Government actions	Government actions to mitigate climate change.	"…Vote now for D2T2 project and help promote ocean energy in EUs largest sustainable energy event…"; "offers world governments a Sustainable Recovery Plan to create millions of jobs and put emissions into structural decline Healthy Recovery BuildBackBetter…";"EU is revisiting its transport vision for the next decade a Sustainable and Smart Mobility Strategy…"	15,724 (21.6%)	Development, recovery, investment, future, economy, fund, technology, innovation, covid, resilient, growth, policy, government, energy, report.
T3. Eco-friendly products	Use of eco-friendly products, brands, and other resources to reduce impact of climate change.	"Its super frustrating that sustainably and environmentally friendly products are so hard to find theres hundreds of …ones wrapped in pounds of plastic…"; "We installed Solar WaterHeating and SolarPV systems at ….a luxury and ecofriendly resort"; "This brands latest collection named remade is repurposing their own fabric waste to create a new line of clothing"	8,590 (11.8%)	Plastic, product, eco-friendly, clothing, waste, fashion, help, shop, alternative, nuclear, chemical, ethical, paper, reusable, pandemic, biodegradable, recycle, brand
T4. Food	Alternatives in food industry to mitigate climate change	"…Food production is the biggest contributor to climate change but one third of food is wasted We want to change that..."; "…Sustainable naturally raised meat production integrated closely with plant production is the way to go it is not even debatable…"; "…Canadian meat dairy are my countrys sustainable organic natural food sources which my ancestors survived from for hundreds of years Ur not changing that…"	5,314 (7.3%)	Food, farmer, farm, agriculture, meat, fish, diet, animal, healthy, sea, production, crop, organic, dairy, soil, water, nutrition.
T5. Nature Conservation	Conservation of green areas and species	"Well done Great to see the FMCG giant helping to fund reforestation water preservation and carbon sequestration in a commitment to cut company emissions"; "…Check how retailers are doing in sourcing responsible deforestation free palm oil by using the PalmOilScoreCard…"; "…Nuclear Power Plants as they can Generate Supply Affordable Reliable Sustainable 247 Power at Affordable Costs also keep in Mind that Coal Oil Gas are NOT Sustainable globally"	2,111 (2.9%)	Forest, black, electric, present, necessary, plant, conservation, species, loan, driver, climatecrisis, reliable, control, village, secondary, nuclear_power, vulnerable, global, stop, heat
T6. Awareness	Promoting awareness about climate change	"Roadhouse management takes responsibility and the initiative to be more socially and environmentally conscious actively engaged in creating sustainable and a quality road for our clients"; "…environmentally conscious teen …who believes we can all continue to help the environment and remain sustainable even when we are stuck at home…"; "…We have 500 innovations just around sustainable packaging and plastic pollution…"	1,674 (2.3%)	Packaging, bag, fair, range, app, person, env_conscious, aid, man, collectively, consequences, review, incentive, labour, stable.
T7. Third party actions	Observing what third parties and public figures do about climate change mitigation.	"bro arent you using cow milk for your ice cream cows are responsible for climate change as well…"; "a project that combines chitosan from fungi with protein extracted from corn and milk waste to create a new sustainable type of fabric"; "The sustainable decision from the beloved Arab designer comes at a	1,164 (1.6%)	Massive, milk, mining, designer, scientist, metal, furniture, police, racism, carbon_neutral, biomass, river, transfer, gold, cocoa, film, non-profit

