Is #SDG13 Trending Online? Insights from Climate Change Discussions on Twitter

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Abstract

Anthropogenic activities over the past few decades have led to increased vulnerability of environmental and ecological stability on this planet. Accelerated climate change is one such subset of the environmental problems that threatens the very existence of humankind in twenty first century. Governments, United Nations (UN) and other humanitarian agencies across the globe have developed and devised strategies for climate action that requires grater public awareness and actions. Social media has played a vital role in information dissemination and raising public awareness of climate change in the digital era. To this aid, an upsurge has been documented in recent times regarding discussions over climate change with #SDG13 (Sustainable Development Goals) at its epicenter. Following the principles of Actor Network Theory (ANT) we analyzed a large volume of Twitter data to understand general citizens' perception and attitude towards climate change. Our findings unveil people's opinion on causes and concerns related to barriers of adopting a more sustainable consumption and lifestyle practice. There is also a growing apathy towards sluggish government actions that makes little difference. People were also found to exchange innovative concepts and measures towards mitigating the effects of climate change.

Keywords Climate action · Climate change · SDG13 · Public participation · Sustainable development · Twitter analytics

1 Introduction

Due to the pressure exerted by various environment protection groups or agencies, since the beginning of this millennium, the governments of both developed, as well as developing nations, realized that in pursuit to accelerate the residential as well as industrial growth, a huge chunk of the natural forest resources available on this planet has already depleted (Millennium ecosystem assessment, 2005; Makondo & Thomas 2018; Raupach et al., 2021). This depletion has caused immense harm to the environment and thus endangering the lives of living beings on the planet earth besides putting a big question on the survival of our future generations (Burke et al., 2018; Rocque et al., 2021). The changing climate of our

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planet has been in continuous discussions for a long time now, the earliest indications in this regard date back to as far as the 1800s when the world population touched the one billion mark. This was the time, when the process of the industrial revolution had already started in Great Britain (BBC, 2013) as well as most of the European countries. In the nineteen century itself, some scientists like Joseph Fourier, and John Tyndall raised their voices about the rising temperatures and the subsequent greenhouse effect (Fleming, 1999; Mitchell, 1989; Van der Veen, 2000). In 1896, Arrhenius hinted that as a result of this industrial burning of coal, the overall greenhouse effect would take alarming proportion in the future and this would be largely man-made (Arrhenius, 1896; Fourier, 1827; Tyndall, 1863). Four decades later, in 1938, another scientist Guy Callendar reported that in the last fifty years humans have added 150,000 million tons of carbon dioxide to the atmosphere and he confirmed with evidence that the overall global temperature rose at a rate of 0.005 °C in those fifty years (Callendar, 1938).

Through these above-mentioned discussions, we can undoubtedly deduce that the changing climatic conditions were visible even during the early years of the previous century; however, it was only during the 1970s when the discourse about climate change gained some serious attention and started spreading around the globe (Christensen, 2019). By that time, the human population had already reached the four billion mark and so had increased the amount of carbon emissions collectively via industry and transportation. The term climate change was first coined by Wallace Broecker in 1975. Before that, the terms like greenhouse effect and global warming had been used interchangeably; which most of the time hinted toward the rising temperature (Broecker, 1975). The term climate change, however, includes a lot of other factors of our planet's ecosystem and including the rising temperature, the melting glaciers, the rising sea levels, extreme weather conditions, calamities, impact on human and wild-life, besides food and water crisis (Rajkumar, n.d.).

Over the decades, anthropogenic processes have heavily contributed to climate change and are continuing to do so. The global average temperature has already risen by 1 °C and is being projected to rise further; besides being accompanied by extremely harsh weather conditions. The environment scientists believe that once we touch the 1.5 °C uptick mark, the further deterioration will become much more rapid (The Conversation, 2021a). Even after meeting all the targets set by the United Nations Environment Program (UNEP) as part of the Paris agreement, it is being predicted that by the end of this century, the average global temperature would rise by at least 2.7 °C, which looks scary (The Conversation, 2021b). The developing countries especially the countries with a large population, as repercussions, are expected to be the worst hit. These nations are more likely to adapt to these worsened conditions as they look vulnerable and lack resources to mitigate climate change (Beg et al., 2002).

In 1988, Intergovernmental Panel on Climate Change (IPCC) was formed to understand the science behind climate change though it took nearly thirteen years to establish an international body to analyze climate change after the term climate change was coined in 1975 after the ill effects of climate change were captured and reported. In 1992, United Nations Framework Convention on Climate Change (UNFCCC) documented a treaty to combat climate change. It has been thirty years since that treaty but sadly, the climate conditions have further worsened and the carbon emissions have been continually increasing year after year. Although there are undoubtedly increased efforts being witnessed toward climate safety worldwide, there is a dire need for emergency action and more stringent laws; besides there is an urgent prerequisite of truthful cooperation among the nations to achieve the targets set in the Paris Agreement (Kumar, 2018). To challenge such grave problem of climate change which has emerged as a threat to the entire mankind, it becomes a moral obligation of the developed countries to support both the developing nations as well as countries with poor resources in defying this situation (Berrang-Ford et al., 2011) and thus move collectively towards the sustainable development. In addition, there is an intense need to raise awareness at both the local and the individual levels to achieve these goals.

Climate change is indubitably the biggest threat to our planet earth and our goal of sustainable development (UNFCCC, 2021). To address this rising threat and mitigate its effects the member countries of the United Nations 2015 pledged the 2030 Agenda for Sustainable Development. 2030 Agenda is a comprehensive global plan of actions that comprise 17 SDGs and 169 targets to be achieved by 2030. SDG13 proposes the actions to be taken to mitigate the effects of climate change (Fuso Nerini et al., 2019; UNEP, 2021). Ever since industrialization, globalization, and urbanization gained pace, directly or indirectly it has proved extremely harmful to the global climate. As per United Nations data, the previous decade i.e., 2010–2019 has been reported as the warmest decade ever with the year 2019 being recorded as the warmest year to date (UN, 2021). Despite the endless efforts toward climate change mitigation, the levels of greenhouse gases, especially CO_2 were at a record high in 2019. However, the year 2020 witnessed a fall in these levels due to the worldwide economic slowdown as a result of the outbreak of the COVID-19 pandemic. With the situation getting back to normal, once again a rise in the levels of greenhouse gases is anticipated. Already the average global temperature is in excess of $1°C$ more than that in the 19th century and the collective worldwide emissions of CO_2 have increased by 50% after 1990 (United Nations India, 2021). Without any stringent actions, the global temperature will rise about $3°C$ by the end of this 21st century (United Nations India, 2021). This rapid climate change

has already caused irreversible damage and is continuing to disrupt lives on our planet. Drastic changes in weather conditions, heat waves, natural disasters like floods, cyclones, draughts, loss of biodiversity, scarcity of water, shortage of food, rising sea levels, melting of glaciers, polluted air for breathing are some of the most alarming issues, the humanity is staring at today (IAEA, 2021; IISD, 2021).

Drawing motivation from the above statements, this paper examines the gravity of discussions about climate change on the Twitter platform. The main objective of this research is to draw valuable insights from the Twitter discussions that address the significant causes and the possible solutions which need to be promoted as well as adopted by individuals to climate change. We further examine the relevance and importance of promoting SDG13 for performing mass mobilizations to draw the attention of people through social media platforms and create awareness (Murayama et al., 2021) among them about the alarming effects of climate change.

For better understanding, we have divided this whole study into seven sections; Section 2 discusses a brief literature review while Section 3 deliberates on the research questions that we attempt to answer through this study. In Section 4, the research methodology is conclusively discussed. Section 5, provides the outcomes and results of various analyses performed and followed by the details discussions in Section 6. Finally, we conclude our research work in Section 7.

2 Literature Review

This section is further divided into three sub-sections (a) the attitude toward climate change, (b) diverse climate change studies and (c) Role of Social Media in mitigating the effects of Climate Change.

