Communicating Science: Exploring the use of narrative in the top-cited academic papers in climate change and sustainability literature

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1. Introduction:

Over the past half century, climate change discourse has become an increasingly central, and often divisive, global issue for many. Although, each year, thousands of peer-reviewed scientific evidence of human-caused environmental impact continue to be published, and the climate-action deadlines proposed by intergovernmental bodies become ever-more urgent, public attitudes and understanding on the matter remain largely governed by partisan identity, the stubbornness of human cognition, and media fragmentation (International Panel of Climate Change, 2018; Nisbet, 2009). The growing demographic of individuals disagreeing with the 97 percent consensus of climate scientists emphasizing the anthropogenic origin of global temperature rise indicates a pressing need for the field of science communication to rethink its' approach (Klein, 2014; Cook et al., 2016). Climate scientists must find new ways to communicate their findings in order for them to unequivocally resonate with all audiences, and encourage the necessary shift in paradigms for research, technology, business, and industry.

Peer-reviewed scholarly publication is regularly viewed as a specific form of communication, exempt from qualities of narrative. However, unlike modern conceptions of what objective scientific discourse should look like, storytelling has long played a fundamentally constitutive role in accounts of mathematics and science. Within the works of some of the greatest scientific discoveries and revolutions in history, we see an overarching union of science and narrative. From Galileo's loaded ship and Newton's apple, to Schrodinger's cat and Einstein's train, use of narrative has proven to be an essential means of demonstrating scientific thinking and argument to scientists, contemporaries, and lay persons alike.

The objective of this Honours Thesis is to synthesize the literature of narrative and framing theory and place it within the context of climate change science communication. Ample evidence within the literature already exists suggesting that scientists' incorporation of narrative elements in their writing style increases the citation uptake of their articles and the public influence they embody (Nisbet, 2009; Hillier et al., 2016; Spence & Pidgeon, 2010; Dahlstrom, 2014; Lejano et al., 2013). By more closely mirroring the way humans experience and understand the world—through storytelling—scientists have the opportunity to render their work more notable among scholarly and public audiences. In response to this, this research will look to the top 10 most-cited climate change- and sustainability- related articles and search for common trends in theme, framing, and narrative to gather insight as to what communication devices carry the most significance in an articles' success. Using high citation uptake as a measure for a paper's impact on advancing academics' understanding, altering the course of climate research, and inspiring future generations, this study will deliver an in-depth profile of what narrative elements can be found in the most successful and influential works in climate change and sustainability literature. It will also offer considerable insight on how climate scientists and researchers should move forward in communicating their results and how to increase their chances of contributing to the existing bedrock of literature underpinning climate policy and mitigation action worldwide.

1.1 Research Question What common themes, frames or narratives appear across the most-cited academic papers in climate change and sustainability literature?

2. Context within the literature:

2.1 The trouble with cultural cognition

Cultural cognition is the process by which individuals filter new information in ways that will protect their own moral or preferred understandings (Kahan et al., 2011). Essentially, any new information projected at an individual that does not match with their belief system, even information backed by insurmountable scientific evidence of causality, is instinctually rejected due to an irrepressible emotional predisposition of not wanting to be proven morally or intellectually wrong. Likewise, if the new

information matches our preconceived understanding of the world, it is integrated into our learning effortlessly. This same understanding of human cognition is asserted in Lakoff's "Don't think of an Elephant!: Know Your Values and Frame the Debate" (2004). Simply put, Lakoff asserts that humans understand the world in a series of frames, and that their repetition is what makes them stronger, no matter their accuracy. Similar to Kahan et al., new information in the form of preconceived frames would be integrated into an individual's learning much more easily.

As a result, science communicators' task to convince climate change deniers of scientific evidences' significance proves to be much more challenging than expected. A discipline that used to be governed by the Information Deficit Model, assuming that the reason for lack of engagement was a lack of information and knowledge, must now transform its tactics and take a more personalized and humanist approach (Moser & Dilling, 2012; Nabi et al., 2018; Blue, 2018). The challenge is not that people don't know, it's that what is being articulated does not confirm many persons' pre-existing biases and ideologies.

2.2 Narrative style's influence in the literature

"Narrative Style Influences Citation Frequency in Climate Change Science" by Hillier et al. (2016) was the foundational research motivating this study. Hillier et al.'s results indicate that sensory language, use of conjunctions, connectivity, and appeal in scientific abstracts, all of which are distinct elements of narrative writing, each have a strong positive correlation with citation frequency (Hillier et al., 2016). These results suggest that writing in a more narrative style increases the uptake and influence of articles in climate literature. These findings that highlight the power of literary theory are accompanied by various psychological studies across multiple disciplines, emphasizing that use of narrative is the most effective way of helping the public conceptualize findings and overcoming barriers of cultural cognition. In Dahlstrom's "Using narratives and storytelling to communicate science with nonexpert audiences", narrative communication is asserted to include messages that follows a particular structure that describes cause-and-effect relationships between events situated in a particular place and time with an impact on particular persons or characters (2014). In his study, it is shown that given the narrative format of most mass media content that nonexperts rely on to acquire information, scientific communication in the form storytelling increases comprehension, interest, and engagement (ibid.).

This tenet carries across many fields of science, including medicine. In fact, studies show that using narrative alongside didactic information has significant positive effects on healthcare participation (Wise et al., 2008). Similarly, physicians frequently use metaphors and analogies in patient-doctor conversation in order to not only better communicate, but also to help patients conceptualize their illnesses in ways that can conduce beneficial health behaviour and attitudes (Casarett et al., 2010). For example, patients with cancer who reportedly saw their illness as the "enemy"—a frame initiated by militaristic metaphors describing cancer as an invading army—were found to have higher levels of depression and anxiety than patients who used a more positive depiction like "a journey" (ibid.). This not only exemplifies the power of metaphor to render understanding but also its ability to promote entirely new ways of thinking.