		time when we all need to step up for mother nature and reduce our environmental impact"		
T8. Protest to governments	Protesting to authorities about climate change.	"…Leaving the European Union now means Massive increases of UK Carbon Footprint and Contribution to Global Warming due to increase Transport of goods Racist English…"; " Some are already seeing COVID19â€™s stimulus packages as an opportunity to spur green growth The United Kingdom plans to spend 250 million pounds of its stimulus package on walking and cycling infrastructure…"	1,093 (1.5%)	Economically, phase, cycling, timber, working, outdoor, textile, vote, colleague, glass, exchange, bet, wool, action_climate, auspol, greenhouse, evolution, summit, minute.
T9. Collective actions	Collective behaviours, listing behaviours to be undertaken as part of a community or a group to combat climate change.	"Newly Guaranteed Fair Trade Enterprise Machakos Cooperative Union ensures that sustainable livelihoods for producers means putting environmental focus on their production and farming"; "…celebrates 26 years of unique hospitality…. the trendsetter in sustainable development and the pioneer of eco initiatives celebrates 26 years of breaking barriers and lighting the path for a sustainable hospitality industry"; " globalists climate alarmists etc dont want electricity available to the masses They know electric cars solar panels and windmills are not sustainable So their solution is communism and energy poverty"	1,019 (1.4%)	Threat, regulation, boost, category, hospital, adapt, cooperative, electric_car, corona, innovate, hospitality.
T10 Sustainable production	Alternative sustainable products and actions to mitigate climate change	"Over the next three years in the Netherlands will be investing 55 million in a testing facility for the development of sustainable plastics…"; "…replacing palm oil with another oil will just mean more deforestation Choose sustainable palm oil and support local initiatives…"; "Paying farmers a living wage is essential to ensuring sustainable coffee production…"	801 (1.1%)	Coffee, palm_oil, death, recycled, Indian, hotel, chocolate, manufacture, rainforest
T11 Organisation's actions	Describing organisation's actions to combat climate change.	" FYI systemic barriers to energy efficiency low zero carbon world banks funding of high carbon polluting investments" ; "Amazon pledges 2bn investment to fight climate change…"; "EU Parliament adopts measure to boost green investment The European Parliament has adopted a key piece of legislation to add to the European Green Deal whose aim is to increase private sector investment in sustainable and eco-friendly projets"	584 (0.8%)	Bank, powerful, museum, disease, trump_admin, amazon_pledge, parliament_adopt, registration, crash, fire.
T12 Innovative Solutions	Promotion of innovative initiatives for tackling climate change	"desserto a highly sustainable plant based vegan leather made from cactus"; "…Australia aims to produce vehicles that are sustainable in every aspect made from strong biocomposite body materials that will maximise energy efficiency with a hybrid power system…"; "As the pandemic forces us to rethink our old approaches and ways we call on our industries businesses policymakers and households to promote sustainable	582 (0.8%)	Aim, park, lesson, leather, behaviour, dangerous, press, composite, telehealth, fiberboard, paint, gastronomy.

		gastronomy by respecting food and everything that goes with it…"

Note: Description column is based on the interpretation of the topic based on the relevant terms and analysis of the tweets for further context. Example of tweets show fragments of the tweets where the topic was present.

789 **Table 7 Time 3. Labelled topics and topic words within tweets from October 2020.**

Topic's Name	Description	Examples of tweets	Number of Tweets and % of data	Topic words
T1. Environmental behaviour	Observing the different industries or types of behaviour that may help with climate change mitigation.	"So you want to burn all the fossil fuels on the planet accelerating global warming and at the final years when Fossil fuels are all extracted and burn have a massive crises cus you ran out of energy probably ending society as he know it…"; "Hydropower developers conservationists and former energy officials announced a major collaboration yesterday to burnish hydros credibility as a renewable resource and expand its role in fighting climate change" ; "…FoodHeros we reiterate our commitment to contribute to creating a robust sustainable resilient food system…" ; "…Irish dairy farming which has been found to be highly sustainable with regard to water Almond farming in California uses tens of billions of water per annum There is no comparison"	41,531 (69.9%)	Energy, food, development, future, way, new, solution, people, system, industry, community, emission, company
T2. Eco-friendly products	Use of eco- friendly products and brands and other resources to reduce impact of climate change.	"…the largest organic vegetable producer in the USA is exhibiting new products and sustainable packaging initiatives this week at the first ever virtual Produce CalOrganic…"; "…just launched ReStyle 2020 a fashion collection upcycling discarded materials from automotive manufacturing and scrapping into fashionable products…"; "…fashion brand will be the FIRST 100 biodegradable sustainable and eco friendly fashion brand And its created by a black woman";	6060 (10.2%)	Product, packaging, brand, material, fashion, cheap, full, eco-friendly, plastic, clothing, ethical, collection, luxury, slow, lockdown, sustainably.
T3. Support Farmers	Promote awareness about the future of Common Agricultural Policy in Europe and promoting to support farmers.	"empower farmers to provide sustainable food for our communities Dont get fooled and vote for a future of CAP…"; "the future of sustainable farming in Europe is at stake after in the struck a deal that will syphon tens of billions of euros to big farmers with few environmental conditions FutureofCAP"; "Heres a funding opportunity for female entrepreneurs building a sustainable future…"	2,614 (4.4%)	Pay, matter, manager, true, person, entrepreneur, common, wood, art, European, delivery, investing, futureofcap, disaster, fix , ecological, corporate, pesticide.
T4. Sustainable production.	Alternatives on sustainable production to mitigate climate change	"…Various clothing stores are specialized for providing the ethical and sustainable apparels to its customers…"; "Useful info to share from when youre dairy free get challenged about the source of the soya you use I only buy from EUCanada sustainable sources dairy free environmental"; "…The demonstration farm in Dowth anmhi will develop this sustainable farm platform which can underpin irishbioeconomy development buildbackbetter"	2,139 (3.6%)	Store, retailer, ban, gift, dairy, engender, exciting, legislation, products_sold, bottle, loan, beef, trading, locally, heat, border