2.1 Attitude Towards Climate Change

Sustainable development and addressing climate change require a tremendous amount of work and labor from governments, international agencies, preservationists, and the think-tanks from all over the world (Mensah, 2019). Most importantly, it demands both public awareness as well as participation in achieving these goals. Public support is the most essential ingredient for the governments and the agencies to take necessary actions (Bain et al., 2019). Moreover, an informed public can assist in policy formation as it demands greater transparency and better accountability. Their involvement facilitates a system of checks and balances which seems compulsory for a problem as grave as climate change (Guan et al., 2019). Fortunately, in the past decade, there has been an immense surge in the willingness to challenge the climate change by the people owing to the

reorganized awareness spread by constant campaigning and worldwide interaction made possible by online media technologies (Grover et al., 2021). According to Pew Research Centre's recent survey on how people around the world see climate change, it has been reported that concerns about climate change have risen significantly since 2013, and citizens in 23 countries consider climate change as a major threat (Pew Research Center, 2019). In addition, education level, age, gender, and use of social media are considered individual-level climate change concern attributes (Zerva et al., 2021). The younger and educated people are observed to be highly involved and informed (Arikan & Günay, 2021).

United Nations Development Organization (UNDO) organized a one-of-its unique survey 'Peoples' Climate Vote' in 2020 intending to know people's perspectives on climate change. It was the largest survey ever conducted on climate change which covered 50 significant countries with nearly 56% of the population (UNDP, 2021). The results demonstrated that the people across the globe not only want some strict climate action but are also keen to help provide suggestions and solutions to the policymakers. People are enthusiastically supporting policies like conservation of forests, utilization of renewable sources of energy (solar, wind), implementation of climate-friendly farming techniques, investment in the green economy (Alaraja et al., 2022), promoting e-vehicles, and much more (The Conversation, 2021c). Despite the ongoing Covid-19 pandemic, people still consider climate change as a much bigger threat to life and they want our governments and policymakers to deploy stringent and concrete solutions to mitigate the threats to our climate (European Commission, 2021). They are willing to adjust their lifestyles for the global good. Sisco et al. (2021) found that the magnitude of climate activism was at its high in 2019 just before the onset of Covid-19. They analyzed the attitude of the people towards climate change through the online searches performed in this regard. It was noticed that the volume of search expressions like "climate change" and "global warming" has increased from 2015 to 2019. Such magnitude of citizen support and participation is extremely important for exerting pressure, forming and executing policies globally (Global Environment Facility, 2016; OIDP, 2020).

2.2 Diverse Climate Change Studies

To comprehend the impact of the climate change over different domains of research fronts, we scrutinized the available literature that provided some intriguing findings. Generation Y of Australia is determined to develop an action plan to mitigate the climate change. They deliberate on the human intervention and the activities that may have directly or indirectly impacted the environment and resulted in climate change (Vermeersch et al., 2017; Azadi et al., 2019)

have investigated the effects and relationships of different psychological factors (trust, belief, psychological distance, risk salience, and risk perception) on the adaptation strategies to be implemented by the farmers. These discoveries reveal that both trust and risk saliences are important factors in persuading the farming community to adopt sustainable farming practices.

On similar grounds, Bayer and Genovese (2020) have examined the role of politics in shaping the people's beliefs over the climate change policy. Their findings suggest that the people have hope and optimism about getting benefited from the implementation of some concrete policies of climate action. Turkish people view climate change as a threat to their survival and are precarious towards the implementation of COP-21 commitments to mitigate droughts, floods, and desertification viewed as negative effects of climate change (İşeri & Günay, 2017; Ng et al., 2018) made a comprehensive study on how the Canadian ports participate and develop some strategies towards the climate change. They highlighted the importance of co-developing and implementing the climate change policies besides optimizing the port operations to benefit the port stakeholders as well as port operators towards minimizing the carbon footprints.

Researchers have also given attention to managerial policies and consumer attitudes towards climate change. A recent study by Schill et al. (2021) has revealed that consumers' attitudes are highly dependent on climate change actions at the national level. Application of the theory of planned behavior by Chen (2020) unveiled that the public's perceived moral obligation and self-identity showcased a positive effect on consumers' purchase intentions towards sustainable products; whereas, the purchase intentions of consumers were negatively impacted by climate change skepticism. Wang (2018) combined the attitude functional theory and theory of planned behavior to find that three attitudinal motivations namely utilitarian function, self-esteem maintenance function, and value-expressive function predicted consumers' attitudes.

2.3 Role of Social Media in Mitigating the Effects of Climate Change

Social media especially Twitter platform has seen an exponential growth in the last decade (Dwivedi et al., 2018, 2021; Lal et al., 2021). Social media have become an integral part of our everyday life, as it enables us to discuss a wide range of topics ranging from elections (Grover et al., 2019; Singh et al., 2017a, b, 2020a), public policies (Harris et al., 2014; La et al., 2020), warning for natural disasters (Chatfield et al., 2013; Singh et al., 2019a; Mirbabaie et al., 2020, 2021), social tensions (Burnap et al., 2015), diseases/pandemics (Kankanhalli et al., 2016; Smith et al., 2018; Singh et al., 2020c; Hassan Zadeh et al., 2019; Modgil et al.,

2021), etc. Social media provide us with a comprehensive virtual platform where individuals can share their viewpoints with like-minded persons globally, without any geographical barrier in real-time, and that too free of cost (Kapoor et al., 2018; Singh et al., 2020a, b). In short, social media has entirely transformed the face of the traditional media industry. Every other minute, tonnes of information is getting uploaded and shared on various social media platforms which eventually have resulted in global communication (Our World, 2010). Social media has become the primary means for information diffusion and influencing the common people since the majority population relies on the internet for news, discussions, and socializing (ACCEPT, 2021).

The individuals have increasingly started using social media to create awareness among the people on topics related to planet earth like sustainable development goals including climate change (Cody et al., 2015; Williams et al., 2015; Pearce et al., 2019; Singh et al., 2021; Jha & Verma, 2022). Social media has the causes of the discussion and forming public opinion on climate change by providing the virtual space (Atlas Corp, 2018). On the other hand, the governments, the policy makers, and the stakeholders (Jha & Verma, 2022) too trust the social media to spread the concept words so as to study public response to those concept words. There have been a handful of studies that evaluated the relationship between the usage of social media and the climate change activism. William et al. (2015) analyzed Twitter user data to study people's attitudes towards the climate change based on their message contents. Zhang et al. (2021) have performed the sentiment analysis on Twitter data to analyze the anticipated changes in the attitude of people towards carbon taxation in Europe. Anderson (2017) outlines a distinct relationship between climate change opinion, knowledge & behavior and the use of social media to emphasize on how the awareness among people can ensure a positive behavioral impact. Holmberg and Hellsten (2015) analyzed 250,000 tweets and retweets to study the gender differences in the climate change discussion and reported that female users were observed to be more significantly involved in the climate campaigns and organizations. The Pew Research Center (2019) reported a similar trend; where female citizens of the surveyed nations were more involved in support of the climate action. Loureiro and Alló (2020) deliberated upon the sentiments of general public of UK as well as Spain towards the renewable sources of energy and confirmed that there has been an overall positive perception in the minds of the public related to this context. They further advocate the use of social media data to assess public emotion in real time to implement any climate change mitigation policies. Segerberg and Bennett (2011) in a detailed survey done in 2019 examined the role of Twitter on the climate change protests by analyzing two hashtags #thewave and #cop15, and highlighted three important aspects; (i) the diversity of actors who were

attracted by Twitter streams (Arolfo et al., 2020), (ii) how the twitters streams are linked in protest ecologies and (iii) how the linking and user dynamics change over time. The study aimed to bring out the schemes in a protest ecology. Roxburgh et al. (2019) have reported an increased participation of twitter users in climate change discussions during extreme weather conditions by examining the tweets posted referring to three major extreme weather events, viz., Hurricane Irene, Hurricane Sandy, and Snowstorm Jonas. Many thought-provoking assumptions related to the context of the tweets which include criticism of climate change, condemnation of anthropogenic activities, the socio-economic impact of climate change, political agenda and scientific angles have been deduced. The study further explored that the extent of discussions that take place on Twitter largely depends on the amount of damage caused by a particular event.

Thus, the social media roles vary from engaging the general public in online discussions to providing a platform for raising their voices towards promotion of global communication. The policy implementation can be considered a form of soft power that can affect and move things globally (Mavrodieva et al., 2019). There has been a skyrocketing growth in social media commentary on climate change which includes persons from all sections of the society that includes politicians, CEOs, actors, sportspersons, or even the general public. A single tweet by a celebrity gains thousands of retweets and comments which eventually helps to engage a larger audience from various geographical locations (Climate Reality Project, 2015). We can imagine the impact of someone like Elon Musk, who has nearly 61 million Twitter followers, can have on people with a single tweet in this regard. Thus, this vast amount of user data generated by these widespread users from different backgrounds, races, and socioeconomic statuses, can prove valuable in analyzing public awareness and indulgence in climate action (Madila et al., 2021).