Thibodeau & Boroditsky's "Metaphors We Think With: The Role of Metaphor in Reasoning", explores how even a single, unnoticeable metaphor, and the frame it induces, can perpetuate significant differences in opinion about how to solve social problems; more so than the pre-existing differences in opinion that come with partisan identity (2011). The study found the following: 1) if the frame "crime is a virus" was used, people advocated for diagnosing the root cause of the issue and pursuing social reform that helps the community stay out of trouble; and 2) if the frame "crime is a beast" was used, people advocated for arresting and imprisoning criminals in order to fight off the crime attack (ibid.). The impact that a seemingly unnoticed metaphor can have on public opinion on crime in this study highpoints palpable potential in shifting public opinion on climate change and climate science. Indeed, Niebert &

Gropengiesser explore how use of different metaphors in conceptualizing the mechanisms of global warming for students in 12th grade, alter their mental models (2013). What makes the metaphor so powerful is its ability to bridge the explicitly perceivable and tangible dimensions of the human experience with the complex functions and procedures that serve as foundation to scientific concepts. It is this bridging that is critical to climate science understanding—a bridging manifested primarily, if not exclusively, through storytelling and the use of narrative elements.

3. Methods:

3.1 Database search

Given that the desired sample for this research is determined by citations, Scopus seemed to be the best database to conduct a search for the top-cited articles in climate change and sustainability literature since it is the world's largest abstract and citation database of peer-reviewed literature and encompasses a wide breadth of multidisciplinary publications. A search for academic papers with the exact terms 'climate change' in the title, abstract or keywords produces a very large and broad range of articles; 256,654 to be exact. Considering the high probability of unrelated or only vaguely-related articles being included in these results, the search was narrowed down to academic papers with the exact phrases 'climate change' AND 'sustainability' in the title, abstract or keywords. This search produced 12,363 results. While this decision certainly removes a number of influential climate change papers from the sample, it will ensure that the research conducted will be thorough and more precise given its smaller scope, and more suited to this paper's area of interest if it includes the word 'sustainability'.

3.1.1 Search results

Upon producing these results, the refine values were exported to piece together the useful information regarding the profile of this body of literature such as: year, author, subject area, document type, source title, affiliation, and country, which can be found in Appendix A.

3.1.2 Acknowledgment of error in database search

Within these results, it is important to note that Scopus does not have comprehensive citations for articles published before 1970 so papers published earlier on might be understated in the top 10 most-cited papers. More recent papers will likely show higher citation uptake because there are more climate change- and sustainability- related papers being published which increases the chance of papers being cited. Similarly, papers published very recently, like 2018 and 2019, will not accrue as many citations as others since they have not had as much time to circulate. These assumptions appear to hold true as the top 10 most-cited papers are all between the years 2002 and 2011 (Appendix B).

3.2 Qualitative text analysis

By adopting a text-type approach to narrative, this research will capture structural, functional and other conventionalized patterns of narrative in climate change- and sustainability-related literature that are suggested to be centrally concerned with readers' experientiality (Fludernik, 2002). Referencing a list of common, published and critiqued narrative elements, composed primarily from Herman et al.'s (2005) *Routledge encyclopedia of narrative theory*, this study will shed a light on commonalities and differences within the range of highly-cited texts. It is important to note that the boundaries of narrative theory for this approach have mostly been determined in terms of text-internal criteria (i.e., form and content) and at the expense of text-external (i.e., functional, socio-cultural) criteria (Herman, 2005). This means that the following classifications, applied to the top most-cited articles in climate and sustainability literature, will not necessarily account for the historical or scholarly contexts by which the works are situated unless explicitly founded within the text. Upon conducting a review of the literature, this research

explores identifiable narrative attributes within the following aspects of narrative theory: the narrator, setting, didactive approach, and framing.

3.2.1 The Narrator:

Lejano et al. (2013) offer a minimum distinguishing definition of a narrative to be something that is told by a narrator. The presence of a narrator, and the various ways they establish that presence, has the power to elicit an affective response (Peterson & Langllier, 2006). The affective impact of a text is its power to elicit emotion from the reader. Audiences react to the events presented within the story and respond to the features of the discourse that they like or dislike with what can most simply be described as 'empathy'. Empathy captures a person's situation as well as to evaluate the relevance and desirability of a situation and its potential outcomes, and while narratives often invite recipients to share specific sets of assumptions about the world, the evaluative stance taken in the reception of narratives ultimately depends on the reader's own attitudes, values, and beliefs as shaped by cultural context (Herman et al., 2005). The types of emotions resulting from empathy, and how intense they are, depends greatly upon the reader's attitude towards a character or narrator, and as such, readers are often invited to consider their motivations in detail and to share that character or narrator's unique perspective. According to Herman et al., "if the reader gets access to the character's plans, hopes, wishes, etc., a mode of access which is achieved mostly by techniques of presenting the character's consciousness, this will have especially powerful effects" (ibid). The following narrative attributes, related to the narrator, are included in article analysis.

3.2.1.1 Narrative perspective

The difference between first-person, second-person, and third-person narration, according to Graesser et al. (2002), is the extent of fusion of agents within the writing that sweeps up the reader as a participant in the microworld and thereby increasing reader involvement. In the first-person narration, the narrator is fused with the character agent, taking the point of view of the focal character, using the referent "I", and encouraging the reader to understand the world and their consciousness from their perspective. Alternately, in third-person narration, the narrator is functionally separate, reporting the actions, events and states of the situation. In second-person narration, there is a fusion of four agents; the reference of "you" is to the narrator, narratee, character, and reader. By means of a source memory test, the study by Graesser et al. (2002) reported that a narrator has a stronger narrative presence and is more salient in a reader's memory when it is fused with more agentive roles. The gradient by which narrative perspective influences resonating memory within a reader is as follow: second-person > first-person > third-person. As such, this research looks to narrative perspective in the articles and compare use of first-person narration, indicated by referent of "I", "we", or "our", second-person and third-person narration.

3.2.1.2 Reader address

Vocative formulations that identify the reader directly, by referent of "you" or "the reader", is an interpreted strategy to get the reader more involved as the second-person pronoun wields power to make the reader feel individually addressed and encouraged to feel strong emotions about the utterance (Herman et al., 2005). This study explores the presence and frequency of reader address in the texts.