T5. Government actions	Government actions to mitigate climate change.	"Climate change is real We need to stop the spread of covid19 help families in need make education healthcare free or affordable"; "…whether we believe in climate change and accept a womans healthcare is not the governments business to regulate I also want us to accept healthcare is a human right"; "He would build infrastructure fight climate change raise wages guarantee health insurance coverage expand childcare…"; "There is no insurance policy Governments can buy against the catastrophe of abrupt climate change … We must invest in solar radiation management infrastructure to balance Earths energy now along with CO2 drawdown…"; "…electric motorcycle taxis and recycling 500 billion bottles for a sustainable Thailand a UN Resident Coordinator…"	1,664 (2.8%)	Plan, healthcare, act, insurance, data, expertise, police, socially, council, taxis, stability,
T6. Innovative solutions	Promotion of innovative initiatives for tackling climate change	"Want to fight climate change I just signed up for first wooden debit card powered by …80 of profits to responsible reforestation Sign up now and theyll plant 3 trees plantchange woodendebitcard"; "Solar Powered Luxury Yachting by SILENTYACHTS Yachting SILENTYACHTS create an independent and sustainable yachting experience…";" Great to see supermarket chain Tesco furthering its mission to eliminate deforestation from their own supply chain"	1,070 (1.8%)	Profit, powered, sign, they'll_plant woodendebitcard, tree_plantcharge, democracy, taxpayer, reserve, faster, wide, supermarket, provision, universal, sailing_boat
T7. Consequences of climate change solutions	Paying attention to the consequences of climate change mitigation strategies and other events.	"Electric cars are to climate change what electric cigarettes are to lung cancer"; "And this is an ever reducing problem what with emissions control electric cars but the intensified pressure on local ecosystems by urban centres and the non sustainable agriculture models used to feed them is getting worst…" ; "…FDA of the United States of America Stop Using Sharks in COVID19 vaccine Use EXISTING Sustainable Options Sign the Petition…";" Legacy cities Detroit Gary Cleveland Baltimore etc should be allowed to establish their own utility companies based on wind and solar energy that belongs to everyone It would solve for climate change and economic racial justice at the same time …"	1,069 (1.8%)	Mining, interest, director, foundation, make, electric_car, Australian, vaccine, pool, film, renewable, accelerate, beach, please, fake, virus, lithium, solar_energy
T8. Organisation's actions	Describing organisation's actions to combat climate change.	"Antarctica shouldnt strive for cost effective sustainable energy without worry";" Alaska Airlines and Microsoft sign partnership to reduce carbon emissions with flights";" Beer company… in Colombia introducing an Airbnb style platform showcasing Colombian ecohotels that…sustainable tourism…"	891 (1.5%)	Forever, cost_effective, fabric, rapid, metal, hotel, airline, audience, conventional, innovator
T9. Collective actions	Collective behaviour, noting behaviour undertaken, or that could be undertaken, as part of a community or a group to combat climate change	"…climate neutral farms and food businesses reducing dependence on chemical inputs reducing waste and sustainable diets Projects will fundamentally depend on cross organisational…";"… Elements of capitalism socialism can be used to drive an economy with social ecological sustainable economic goals a balanced approach"; "Sustainable behavior begins at home kick starts the International EwasteDay caign by pledging to dispose off old electronics responsibly…"; "pull nitrogen out of the air and fix it into a form that other plants can use… These and other insights can be used to design and create sustainable agricultural systems… What is Permaculture"; "…the 5year sustainable development bond raised 800m British pounds will	829 (1.4%)	Chemical, bag, bond, solid , wealthy, attention, cancer, rain, comfort, consume, tea, ewaste, evolution, socialism, nitrogen.