Drawing motivation from these above-mentioned findings, in next sections, we will utilize the Twitter to mine the public opinion on climate change.

3 Theoretical Underpinning and Hypothesis Development

In consolidating the theoretical foundations of our study, we focused on the fundamentals of Actor Network Theory (ATN) (Callon & Blackwell, 2007; Walsham, 1997), with a view to draw valuable insights from the nature of climate change discussions representing everyday citizens' opinion beyond mainstream media. In doing so we aim to understand the discursive nature of opinion that dominates climate change agendas at the brink of critical global warming and long lasting impact environmental calamities. It is important to realize whether wider public sentiment is purely reflective

in nature or there is elements of resistance and rebellion that opposes the power structure (governments and large corporations) promoting sluggish 'carbon neutral' pledge.

Proposed in the 1980s ANT has provided a solid foreground for understanding transforming relationship between human, society and nature (Kivimaa et al., 2021). Theoretically and methodologically the dichotomy between human and nature has guided the principle development of ANT across many disciplines of social science and geography. Over the last four decades the proponents of ANTs have repeatedly demonstrated symmetry between human inscribed society, culture, technology and nature (Blok et al., 2020). In their opinion, people, politics, education, culture are all entangled into the very fabric of human perception of nature. However, previous research streams, that concentrated on extending the very foundations of ANT, mostly placed emphasis on actor and agency powerplay without considering cross-cultural dimensions of human-nature relationship networks (Welch & Yates, 2018). Other studies were more philosophically focused on debating growing nature and society divide resulting from the onset of modernity, expanding civilizations, and transforming human consumption (Tura et al., 2019).

Following these line to arguments, we believe that modernity has provided the very foundation of expanding civilization activities and technological advancement, fueling an agnostic attitude towards nature and climate change (Welch & Yates, 2018). Although government, humanitarian agencies, and large organizations are vowing to take climate action through the 'net zero' pledge, it is also a paramount importance to understand collective humanitarian voice and everyday citizen's perception of this issue. Following the principles of ANT we believe that perception and understanding of nature and its integral roots into human evaluation varies across nation and culture (Kanda et al., 2020). However, limited attention has gone into understanding collective perception of climate change beyond government and humanitarian agencies that are not represented in mainstream media.

Collecting, organizing and triangulating multifaceted data from across the world is an exceptionally challenging work, but our study overcomes this limitation by gathering topic specific insights collected from major developed and developing nations across the world. In our endeavor, we perceive the citizens as 'actors', the ever evolving issue of climate change as the 'actant', and technology as the 'catalyst' that provides the basis for cross-cultural debates and discussions to materialize (see Fig. 1). Despite the cross culture nature of the study it is important to remember that the study does not represent a full scale global overview due to linguistic, demographic and geographical limitations of Twitter data (García-Gavilanes et al., 2014). However, the volume and veracity of data collected represents wider citizen opinions from developed and developing economies at a scale that has not achieved before.
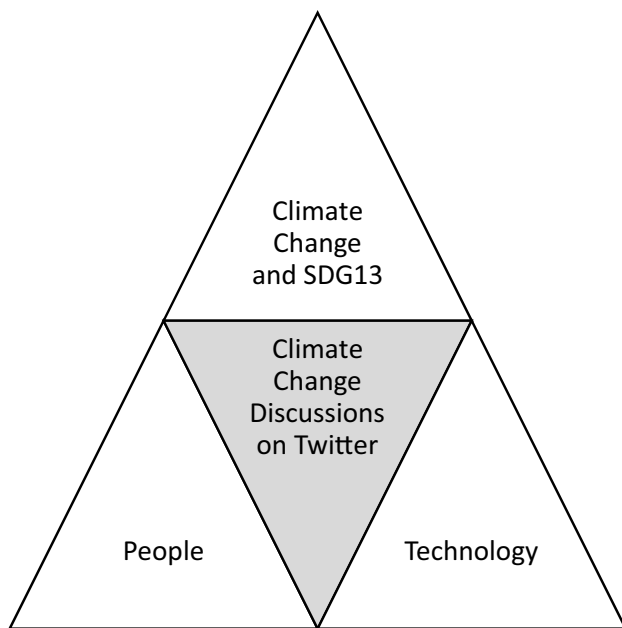
Fig. 1 Conceptual framework developed on the principles of Actor Network Theory. (Adapted from Grover et al., 2018)

3.1 Actors of Climate Change Discussion

Developing on the identified research gaps, we further develop the following research questions in order to solidity our contribution during these challenging times of unprecedented climate change. As a democratic social media platform Twitter is often regarded as data mines of public opinion (Karami et al., 2020). Therefore, considering the research rationale and characteristics of Twitter data we design the following research questions.

(RQ1) What Popular Topic Based Tags are Used by Citizens to Initiate and Propagate Climate Change Related Debates and Discussions? Twitter hashtags were described as the emblems of human expression (Duguay, 2016). Hashtags represents topic based cohesion and propagation of human opinion, remarks, debate, emotion, resistance, empathy and action. Prior studies in business research and social science have unveiled the importance of hashtag analysis in developing deeper insights into people's reaction to economics, politics, sports events, and even natural disaster (hurricane Sandy) (Kumar et al., 2020). Hashtags provide the 'actors' opportunities to affiliate and participate in debates and movements through shared ideologies and expressions (Chae, 2015). Therefore, by extracting and analyzing popular Twitter hashtags related to climate change we aim to address RQ1.

(RQ2) What is the Nature and Classification of Climate Change Discussions and Opinions Represented by Citizens on Twitter? Being an open democratic digital media platform, Twitter harbors a vast amount of opinion and conversation on

climate change reflecting everyday citizen sentiments on the topic. While some discussions are expected to be focused on increased natural calamities, i.e., rising global temperature, food shortages, water scarcity, loss of biodiversity, extreme weather conditions, air pollution, rising sea levels, melting glaciers etc. (Fathi et al., 2020). Other opinions may potentially be increasing awareness of the issue through extended social network message amplification. Some are perhaps driving movements against sluggish government policies that has failed to produce fruitful outcomes. Diverging from the issue, other groups could be proposing innovative solutions to combat climate change using renewable energy, internet of things (IoT), artificial intelligence (AI) etc. (James et al., 2020; Sinha et al., 2019). Therefore, by investigating RQ2, we propose to understand the underlying nature and classification of climate change based opinion and discussions represented by everyday citizens from across the world. In order to statistically validate our argument we develop and test the following hypothesis.

> H1: The mean discussion on the problems and their potential solutions regarding climate change are the same on Twitter.

(RQ3) How Public Opinion Compare and Differ Across Various Sections of Society? Climate change, in today's world, is not only a cause of concern for the preservationists, environmentalists and world humanitarian organizations, rather it is a global issue threatening the very existence of harmonious life and eco-system on this planet. Since, the magnitude of the issue is beyond current scientific predictions and calculated government action; it is important to understand how citizens from different sections of society perceiving and acting on this problem. Systematic investigation is required to what type of people initiates climate change discussion, what type of people act as network propagators, what type of people act as gatekeepers within the extended networks surrounding these discussions. By addressing RQ3, we propose to investigate how climate change opinion and action compares across different users belonging to different parts of society. In order to statistically validate our argument we develop and test the following hypothesis.

> H2: The mean discussion regarding climate change and climate action involving different sections of our society is the same on Twitter.