3.2.1.3 Rhetorical questions

Here, we establish another form of reader address—the rhetorical question. A rhetorical question, according to Howard (1990), is a question that suggests a certain response from the reader, where the answer is implicit within the question. It is asserted that rhetorical questions have the capacity to motivate readers to more intensively process a message and elicit judgement on the topic of its request, more convincingly so when the necessary information is already presented (ibid.). This study considers the presence of a rhetorical question as an example of direct address to the reader, implicitly evoking a

response from them, and assesses the presence of rhetorical questions within the articles. Examples of this found within the 10 most-cited articles include "What determines the maximum rate of environmental change that populations can cope with? (Chevin et al., 2010) or "How long before such reactors run out of fuel?" (Hoffert et al., 2002).

3.2.1.4 Metanarrative comments

According to Herman et al. (2005), metanarrative comments are self-reflexive references to the act of storytelling or to the elements by which a narrative is constituted and communicated. These comments by the narrator, for the most part, bear a functional value in narrative transmission. This includes comments regarding the discourse that may possess directing functions, like thematizing the internal organization of the text, empathy-inducing functions, like warning that the following text may reveal unfavourable results, or parodic functions, like emphasizing the nonsensicality or irony of something within the discussion. As such, this research looks for metanarrative phrases as another indicator of a narrator's presence. For example, "Our analysis suggests that three of the Earth-system processes — climate change, rate of biodiversity loss and interference with the nitrogen cycle — have already transgressed their boundaries" (Rockström et al., 2009).

3.2.1.5 Quotation Theory

According to Herman et al. (2005), quotation is a process of mutual value assignment between two parties: a "quoter", who provides a discoursal frame, and a "quotee" whose discourse forms a quotational insert. Both parties' positions are reinforced as the quoters discourse is enriched by including memorable thought, and in turn, the quotation ensures the quotee's enduring reputation. Here, it is asserted that evidence of quotation or reference within an article of study could facilitate a trustworthiness in the narrator because they support their arguments with pre-established legitimacy. Whether the number of times an article references other work has an effect on the success of an academic article, their notability within the literature, is something to be explored. As such, this study will also explore the number of times a "quoter" quotes a "quotee".

3.2.1.6 Appeal

The power of a character or narrator's conscious presence to elicit affect has already been discussed here. However, another mode of access by which disclosure to plans, hopes, and wishes can be facilitated are explored as follows. According to Hillier et al. (2016), appeal refers to the moral and evaluative orientation of a narrative. Answering the questions of why the story is being told reinforces the 'tellability' of the story, the quality that makes stories inherently worth telling or newsworthy independently of their textualization (Herman, 2005). It's the quality of the story that answers the question "so what?", "why is this important?" or "what can I do with this information?". This study assesses the use of appeal by exploring whether the texts make explicit appeals to the reader via a clear statement of what makes its content valuable or a clear recommendation for action.
Examples of this found within the 10 most-cited articles include "We need a major new global contract between rich nations and poor and between the rich and poor within nations that revamps our relation to nature and the future" (Norgaard, 2010) or "we must find more sustainable pathways for intensification that increase crop production while greatly reducing unsustainable uses of water, nutrients and agricultural chemicals (Foley et al., 2011).

3.2.2 Setting

3.2.2.1 Spatial and temporal dimensions

Setting is a fundamental component of narrative that distinguishes it from other forms of discourse (Chapman, 1990). It is established by spatial and temporal dimensions that help create a mental image or description of where and when events occur (Holstein & Gubrium, 2012). Spatial situating and temporal ordering of events is also a crucial attribute of narrative as it not only helps with readers' understanding but also implies a momentum towards completion (ibid.). Spatial situating includes mentions of location and terms in to a reference point such as "next to", "alongside", or "above/below". Temporal ordering includes mentions of past, present, or future and terms such as "afterwards" "after x months", or "last year" that implement chronological sequence (Norris et al., 2005). Thus, this study looks for specific, and following, relative, mentions of time and place in the articles establishing a base setting.

3.2.2.2 Conjunctions

Conjunctions are connecting words used to bind narratives together into one cohesive, logical form. It is suggested that conjunctive markers can signal a relationship of cause and consequence (e.g., consequently; as a result; for this reason), signal that subsequent information modifies preceding information (e.g., however; although), signal for additional information (e.g., furthermore; in addition), exemplification (e.g., for instance; thus) or the restatement of information previously given (e.g., in other words; namely) (Sydserff & Weetman, 1999). This connectivity, and the shift in information category and specificity it facilitates, increases the texts readability. Therefore, since conjunction use reduces the complexity of the text by signalling information category and establishing causal ordering, conjunctions guide the reader along to follow a particular story and stimulate an easier reading experience to enjoy. Considering this, this research looks to the frequency of conjunction use and analyzes its incidence across the articles.

3.2.2.3 Sensory language

Sensory languages is the use of descriptive words that can appeal to the senses and emotions of the reader by describing how both the narrator and reader experience the world (Holstein & Gubrium, 2012). This includes the use of words that refer to: 1) sight, like colours, shapes, or appearance, 2) touch, describing texture, 3) hear, describing sounds 4) taste and smell, or 5) motion, like active words describing movement. Since sensory language encourages readers to experience conditions within the text, this study assesses the number of times sensory words appear in the texts.

3.2.3 Didactic approach:

A didactic approach within a text indicates its main purpose is moral education and transmission of particular kinds of knowledge, often combined with the teaching of literacy skills. According to Herman et al. (2005), didactic narratives include apparent simplicity and accessible meanings, though often with more profound layers of interpretations, memorable content, highlighted language using formulaic phrases like metaphors, and a wide applicability of the teaching point through analogy. Didactic approaches within the articles are identified using the following devices:

3.2.3.1 Anecdotes or short exemplars

An anecdote is a short, and often humorous, narrative, purporting to recount a true incident involving real people; they tend to be heavily dialogic in construction, often culminating in a punch line rendered in direct discourse (ibid.). According to Dahlstrom, anecdotes are a routinely relied upon literary device that cut through information clutter and resonate with audiences in a way that has a greater chance of engaging them (2014.). As such, this study assesses whether there is a consistent presence of anecdotes among the most popular articles in the literature. Examples found within the 10 most-cited articles include "Targets of cutting to 450 ppm, and certainly 350 ppm, could require *Herculean* effort" (Hoffert et al.,

2002) or "The 'Goldilocks' problem of nutrients (that is, there are many regions with too much or too little fertilizer but few that are 'just right') is one of the key issues facing agriculture today" (ibid.).