		finance AIIB in sustainable infrastructure unlocking new capital technologies ways to address ClimateChange"		
T10 Awareness	Promoting awareness about climate change.	"Continually impressed with the ingenuity of Utah companies a STEP Grant recipient created a sustainable way to make jeans from coffee grounds and plastic water bottle…"; "Young people all over the world are working hard to raise awareness about ClimateChange …Climate change is real and we need to dramatically reduce greenhouse gas emissions"	775 (1.3%)	Coffee, cover, minimum, realistic_source, code, river, eat, trash, raise_awareness, fundraising, income
T11 Third party actions	Observing what third parties and public figures do about climate change mitigation.	"…An organism commonly used in biology labs engineered to take carbon out of the air … Synthetic biology could help mitigate climate change"; "Apple has a strategy to encourage customers to purchase almost annually for a new iphone…Environmentally this is not a sustainable product strategy …" ; "We applaud <U+0001F44F> Apple's effort to reduce ewaste emissions by NOT including a USBC charger with iPhone 12…"; "Instead of focusing on what travelers shouldnt do or limiting behaviors highlight instead deeper more unique experiences that sustainable tourism provides…"; "A big step for the airport … added 5 new electric buses which will result in a reduction of 50000 gallons of diesel fuel each year …"	773 (1.3%)	Engine, destruction, inclusion, island, integration, diesel, disease, trial, planting, tv, veggie, territory, soy, destination, plate, apple, petroleum, tv, intelligence, edge, traveler, applevent.

790 Note: Description column is based on the interpretation of the topic based on the relevant terms and analysis of the tweets for further context. Example of
791 tweets show fragments of the tweets where the topic was present

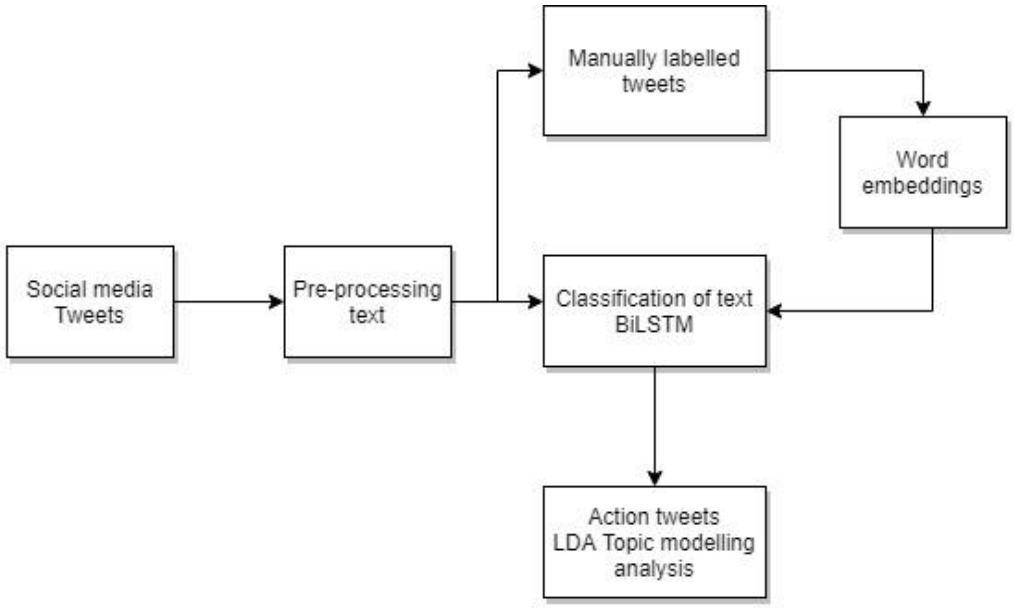

Figure 1 Diagram of tweets processing and analysis. Tweets were streamed from social media on the three-timepoints, then pass through a pre-processing phase (removal of punctuation, mentions, etc.). A Bi-Directional Long Term Memory (BiLSTM) model was used for the classification of tweets into action and non-action tweets. The inputs for the model were the word embeddings created from the manually labelled tweets. The action tweets detected from BiLSTM were then used for the analysis of the content with unsupervised technique LDA Topic Modelling.