4 Research Methodology

To accomplish our research objectives, we followed the theory proposed by Fan and Gordon (2014) to extract useful patterns and insights. Fan and Gordon (2014) stated that the process of social media analytics can be divided into three phases i.e. capture, understand and present. For

Fig. 2 Different phases of research methodology
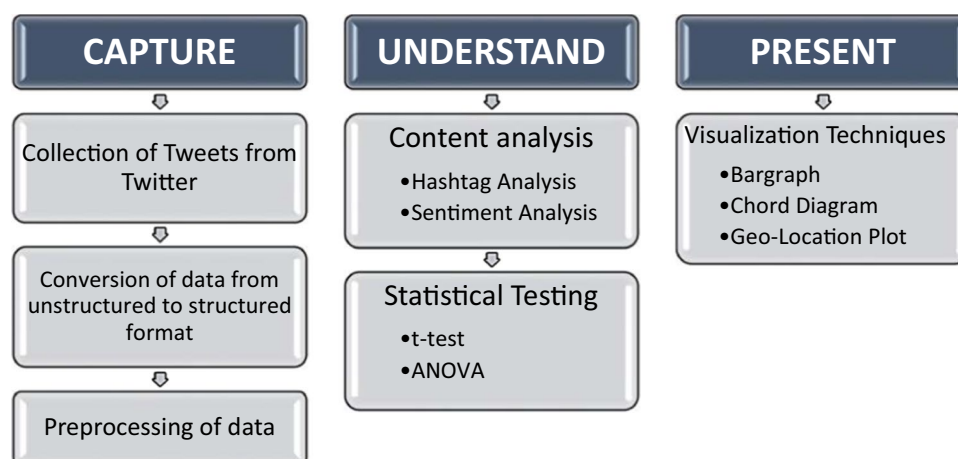
the successful completion of our research objectives, the same three phases have been followed. Phase one deals with (a) extracting data using hashtags and keywords; (b) conversion of unstructured data into structured data; (c) pre-processing of data. Phase two deals with extracting useful insights from the captured data by using (a) content analysis; (b) statistical testing. Phase three deals with representing results using various visualization techniques for ease of understanding. The pictorial representation of the entire process is shown in Fig. 2.

4.1 Capture (Phase-1)

The capture phase takes into consideration the collection and the transformation of data. To make it simpler, this section is further divided into three sub-sections namely (a) data collection, (b) conversion of unstructured data into structured data and (c) pre-processing of data. The details of each component are explained as follows:

(a) Data Collection: The collection of data always remains the most crucial part of any research as it forms the fundamental of a sustained foundation of the entire research work (Stieglitz et al., 2018, 2020; Singh et al., 2018a). Hence, Twitter API was integrated into the R-language script to retrieve data (tweets) from Twitter in an authenticated manner. To collect the tweets from Twitter, we used certain trending hashtags as search keywords. For the selection of these hashtags, two independent yet so connected teams were constituted having three members (authors) each (Singh et al., 2020b). Both these teams gave different sets of keywords that were directly or indirectly related to SDG13, Climate Chan and the related areas. After thorough discussions within both the teams, a list of hashtags was finalized that were used to fetch tweets from Twitter.

A team of two independent researchers was assigned the task of finding the keywords. They found maximum co-occurrence of *#sdg13* and *#climatechange*. Both the hashtags are linguistically closest to the topics of this research (i.e. Climate change and SDG13). To avoid losing any vital information in the form of tweets following query was suggested by the researchers using hashtags in conjunction with 'OR' clause to collect all possible related tweets from Twitter: *(#sdg13 OR #sdg-13 OR #climatechange OR #environment OR #sustainability OR #nature OR #globalwarming OR #savetheplanet OR #climate OR #ecofriendly OR #climate-crisis OR #climateaction OR #zerowaste OR #sustainable OR #gogreen OR #climatechangeisreal OR #plasticfree OR #sustainableliving OR #recycle OR #climateemergency OR #pollution OR #climatestrike OR #climatejustice OR #renewableenergy OR #reuse OR #plasticpollution OR #noplastic OR #saveourplanet OR #ecology OR #green-energy OR #environmentallyfriendly OR #cleanenergy OR #saveearth OR #environmentalist)*. Using the latter query, a total of 45,874 tweets were collected from 32,715 unique disseminators over a brief period of five days (Feb 7, 2021, to Feb 11, 2021). For our analysis, only the original/unique tweets were collected and retweets weren't considered in a premeditated plan. Figure 3 below shows a sample of a tweet.

The collected data contained attributes namely tweet date, tweet ID, tweet text, sender, retweet count, favorite count and the location. All these attributes formed the very basic foundation of our analysis. The details of collected attributes are shown in Table 1.

Out of the total 45,874 tweets collected during the sample period, only 20,583 tweets were observed to be geo-tagged. A geo-tagged tweet is actually a tweet containing a geographic coordinate (latitude, longitude) that indicates the location where the tweet was generated (Karami et al., 2020; Lim et al., 2020). The continent-wise tweet share regarding climate change discussions is shown in Fig. 4. Similarly, Fig. 5 shows the top ten countries contributing maximum in
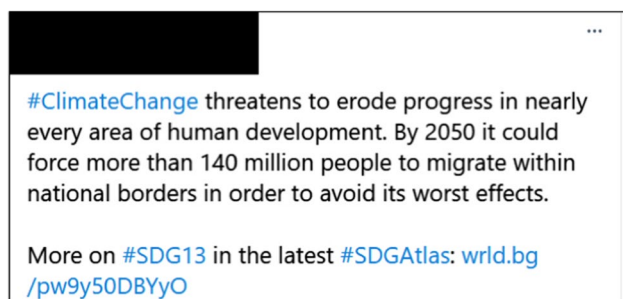
Fig. 3 Sample tweet

terms of climate change discussions. It is quite evident from both Figs. 4 and 5, that the majority of these geo-tagged tweets were posted from European countries and North American countries.

(b) Data Transformation: Since, data fetched using Twitter APIs is normally in an unstructured form i.e. JSON format. For further analysis, it becomes pertinent to convert

this unstructured data into a structured data i.e. excel format; since a few analyses that we intend to perform (especially sentiment analysis and content analysis) require data preprocessing. Therefore, once we convert the data into a structured format, we further preprocess the (data cleaning) to make it ready for analysis and become eligible to draw further valuable insights.

(c) Data Preprocessing: Data preprocessing is an important task that needs to be performed in order to avoid the ambiguities in the final results (Naseem et al., 2020; Singh et al., 2018a). Since Twitter data contain a lot of noise and unwanted stuff; it becomes mandatory to preprocess the collected Twitter data (Haddi et al., 2013). The task of data preprocessing has been performed in R-language, using coding skills. In the data cleaning process, firstly we convert the tweet into lower case format. Further, we remove all the web links using a special function. Then we remove the prepositions, numeric data, special symbols and stop words. Next we perform the stemming operation which gets followed by the removal of extra whitespaces. The details of the data preprocessing are given in Table 2.

Table 1 Details of different tweet attributes

| Sr. No.	Attribute	Description
1	Tweet Date	Date and time of tweet when it was posted.
2	Tweet ID	Unique ID of the posted tweet.
3	Tweet Text	Actual Tweet posted.
4	Sender	The name of the person who posted the tweet.
5	Retweet Count	Total number of retweets posted in favor of that particular tweet.
6	Favorite Count	Total number of likes in favor of that particular tweet.
7	Location	The geo-location of the Tweet from where it was posted.