3.2.3.2 Metaphors

Metaphors are deliberate figures of speech that involve understanding one thing in terms of something else. Metaphors can play rhetorical, linguistic, or structural roles within the narrative that increase comprehension, interest and engagement (Herman, 2005; Dahlstrom 2014). Presence of metaphors across the top-cited articles, as well as similes since that can also be seen as similar figures of speech, are assessed in this study and examples of metaphors found include "this paper is a roadmap" (Ragauskas, 2006) and "this field of study is ripe" (ibid.).

3.2.3.3 Visual aids and photographs

The use of graphic aids and photographs are a specific form of the didactic strategy that assists with the transmission of particular kinds of knowledge by explicating complex concepts in a visual way. This study also collects information about what types of visual aids are included in each of the articles and looks at whether there is any specific format that appear in the articles repeatedly.

3.2.4 Frames

Frames are the lenses through which a story is told, the specific 'defaults' encoded into a text that fill the gaps regarding a specific topic or subject for the reader and provide the situating presuppositions that enable one to understand what the text will be about. In her essay on literary dynamics, Perry (1979) asserts that a frame captures a reader's current knowledge representation vis-à-vis questions like "What is happening?", "Where is this happening?", "What is the situation?", "Why is this happening?", "What are the motives?", "What is the purpose?", and "What is the speaker's positions?".

According to Somerville & Hassol (2011), once you configure the necessary frame, sticking to something simple, memorable, and repetitive is the best way to take advantage of our most recent understanding of information-cognition patterns. So which frames relay the climate change and sustainability message best? This study assumes that whatever frame the most-cited articles have been using must be the most successful at resonating with the "cultural cognition" frames of the majority of audiences, and as such seeks to find the predominant frame used among them. The following frames are explicated thoroughly within the literature and inspired this study's search for frames.

3.2.4.1 Issue or subject presented in terms of gain or loss

In an attempt to better understand which ways of framing more significantly influence audience reception, Spence and Pidgeon's *Framing and communicating climate change: The effect of distance and outcome frame manipulation* investigates how outcome framing affects attitudes towards climate change mitigation and the perceived severity of climate change impacts (Spence & Pidgeon, 2010). Outcome framing is the process of presenting an issue or subject in terms of gains or losses, and research on this concept has had a lot of prevalence in health psychology. Studies show that between prevention behaviours, like use of sunscreen to prevent UV rays, and detection behaviours, like testing for HIV, loss frames are found to be most effective for encouraging detection and gain frames for encouraging prevention (Rothman et al. 1993). Given the invisible, indirect, and "dormant" nature of climate change, encouraging its mitigation could more closely be compared to encouraging prevention behaviours. Similar to how use of sunscreen prevents potential skin cancers, adopting environmentally conscious behaviours can prevent potential global climate catastrophe. In comparing the attitudes that result from framing in terms of the positive consequences, or gains, of mitigation and the negative consequences, or losses, of no mitigation, it would be reasonable to assume that gain frames would be more effective. And likewise, the results of Spence and Pidgeon's research proves that gain frames are more effective than loss frames as

both mitigating attitudes and perceived severity of climate change impacts are increased considerably when positive consequences are emphasized over negative ones (Spence & Pidgeon, 2010). As a result, this study explores whether the articles' issues or subjects are presented in terms of gain or loss and, likewise, hypothesizes that gain frames will prove to be more prevalent among the most effective articles in the literature.

3.2.4.2 Issue or subject presented locally or distant

Many previous authors have stressed that emphasizing the personally relevant aspects of climate change more effectively promotes action among audiences (Nisbet, 2009; Spence & Pidgeon, 2010). As a result of this research, science communicators often use a public health frame that highlights climate change's potential to give rise to various infectious diseases, allergies, asthma, and heat stroke—all of which impact the most vulnerable of demographics, children and the elderly. According to Nisbet (2009), by doing this, climate change is made more personally pertinent as the frame shifts "the geographic location of impacts, replacing visuals of remote Arctic regions, animals, and peoples with more socially proximate neighbours and places across local communities and cities".

Spence and Pidgeon's study (2010), however, has brought to light a slightly different understanding. Their study also explored the influence that local and distant frames of climate change impact have on attitudes towards mitigation and perceived impact severity. Contrastingly with the previous research, their results indicated that distant frames were perceived as more severe, and that attitudes towards climate change mitigation were only more positive when participants were asked to consider social rather than personal aspects of climate change (ibid). The significance of social concern over personal apprehension in the climate change context, here, is vital. Perhaps, the reason why the public health frame is so effective is not because it triggers personal affect but because it emphasizes the social consequences of health hazards in the community. Thus, Spence and Pidgeon recommend focusing individuals on the social impacts in addition to the personal impacts of climate mitigation (ibid.). Therefore, this study also explores whether the articles' issues or subjects are presented locally pertinent or distant, indicated by content associated with a geographical location or more global scale, and hypothesizes that the common frame will be on the social impact in addition to the personal impacts of climate mitigation.

3.2.4.3 Issue or subject is present in terms of fear or hope

Initiating an audience's emotive reaction is another frame frequently considered in climate change communication; in particular, evoking fear. Fear framing is the emphasis of threat content in a message, emulating a more extreme loss frame (Spence & Pidgeon, 2010). A large repertoire of fear framing exists in the world of environmental advocacy, some of the most frequent buzzwords of which include "crisis", "emergency", "high-risk", "the runaway" greenhouse effect, and "tipping points". The documentary *An Inconvenient* Truth, featuring Former United States Vice President Al Gore's campaign to educate people about global warming, is an archetypal example of this (David et al. 2006). Gore's lecture, which since the movie's release has become a highly-regarded and popular classic among environmentalists, features a "Pandora's Box" frame made up of images including hurricane devastation, stranded polar bears, drought-afflicted landscapes, and highly-populated, metropolitan cities underwater (Nisbet, 2009).

Alongside *An Inconvenient Truth,* fear discourse in media and journalism has long been under skeptic scrutiny (Moser & Dilling, 2012; Spence & Pidgeon, 2010). In 2006, Time Magazine featured an article on its cover headlined "Global Warming: Be Worried, Be VERY Worried" which triggered many claims of liberal "alarmism" supposedly exaggerating claims in order to provoke unwarranted anguish (Nisbet, 2009; Kluger, 2006). Besides the reinforcement of the partisan divide (climate change skeptic vs. advocate), the key issue in fear framing, according to Moser et al. (2012), is that what grabs the

audience's attention, such as severe consequences and calamitous forecasts, is not necessarily what facilitates action and engagement. Instead, effective engagement through fear must be supported by recommended "solutions that help audiences translate their concern into feasible and affective action" because blatant fear appeals often come off as merely manipulative (ibid.).

This introduces a contrasting emotive frame that has also been recognized as a key mediator of framing and resulting audience attitudes—hope (Nabi et al., 2018). Nabi et al.'s *Framing Climate Change: Exploring the Role of Emotion in Generating Advocacy Behaviour* found that audiences exposed to threatening messages experience more hope if a solution-oriented efficacy message is integrated, and when hope is generated, negative message assessments are minimized and supportive attitudes and, in turn, advocacy behaviour is boosted (2018). Science communicators still debate whether it's needed that we more radically communicate the severity of our climate problems and appropriate the necessary anxiety to move people to action or instead to only convey images of hope that that avoid fatalism. In response to this ongoing debate, this study assesses whether the issues or subjects in the articles are presented in terms of fear or hope, indicated by threat content or feasible and effective suggestions for solutions, and identify which of the two appear most frequently among the most popular works in the literature.

3.2.5 Other aspects

Alongside the narrative devices already mentioned, other aspects highlighted by the literature review that were considered include: 1) the political inclination of the author and reader, 2) pre-existing cultural biases and ideologies in the reader, and 3) whether the information is relayed by a trusted messenger. Although these three considerations would undoubtedly provide a more nuanced understanding, it was decided that, given their ambiguity, subjectivity, and need for extensive and hard-to-find background research, they would not render meaningful or certain results. Therefore, they are not included in the analysis.

3.3 Data Collection

In an attempt to explore if any trends exist within the types of narrative mentioned in the 10 most-cited climate change- and sustainability-related papers, thorough reader-based qualitative text analysis is necessary. The papers are read, paying attention for evidence of the indicators listed above. Upon carrying out individual analyses, a qualitative analysis software, MAXQDA, is used to code observations, quantify frequencies, and organize types. *MAXQDA* is a text analysis software that facilitates very practical visual tools tailored for qualitative research. In this study, the observation frequencies are quantified and colour coded into document portraits, visualizations of all coded segments in the articles in order of sequence.

3.3.1 Importance of readership

It is important to note that many of the elements of narrative discussed can only be identified by thoroughly reading the articles. This study is incredibly context-dependent. Whether the way a topic or issue is being discussed is merely expository or story-like depends on how it is situated in the text. As such, it is integral that this analysis be done through readership and not computer coding exclusively. To highlight one straightforward example of how search-based coding would skew the quality of this analysis, consider a computerized search for the term "last [x] years" in an article. Independently, the term "last 50-100 years" would be noted in this analysis as a temporal referent of the past. However, in considering the context of the sentence in which this term is used, the phrase "*for* the last 50-100 years" would indeed be a referent of the past, but "*will* last 50-100 years" is unquestionably an indicator of future reference. This distinguishing would be overlooked if analysis was conducted exclusively on a coding basis.

4. Results:

4.1 Coded segments

Shown below are the matrices of all of the codes appearing in all 10 of the analyzed published papers. Documents are listed in the columns while codes are listed in the rows. The numbers at the conjunction points indicate the number of coded segments that are identified with a particular code. These results do not have any weighting or normalizing accounted for them, they merely indicate frequency. Here, I will highlight some of the more notable observations. In Figure 1, in the code matrix for narrative elements indicating narrator presence, we see that there is use of first person identifiers in every article. The most common first-person pronoun is "we", used in every article except one which narrates using first person singular, "I", instead. We also observe that there is ample presence of metanarrative comment throughout. In Figure 2, which illustrates the code matrix for setting codes, we see that although all of the papers' topics are situated in the past and present context, the most frequent temporal reference, in total, is the future. The most frequent spatial scale mentioned in these documents is global. Figure 3 indicates that an increase in use of metaphor or anecdotes is accompanied by an increase in educational or explanatory material in the document. This suggests that use of metaphor and anecdotes is heavily dependent on the explanatory nature of the paper, whether the paper is intended to introduce and teach audiences about scientific concepts or rather contribute to an existing expert audience conversation. Figure 4 indicates that between gain and hope frames and loss and fear frames, the latter is more frequently expressed in the papers.

Code System	1.Th...	2.So...	3.Pl...	4. S...	5.E...	6.A_...	7.Ad...	8.Su...	9.Ad...	10.E...
Narrator Presence										
First-person										
My										3
I										6
Us		1			1					
We	6	27	17	15	1	23	8	17	16	1
Our	1	6	3	4		7	4	5	5	
Quotation Theory										
Explicit reference	10	6	2	12	7	1	18	3	4	10
Direct quotation				2			3			
Appeal										
Call for action	1	10	2					1		
Emphasis metanarrative	4	7	1	5	7	3	11	7	8	26
Statement of content value	3		2							
Possibility/potential metana	7	3	5	12	1	1	12	5	8	2
Meta-narrative comment										
Opinion/belief metanarrative	2	2	2	1			6			16
Empathy-inducing meta-narrati										
Directing meta-narrative		15	11	15	20	14	10	18	20	25
Rhetorical question	1	1		1			5		1	1
Reader address										110

Figure 1: Coded Matrix for codes indicating narrator presence. Documents are listed in the columns while codes are listed in the rows. The numbers at the conjunction points indicate the number of coded segments that are identified with a particular code. These results do not have any weighting or normalizing accounted for them.