Fig. 4 Continent wise tweet share
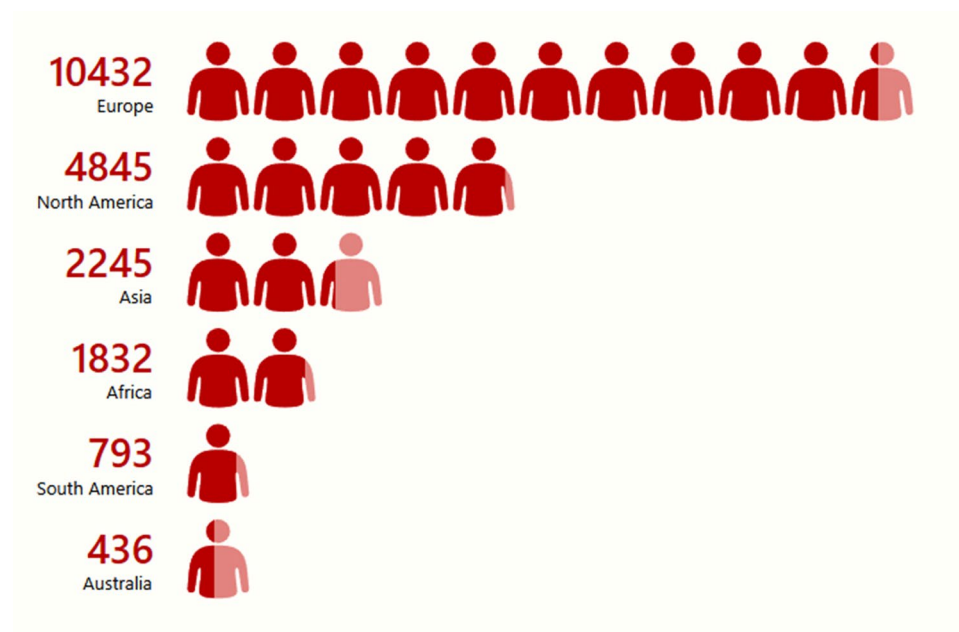
Fig. 5 Top ten countries having maximum discussions
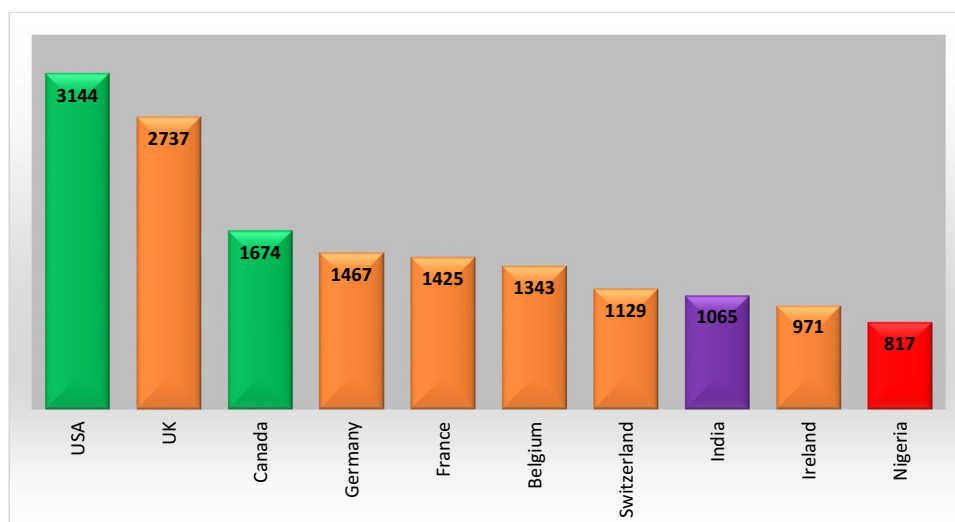
4.2 Understand (Phase-2)

Once we complete the transformation and preprocessing of the data, it becomes ready for various analyses that would help us to uncover the crucial mysteries which we consider critical in achieving our research objectives. Since the research objectives are diverse; hence we have broadly classified the analysis into (a) Content Analysis and (b) Statistical Testing.

(a)   Content Analysis: Content analysis deals with obtaining semantic content from the given text. This is achieved using techniques like sentiment analysis, topic modeling, etc. (Kassarjian, 1977; Kayser & Blind, 2017; Llewellyn et al., 2015; Zhang et al., 2016). Top trending hashtags associated with climate change were identified using hashtag analysis (Duguay, 2016; Chae, 2015).

(b)   Statistical Testing: A statistical test provides a mechanism for making quantitative decisions about a process (Grover et al., 2018). This is achieved using techniques like t-test, ANOVA, etc. The data related to tweets extracted by us for our study was in qualitative form (Mirbabaie et al., 2021). Qualitative data can be converted into quantitate data with the help of inherent semantics and content (Rathore et al., 2016). Statistical significance can be tested using statistical tests, which can be either parametric or non-parametric. In order to decide, whether the test will be parametric or non-parametric, there is a need to check the normality (Kolmogorov-Smirnov test) and homogeneity (Levene test) of variables. The results show that both the tests were satisfied; hence parametric tests can be applied in our case. Therefore, to achieve our research objectives, we applied t-test and ANOVA.

4.3 Present (Phase-3)

The final phase deals with the representation of results computed in phase 2 in a user-friendly format using various visualization techniques (Grover et al., 2018). These techniques have been used in order to affluence the understanding of the results. Visualization techniques such as bar graphs, chord diagrams, and geo-locations plots have been used throughout in this study for better understanding.

5 Results and Findings

In this section, we applied various statistical and content analysis techniques to answer the research questions (RQs) raised earlier (see Section 3). This section has been divided into three sub-sections. The first sub-section deals with content analysis techniques, using which we try to find the answers to RQ1. The latter two sub-sections deal with statistical testing, using which we try to find the answers to RQ2 and RQ3 respectively.

5.1 (#) Hashtag Analysis

Hashtag analysis deals with the various hashtags that occur among the collected tweets. In total there were 20,128 unique hashtags. These 20,128 unique hashtags appeared a total of 98,284 times in 45,874 tweets. The top ten hashtags are shown in Fig. 6. The most trending hashtag was "#sustanibilty" with 6,589 occurrences.

Another interesting observation is that during the data extraction only SDG13 was used to fetch data as it corresponds to the climate action; however, there were numerous hashtags associated with other SDGs. The results of prominent hashtags related to SDGs are shown in Fig. 7.

Inference Hashtags help us to understand the trends being generated regarding a certain entity. Using hashtag analysis, we try to answer **RQ1.** The results of hashtag analysis depict that people all around the world are extensively using different hashtags

Table 2 Details of tweet preprocessing

Sr. No.	Tweet Preprocessing	Description
1	Original Tweet	Inspiring #SDG13 #ClimateAction through her art: #Toronto #Canada's contemporary expressionist #ErinArmstrong's works starkly effective. Tense paintings that explore how we feel about 'irreversible' #climatechange https://t.co/XJffyRfgQ5 via @creativeboom @katylcowan #womensart
2	Lowercase Conversion	inspiring #sdg13 #climateaction through her art: #toronto #canada's contemporary expressionist #erinarmstrong's works starkly effective. tense paintings that explore how we feel about 'irreversible' #climatechange https://t.co/xjffyrfgq5 via @creativeboom @katylcowan #womensart
3	Removing Weblinks	inspiring #sdg13 #climateaction through her art: #toronto #canada's contemporary expressionist #erinarmstrong's works starkly effective. tense paintings that explore how we feel about 'irreversible' #climatechange via @creativeboom @katylcowan #womensart
4	Removing Punctuations, Special Symbols and Stop words	inspiring sdg13 climateaction art toronto canada contemporary expressionist erinarmstrong works starkly effective tense paintings explore feel about irreversible climatechange creativeboom katylcowan womensart
5	Stemming Operation	inspire sdg13 climateaction art toronto canada contemporary expressionist erinarmstrong work starke effective tense paint explore feel about irreversible climatechange creativeboom katylcowan womensart
6	Removing Blank Spaces	inspire sdg13 climateaction art toronto canada contemporary expressionist erinarmstrong work starke effective tense paint explore feel about irreversible climatechange creativeboom katylcowan womensart

Fig. 6 Top ten hashtags related to climate change
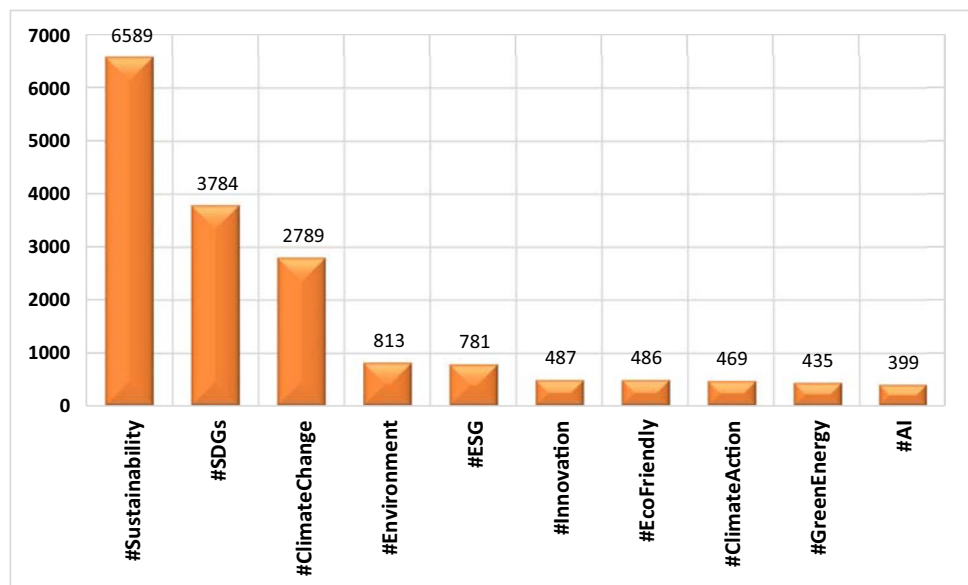
related to climate change in order to raise their voices and create awareness among people globally. These hashtags were not only related to climate change and sustainability, but also to green energy (Sarkis et al., 2013) and artificial intelligence (AI) that can serve as potential solutions to this climate change problem.