Code System	1.Th...	2.So...	3.Pl...	4. S...	5.E...	6.A_...	7.Ad...	8.Su...	9.Ad...	10.E...
Setting										
Sensory language	4	4	12	2	3	2	1		2	10
Spatial and temporal dimensions										
Temporal	1			4					1	1
Long-term	1		2	6	1		5			1
Short-term				3	1					1
Past	11	13	6	9	7	2	8	1	1	12
Today/present/current	5	4	5	12	4	1	13	3	1	12
Future	6	8	4	29		5	17	15	2	23
Spatial		2		8	3				1	1
Continental					4		2		1	
Place		1		2	4		1			
Local				10	15	7	2	1	2	7
Regional	4	28	6	2	34		2	5	1	4
National	9	5	2	18	15		13		1	19
International				5	4	2	2			2
Global/world	9	21	3	10	20	9	18	16	4	24
Planet	1		5	1	6	1	7	1		
Conjunction	42	53	28	100	58	32	25	38	42	86

Figure 2: Coded Matrix for codes indicating setting. Documents are listed in the columns while codes are listed in the rows. The numbers at the conjunction points indicate the number of coded segments that are identified with a particular code. These results do not have any weighting or normalizing accounted for them.

Code System	1.Th...	2.So...	3.Pl...	4. S...	5.E...	6.A_...	7.Ad...	8.Su...	9.Ad...	10.E...	11.
Didactic Information											
Educational											
Visual aid	3	5	2	1	1	4	7	8	2	3	
Example	13	9	8	38	22	5	1	3	5	10	
Explanatory Insert					4	6	12	5	11	1	
Metaphor/anecdote											
Figure of speech	2	5	4	13	12		10	1	4	9	
Metaphor	3		1	4						4	
Anecdote	1	1			3		1			3	

Figure 3: Coded Matrix for codes indicating didactic strategy. Documents are listed in the columns while codes are listed in the rows. The numbers at the conjunction points indicate the number of coded segments that are identified with a particular code. These results do not have any weighting or normalizing accounted for them.

Code System	1.Th...	2.So...	3.Pl...	4. S...	5.E...	6.A_...	7.Ad...	8.Su...	9.Ad...	10.E...	1
Framing											
Hope	1	4	2	3			1	3	2		
Gain		2	1	1	1						
Fear	3	7	4	4	2	4	4	3	4	7	
Loss		4	5	2	6	22		1		3	

Figure 4: Coded Matrix for codes indicating framing. Documents are listed in the columns while codes are listed in the rows. The numbers at the conjunction points indicate the number of coded segments that are identified with a particular code. These results do not have any weighting or normalizing accounted for them.

4.2 Document portraits

Figure 5 shows the document portraits for all 10 analyzed papers. A document portrait is a visualization tool shown as a colour-coded "painting" of all the coded segments found in the papers in order of their appearance. It weights the colours according to the size of each coded segment and therefore this visualization tool exemplifies how heavily each narrative element is used proportionally in each paper. Yellow indicates setting, light blue indicates didactic information, dark blue indicates narrator presence, and green indicates framing. I will now explicate some of the most important observations to be made.

Firstly, we see that there is no obvious trend to underline with regards to narrator presence (dark blue) and setting (yellow), they are evident throughout all of the papers. Secondly, we see that most evidence of framing, indicated by light green in the document portraits, can be found in the introductory pages of the documents. This is common among all of the articles except for document 6 which uses a lot of framing language throughout. And third, didactic strategies, coded as light blue, are rarely used in the introductory and concluding segments of the documents. Didactic approach content being heavily concentrated in the middle body of the paper heavily parallels with the literature review and methodology sections, where papers often have to more straightforwardly explicate complicated concepts to various audiences which may not have as much in-depth knowledge.

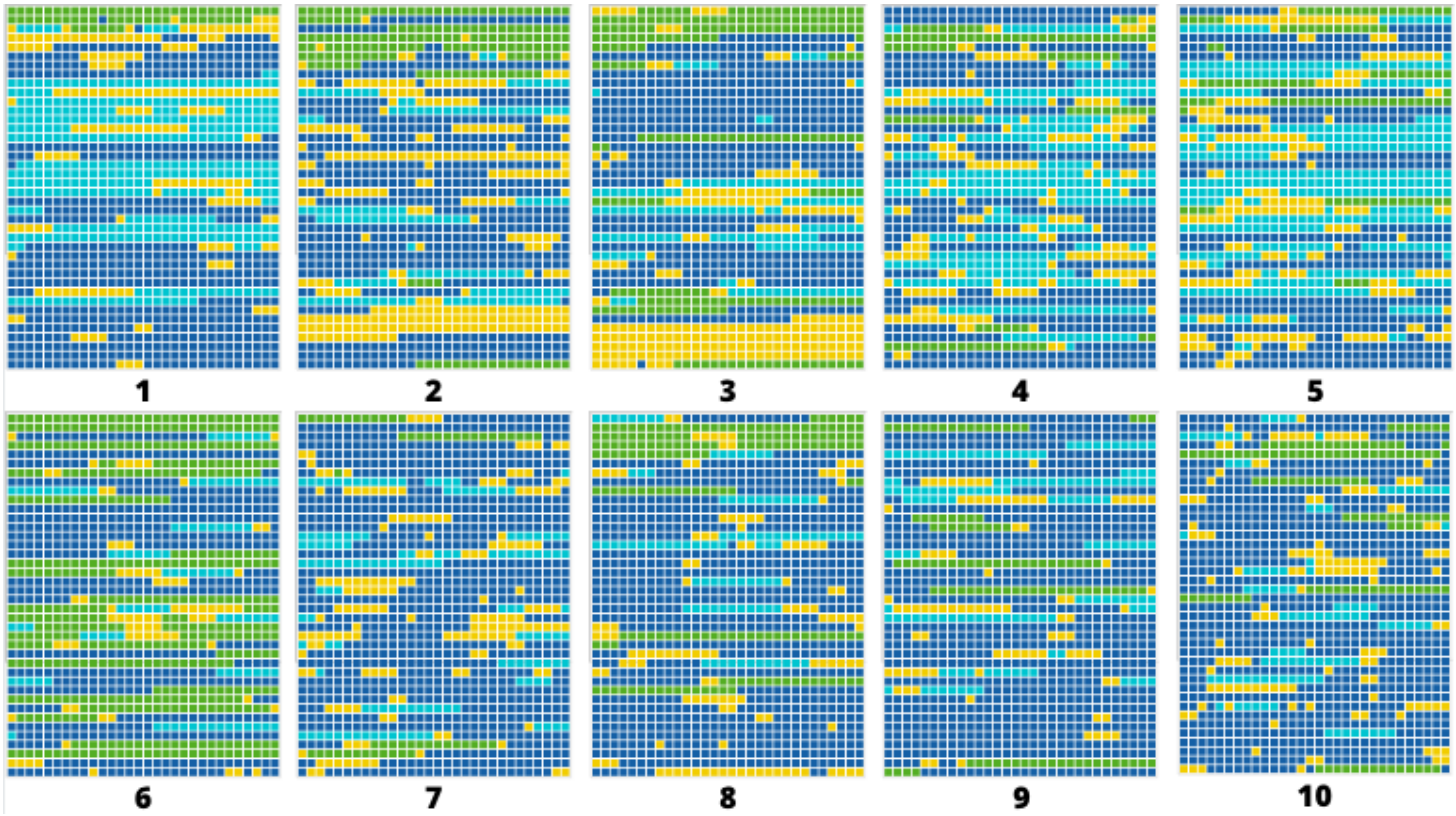

Figure 5: Document portraits of the ten most-cited papers in climate change and sustainability literature. These colour-coded visualizations show all of the codes, by category, in order of sequence and proportionally to how much they make up of all the coded segments. Yellow indicates setting, light blue indicates didactic information, dark blue indicates narrator presence, and green indicates framing.

4.2.1 Framing document portraits

Figure 6 illustrates the document portraits for all 10 of the analyzed documents, but instead of showing all of the codes, it visualizes the proportions of the positive and negative frames used. Here, green represents positive frames, hope and gain frames in particular, and red represents negative frames like fear and loss. Figure 6 clearly indicates that fear and loss frames are the most common frames used in the climate change and sustainability literature analyzed. Indeed, two out of the 10 papers use only fear and loss frames. When hope and gain frames are used, they are most often used to follow and counter a fear frame, illustrated in 6 out of 8 document portraits with hope frames.

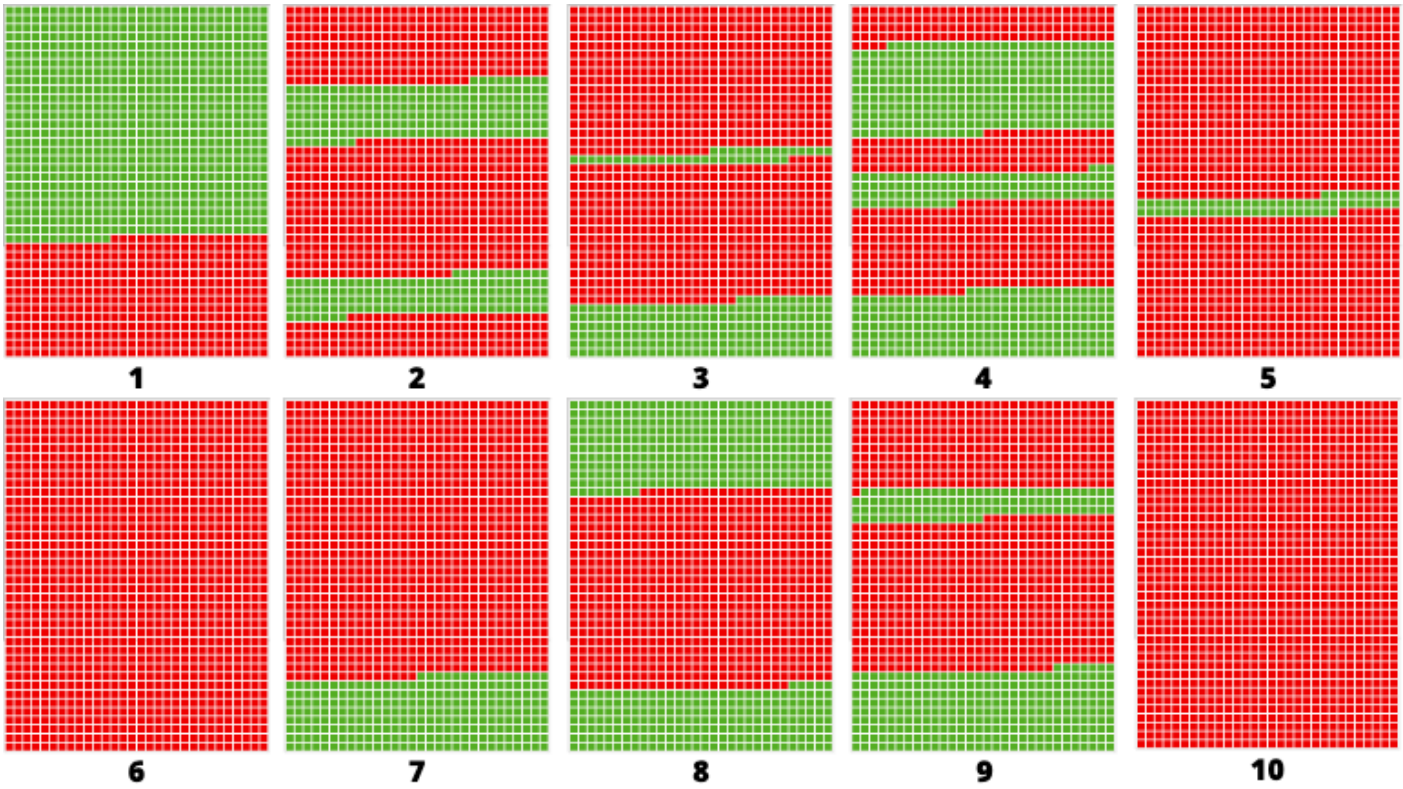

Figure 6: Document portraits of the framing used in the ten most-cited papers in climate change and sustainability literature. These colour-coded visualizations show all of the proportion of fear/loss frames in comparison to hope/gain frame. Red indicates fear/loss frames identified in the text and green indicates hope/gain frames identified.