Further, as we move towards sustainable development goals, the results show that SDG13 (climate action) is tightly coupled with a few SDGs mainly, SDG15 (life on land), SDG14 (life below water), SDG3 (good health & well-being), SDG7 (affordable and clean energy), SDG11 (sustainable cities and communities), SDG8 (decent work and economic growth), SDG1 (no

poverty), SDG4 (Quality Education) where the developments of one largely impact the progress of the others (IISD, 2021). The relationships between various SDGs are shown pictorially with the help of a chord diagram in Fig. 8. It can be observed that SDG13 constitutes a larger part and is deeply intricated with various other important SDGs.

5.2 Problems and Solutions

Now that it has been established that the climate change discussions showcase a concern from Twitter users, the next

Fig. 7 Top hashtags associated with different SDGs.
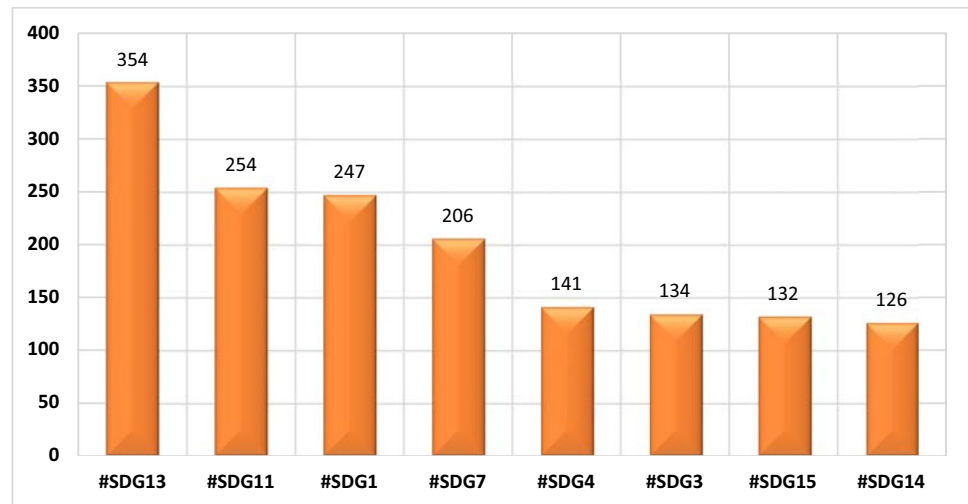
step forward is to analyze these discussions. There has been certainly a significant rise in the awareness of the individuals regarding the climate change which attributes to the discussions being held globally. People now are not only well informed about the factors that accompany climate change, but they have also started to face those in their day-to-day lives. Hence, the next big question is whether the discussion revolves only around the problems that have emerged due to climate change or do these involve potential measures that can be taken to combat the climate change. To deeply understand the extent of awareness in people in both aspects and answer **RQ2**, hypothesis H1 was formulated.

H1: The mean discussion on the problems and their potential solutions regarding climate change are the same on Twitter.

For H1, a two-tail independent t-test was applied to the tweets. The results of two-tail independent t-test at 95% confidence, is T-Value = -0.31304 and $P = 0.7593$. According to the decision rule, since, the value of $P > 0.05$, hence, **H1 is accepted**. This means that there exists no significant difference between the discussion on the problems arising from climate change and the possible solutions to combat the change.

Inference A wide range of problems, including rising temperature, food shortages, water scarcity, loss of biodiversity, extreme weather conditions, air pollution, rising sea levels, melting glaciers, etc. transpired over the years and have gained active public attention. Our analysis supports the fact that there is a significant rise in discussions on the threats posed by climate change and in addition to that, it is also observed that there is a considerable mass of the public that is discussing the potential solutions as well. Various organizations have been working tirelessly to find efficient solutions to progress towards
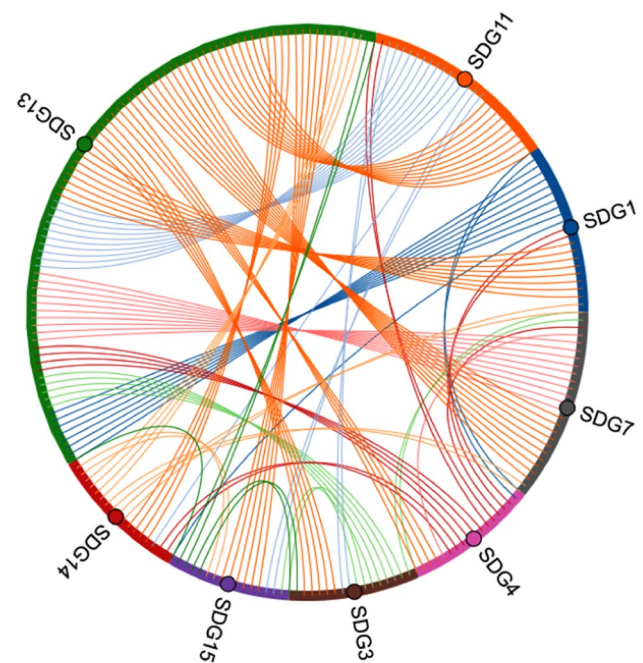

Fig. 8 Relationships between various SDGs

low carbon societies and move towards sustainability (Akande et al., 2019). Foundations like Solar Impulse (Twitter handle: @solarimpulse with 94.4 K followers) are encouraging people to propose profitable environmental solutions by giving them a chance to get featured in their 1000 solution portfolio. Activities like such foster problem-solving capacity and promote the participation of the public in achieving sustainability. As a result of such online campaigns and activities, there can be witnessed a shift in the trend from the mere acknowledgement of climate change to actual climate activism. People from all over the world are discussing innovative and real-time solutions to counter climate change. A broad spectrum of solutions

is being proposed which includes transitioning to renewable energy sources, adopting a circular economy, restoration of forests, depending more on solar farms and rooftop solar panels for electricity, moving towards sustainable transportation and infrastructure, a green economy, cooperation among nations, capacity building, strengthening resilience, etc. (Fathi et al., 2020; Sinha et al., 2019). Moreover, like any other field, ICT finds its applicability in tackling climate change as well. Most recent technologies such as wireless sensor networks, the internet of things, machine learning, and artificial intelligence can be put to develop smart environments and sustainable cities. These discussions highlight an important point that people are not only raising alarms by sharing problems associated with climate change but are also providing potential changes that one should adapt to have a sustainable future.

5.3 People and Discussions

Climate change is a harsh reality and it is affecting every being on earth irrespective of their economic status, social status, race, geographical location, profession, and gender. It is not just a matter of concern for environmentalists and ecologists anymore, it has risen exponentially to become a global threat. It is our collective responsibility to contribute toward the global good and safeguard our future generations. Hence, we further propose hypothesis H2, to examine which sections of society are taking part in discussions regarding climate change and help us to achieve **RQ3**.

> H2: The mean discussion regarding climate change and climate action involving different sections of our society is the same on Twitter.

For H2, we apply one-way ANOVA on Tweets posted by different users. For ease of experimentation, we bundled up these users into the following groups namely organizations (NGOs, government offices, non-profit organizations, societies), eminent personalities (politicians, ambassadors, UN representatives, diplomats, bureaucrats, special envoys), activists (climate change activists, environmentalists, ecologists, social activists), journalists (media houses, news agencies, journalists, climate journalists), celebrities (actors, actress, singers) and the general public.

The results of ANOVA at 95% confidence, is F-Value = 108 and $P = 1.2e\text{-}15$. According to the decision rule, since the value of $P < 0.05$, hence, *H2 is rejected*. This means that there exists a significant difference between one or more groups regarding the discussions done by various sections of our society on climate change.

Inference Though, there is a lot of discussion on climate change on Twitter from people belonging to different sections of society, however, the mean discussion of various groups varies. It is mainly the general public who is contributing the

most to these online discussions, which obviously could be since the general public amounts to a larger part of the overall population. We cannot simply dismiss the contribution of the other sections of society, because a single tweet by a celebrity engages more audience than that of a normal person. On the other hand, environmental organizations, such as the UN Sustainable Development Group (UNSDG), International Institute for Sustainable development, United Nations Industrial Development Organization, and many more are religiously working towards policy making and spreading awareness. Various eminent personalities like Justin Trudeau, Manuel Pulgar Vidal and Malcolm Turnbull, Greta Thunberg, Leah Namugerwa, Trisha Shetty, John Paul, Luisa Neubauer, Jake Horowitz, and Holly Gillibrand regularly post tweets raising their voices and encouraging their followers to contribute towards climate action. Even though these groups are less in number, they have a significant influence on a much bigger audience.

Moreover, it has been observed that people from all across the globe, whether they belong to developed or developing nations are equally invested in climate change discussions. It is quite evident from the nature of the tweets that people are deeply concerned and seeks immediate action from their governments. Twitter users exhibit an increased tendency to enjoy their privacy and hide their geo-location. This behavior has been reflected in the results shown in Fig. 9 with the individuals from some countries showing comparatively less engagement. China a nation with highest population (more than 1.4 billion) in the world was altogether absent in the results as it has strictly banned the use of Twitter throughout the country (Singh et al., 2018b; 2019b; Pobiruchin et al., 2020; Xu et al., 2021; Nachman et al., 2022).

6 Discussions

Ever since environment activists started realizing the importance of climate change and climate action (SDG13) and all the related dangers which may bring the current as well as future generations on the verge of doubts about their survival, various protocols and treaties have been agreed upon by the member countries of the United Nations Framework Convention on Climate Change (UNFCCC) for the collective good of our planet (Climate-Change-News, 2019). This research work investigates how people globally are discussing climate change and climate action (SDG13) on Twitter. Our research was formulated around three research questions, through which we wanted to uncover useful insights regarding climate change discussions on Twitter.

The primary actors that are the general public are becoming aware of actant climate deterioration, in this case, are continuously indulged in healthy discussions on Twitter over climate change; be it to create awareness or give possible solutions in

Fig. 9 Result of geo-location analysis
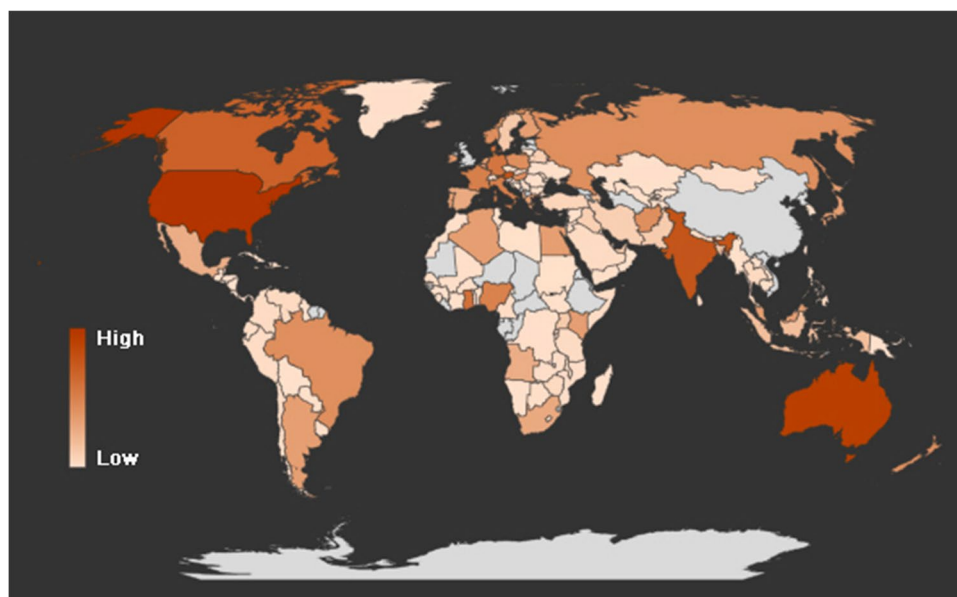
the form IS/ information technologies. Further, the results of hashtag analysis highlighted the fact that actant SDG13 cannot be regarded as a standalone goal as it is a tightly coupled network composed of other SDGs. Therefore, an integrated global action is required to achieve these goals (UNEP, 2021).

This work is concentrated on identifying the depth of conversations regarding SDG13 over social media. Other SDGs such as SDG15 (life on land), SDG14 (life below water), SDG3 (good health & well-being), SDG7 (affordable and clean energy), SDG11 (sustainable cities and communities), SDG8 (decent work and economic growth), SDG1 (no poverty) and SDG4 (Quality Education) that have found a strong correlation with SDG13 in this study need to be looked upon for diving deeper into this research.

The Twitter audience is not only concerned about the problems; rather they present an urgency by sharing potential solutions, that can help mankind combat climate change. The fact that discussions regarding climate change are not limited to the general public, many other actors such as organizations (NGOs, government offices, non-profit organizations, societies), eminent personalities (politicians, ambassadors, UN representatives, diplomats, bureaucrats, special envoys), activists (climate change activists, environmentalists, ecologists, social activists), journalists (media houses, news agencies, journalists, climate journalists) and celebrities (actors, actress, singers) actively participate in the discussion towards climate change.

The appearance of diverse groups presenting concern over the impending issue of climate change underscores the importance of digital technologies such as social media, to be more specific Twitter as a platform in this study can be brought to use by researchers to examine the highly generalized and personal views of the people. Apart from Twitter, the researchers who aspire to look for open data or other social media platforms to examine and understand the general view of society can benefit

from this study in framing the current status of research and proposing future directions (Pfenninger et al., 2017).

6.1 Technology: A Bliss for Climate Change?

Organizations, governments, and policymakers are starting to turn to new-age technologies for innovative solutions to tackle climate change and to achieve targets set by the United Nations framework convention as technology offers huge potential for sustainable development (George et al., 2021). The developments in the fields like wireless sensor networks (WSN), artificial intelligence (AI), and the internet of things (IoT) are offering intelligent solutions to reduce energy consumption which in turn would reduce carbon footprints (World Economic Forum & PwC, 2021; Salam 2020). These technologies are being used for efficient energy management, air quality management, water management, and using smart devices which are certainly having a positive impact (Ismagilova et al., 2019).

However, these devices come with the negatives as well; the disposal of these devices (E-waste) is toxic to the environment (Murugesan, 2008) and newer devices are being released constantly which encourages replacing the old ones. Moreover, some of the devices, we use, consume a high amount of electricity and majority of which still comes from the burning of fossil fuels (Dwivedi et al., 2022). Measures can be taken to strike a balance to use technology in our favor. For instance, devices should be made such that they must have a longer life; besides having low electricity consumption requirements. The increased use of renewable sources of energy; reuse and recycling of products; promote sustainable manufacturing (McLaren, 2020) would be a perfect measure in this direction.

Another digital technology that can be considered big support towards handling mission climate change is social media. Even if

not directly, it is helping to raise awareness among people. Over the last decade, there has been a significant rise in online discussions on this matter and a larger chunk of people from various strata of our society today are becoming increasingly aware of the implications of climate change and they feel an immediate need to control it. Various climate activists, journalists, and organizations have been successful in reaching larger audiences through online platforms and raising their voices to persuade governments and policymakers for taking appropriate actions (Askanius, 2011). But once again, we can't neglect the effect social media data has on the climate, such huge amounts of data generated everyday need to be stored and maintained in data centers which require a lot of hardware and efficient cooling mechanisms which further leads to an increase in carbon footprints (Dwivedi et al., 2022). Hence, when we talk about the role of technology, there is a dire need to balance the negatives with positives to draw the potential benefits out of it with minimal effects on the environment.

6.2 Implications for Policy and Practice

The implication of the study for practice can be divided into four sub-sections (a) Role of Government in formulating policies (b) NGOs and Activists as potential players (c) Indispensable role of the general public (d) A way forward for researchers. These sub-sections are discussed briefly below:

6.2.1 Implication for Policy Makers and Humanitarian Agencies

The Glasgow Climate Pact COP26, held in November 2021, involving major UN countries prove that governments and policymakers across the world are rethinking the measures of Paris Climate Agreement in order to lower the accelerated pace of climate change. Governments in developed countries are making serious pledge to 'carbon neutrality' by introducing more renewable energy based consumption, in addition to transforming people's consumption habits to make it more sustainable, i.e., encourage adoption of electric cars. Large corporations are also becoming increasingly conscious about their environmental impact and introducing 'net zero' policies to offset their carbon footprint across the world. Despite macro level climate action activities, our study shows that wider citizen consultation must be an integral part of national government and UN resolutions related to climate change pledge. In many countries policies are developed on paper but not mobilized at the ground level by educating consumers to adopt more sustainable lifestyle choices. In some developing countries, sustainable urban consumption and lifestyle choices are not even an option to the majority due to higher price premium charged by larger corporations making them more of a premium consumption category. On the contrary, rural living mentality was found to be much more sustainable. People who live close to the nature often create a symbiotic

giving-receiving relationship with nature protecting environmental ecosystem integrity.

Further policies need to be developed at the micro level aiming to transform growing industrial urban mentality. Recycling and renewable energy consumption should be promoted widely, not just making is a niche lifestyle choice for the elites. People should be strategically educated to become responsible for their own action and large corporations should be discouraged from charging price premiums for consumption choices, i.e., renewable energy should be cheaper than coal generated energy, electric cars should be heavily subsidies to encourage people purchasing it.

Our study also unveils an increased displeasure against national and local governments' role in offsetting climate change. At micro level local issues are ignored as governments appeared to be fixated on more macro level agendas. People's opinion and votes on climate issues should be channeled up from grassroot level making them national and international agendas for discussion. Such approach should go beyond just committing to reduced coal consumption (as per COP26). In this way, the government can revalidate public outlook before implementing a project or policy (Aladwani & Dwivedi, 2018; Alryalat et al., 2017; Kar & Dwivedi, 2020; Leiserowitz, 2020). It is a small cost to pay compared to the wider problems humanity is facing at the moment.

Importance of social media platforms in gathering public opinion should also not be undermined given the powerful collective insights that can be harvested from these platforms. Social media platforms should also be used to educate and raise awareness of climate change encouraging more sustainable lifestyle adoption. In a way platforms like Twitter facilitate a system of checks and balances among the various stakeholders in the climate change discourse.

6.2.2 NGOs and Activists as Potential Players

When we talk about climate change, NGOs form one such category of stakeholders which are tirelessly working towards climate change mitigation and are always pleading for sustainable growth. It is a known fact that traditionally the NGOs used to move around to spread the awareness word and had lesser funds and resources for large-scale operations (Schafer, 2012a, b). The presence of online communication channels has helped these organizations a lot in reaching out and influencing a larger audience (Horton, 2004). Online platforms like Twitter have acted as a crucial tool in spreading information regarding climate change, organizing campaigns and events, and gathering more volunteers from the general public (Nisbet, 2009). It has given them a chance to strengthen their networks and persuade the public to take action (Pickerill, 2002). Whenever NGOs or activists realize that certain activity or project would severely affect the local as well as national climate and has the

potential to put human lives in danger, they raise the banner of revolt and social media have assisted their cause (Rana et al., 2019). They may start a protest trend on social media, which can soon be strengthened by many other like-minded people and other organizations, ultimately raising alarms for the government to rethink the activity or project.

6.2.3 The Indispensable Role of the General Public

In modern-day times, the majority of people rely on social media for gaining knowledge on almost every topic (Schafer, 2012a, b). With the increased severity of the discussions held around climate change on every platform, the general public is also becoming increasingly aware of the situation. Today the debate is not just limited to climate activists, journalists, and organizations; it has penetrated through the masses. Although the depth of discussion varies from country to country as well as among different age groups, there is an overall rise (Eurobarometer, 2011) in the numbers involved continuously. People not only discuss the causes of climate change but are actively participating in finding solutions as found by this study. Twitter has given them a channel to express their views as well as question the policymakers and government on the measures taken to tackle climate change. A strong public opinion ensures that the governments will be apprehensive not to initiate action in this regard and thus leading to an increase in the overall transparency of the system (Mavrodieva et al., 2019).

6.2.4 A Way Forward for Researchers

Social media is a platform where all the users can independently share information on topics that are multi-disciplinary (Mehra et al., 2021). Researchers can benefit from this unique feature of social media by putting out multifaceted research works that cover a wider spectrum of global audiences and topics. In the literature survey, we found that most of the research work is based on conventional methods of surveys that generally carries a human bias (Jann et al., 2019). Social media needs to be looked upon as a potent source of data to examine the independent audience over the diverse topics concerning climate change. Researchers need to perform global collaborations in the field of sports (Orr et al., 2022), health (Solomon & LaRocque, 2019), transportation (Creutzig et al., 2015), oceans (Reusch, 2014), agriculture (Arora, 2019) and many more topics to provide more holistic and impactful research towards climate change that guides the governments and general public with the actions necessary to mitigate the effects of climate change.

6.3 Limitations and Direction for Future Work

Through this research, we made an effort to study the public opinion regarding climate change and climate action (SDG13) on Twitter using various content analysis and statistical testing techniques, to get meaningful insights besides finding the answers to three proposed research questions. However, several shortcomings need to be addressed in future studies. Firstly, for this research work, only original tweets were considered while retweets were not considered. As re-tweets almost constitute one-third of Twitter data (Holmberg, 2014; Yan et al., 2021), hence, a considerable amount of Twitter traffic was ignored in our analysis whereas including the re-tweets in the test data, would produce improved results. Similarly, another important aspect of bot detection was ignored in this study (Ferrara et al., 2016; Paredes et al., 2021). Social media bots might adversely affect the results of the analysis by making it biased. Hence, it is very crucial to address both the above points in any future study in this direction. A longer data collection period is another important aspect that would have resulted in more useful insights. Further, we can integrate social media and cloud computing to develop a smart system (Singh et al., 2020b), that can be manageable in achieving smart governance of the environment and climate related policies in smart cities (Ruhlandt, 2018). A deep learning approach of text summarization can also be brought to use to summarize the massive chunk of thousands of tweets into a small paragraph that may help in reducing the task of iterating over semantically similar tweets (Magdum & Rathi, 2021). The official hashtags provided by organizations should be brought to use that promotes actions to be taken for climate change is another recommendation that needs to be considered towards compelling reproducibility of this research in the future.

7 Conclusion

Our planet has suffered from environmental deterioration and some unprecedented challenges in the past few decades. The people now are facing the direct impacts of these man-made catastrophes and hence it swiftly warrants urgent climate action. The main aim of this research work has been to examine how the issue of climate change is being discussed on Twitter. An effort has been made to understand the behavior of people towards climate change using Twitter data. Further, three research questions were formulated to get insights into climate change discussions on Twitter.

It is inferred from the results that not only the developed nations having higher satisfaction indices like Sweden, France, Germany, England, United States, Norway, and Canada are working towards maintaining desired climate action; even the developing nations like India, Malaysia, African countries are equally participating in this regard. People from all over the world belonging to diverse backgrounds have become quite aware of the issues arising due to climate change and are raising their voices for resolving their concerns. They are demanding the concerned authorities take appropriate measures to curb the problem before it reaches alarming proportions to cause further

harm. A great volume of positive support and public participation has been observed. There has been a constant debate and dialogue among nations regarding the climate problems that we are currently facing and will continue to face if not acted upon; however, we have a long way to go before we have this issue well under control. Moreover, the accomplishment of various other sustainable development goals is largely dependent on climate action in some or the other way.

Due to the increased global temperature, there have been reports of natural disasters leading to loss of life, rise in hunger, water shortage, increase in malaria, difficulty to eliminate poverty, and overall economic slowdown which are targets of some other sustainable development goals. Innovative solutions, national strategies, global cooperation among nations, stringent rules, awareness drives, and capacity-building are a few preliminary measures that need to be implemented to achieve the set targets. The governments are shifting from the use of fossil fuels to greener means like electric vehicles to cut down carbon emissions and earn more carbon credits. In addition to these, the role of ICT is indispensable as we progress towards sustainability. The inclusion of technologies like the internet of things and artificial intelligence can prove highly beneficial in achieving these goals in the long run. Sensor technologies and smart systems can help in the design of energy efficient buildings reducing energy consumption, monitoring CO_2 emissions, predicting extreme weather conditions, and much more.

Declarations

Conflict of Interest The authors don't have any conflict of interest to the best of their knowledge.

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