5. Discussion

This research has delivered an in-depth profile of what narrative elements can be found in the most successful and influential works in climate change and sustainability literature. By exploring what types of narrative devices, temporal and spatial settings and frames are used in the most successful and influential works in this field, this study has revealed some general themes. Overall, we see topics discussed in terms of the future with their potential consequences and issues emphasized and explained on a global scale. These papers most often communicate the importance of their findings in response to the potential losses associated with inadequately mitigating climate change and portray the urgency of their research with images and descriptions that trigger fear. Often these fear frames, which capture the attention of the reader, are subsequently countered with hope frames associated with the beneficial potential of their findings.

The most consistent and frequent commonality within all 10 of the analyzed papers is the concentrated use of first person narrative. This finding is particularly interesting considering the prevailing notions of what is and is not acceptable in scientific writing. Generally, using first person pronouns is discouraged because it is believed that doing so would remove objectivity and give the impression that results or observations are unique to only the authors' perspective. Avoiding first-person narration is considered to be a way of maintaining an objective tone that would suggest that the study acquired minimal bias. I suggest here, with the support of my research, that this common practice should perhaps be reconsidered. Firstly, because such claims of objectivity suggest that the onus rests upon the writing and not the analysis. Framing ones' findings in third-person does not make the findings more objective; it only makes them sound as such to the reader. In scientific circles, the verdict regarding the objectivity of one's work should rely upon the content, not the transmission. Secondly, this study suggests

that the articles analyzed, which have acquired considerable clout in climate change and sustainability discourse, *do* impart knowledge in first-person and *have* as a result claimed recognition as some of the most notable works in academia.

Should we aim to model the communication of our own research to this template in an effort to join these notable works? Perhaps. With regards to climate change and sustainability, use of fear frames, countered by hope frames, and mentions of the future and global stage on which its looming impacts will occur, has proven to be an incredibly successful method of narration and communication. It is important to note, however, that this model will evolve as the acknowledgement of climate change-related dangers and urgencies become more tangible over time. The literature analyzed was from years 2002-2011, a time before mainstream climate activism and significant climate change-caused extreme weather events. Indeed, the fear tactics identified in these papers, may no longer be necessary once sea levels infiltrate coastal cities and more species, upon which we rely, go extinct.

5.1 Next steps

With regards to further research on this topic, there are a few areas of interest that require attention. First, in an effort to better the quality of this study and limit my own personal bias in my reading-based analysis, I would consider crowdsourcing the same tasks of analysis and drawing conclusions from the averages. Because narrative analysis is strongly influenced by what speaks out to the reader and individual readers can perceive narrativity quite differently, this step, collecting multiple judgements for each paper, would facilitate a means of quality-control. Another future pursuit following this thesis would be to configure an "average" document portrait that depicts a more descriptive image of what all 10 analyzed papers look like together. There may also be some benefit to including more articles in the analysis, however it should be noted that after the top 10 most-cited articles, there is to be some saturation expected in our findings.

6. Conclusion

Peer-reviewed scientific discourse has often been understood as a specific type of communication, excused from qualities of narrative and storytelling, a type of communication that we require in order to align our understanding of scientific concepts to our human experience of the world. In addition to existing work supporting that scientists engage readers and increase uptake when they incorporate narrative attributes into their writing styles (Hillier et al., 2016), this research has provided a detailed profile of what types of narrative have achieved this. By exploring the ways by which narrator presence is made known, the spatial and temporal scales in which topics are explicated, and the use of metaphor, analogies, and framing, this research provides insight as to what methods of communication have best overcome the cultural cognition barriers proposed by science communication research (Kahan et al., 2011; Lakoff, 2004). This study offers proof that perhaps climate science researchers should stop underestimating the power of narrative and start allowing their voices to be in closer proximity to their work, just like the most successful and influential authors in their field already have.

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Appendix A: "Climate Change" AND "Sustainability" search results from Scopus.

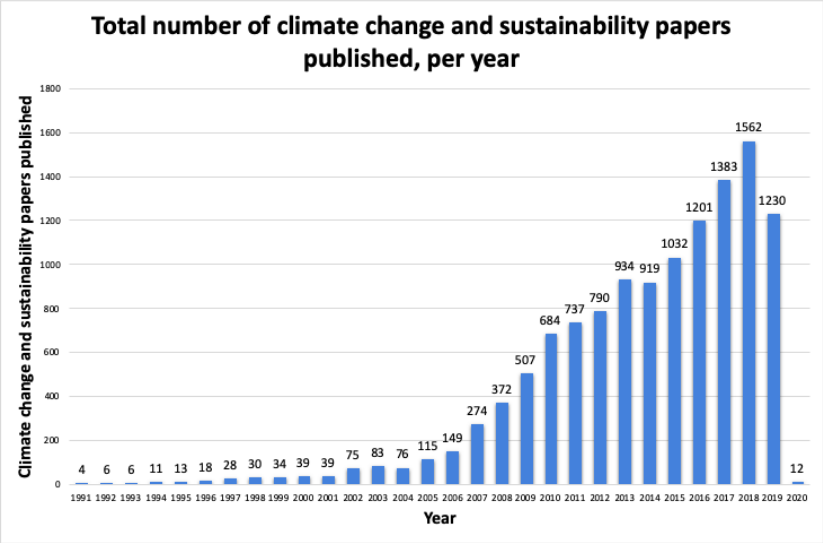

Figure 1: The total number of climate change and sustainability papers published per year from 1991 to 2020. This figure illustrates a significant rise in contributions to climate and sustainability research in the last decade. Since 2009, the number of papers published per year has approximately tripled. Note that the tapering off of publications in the years 2019 and 2020 is because many are still in the process of publication or need more time to circulate and be included in multiple databases. Data from Scopus.

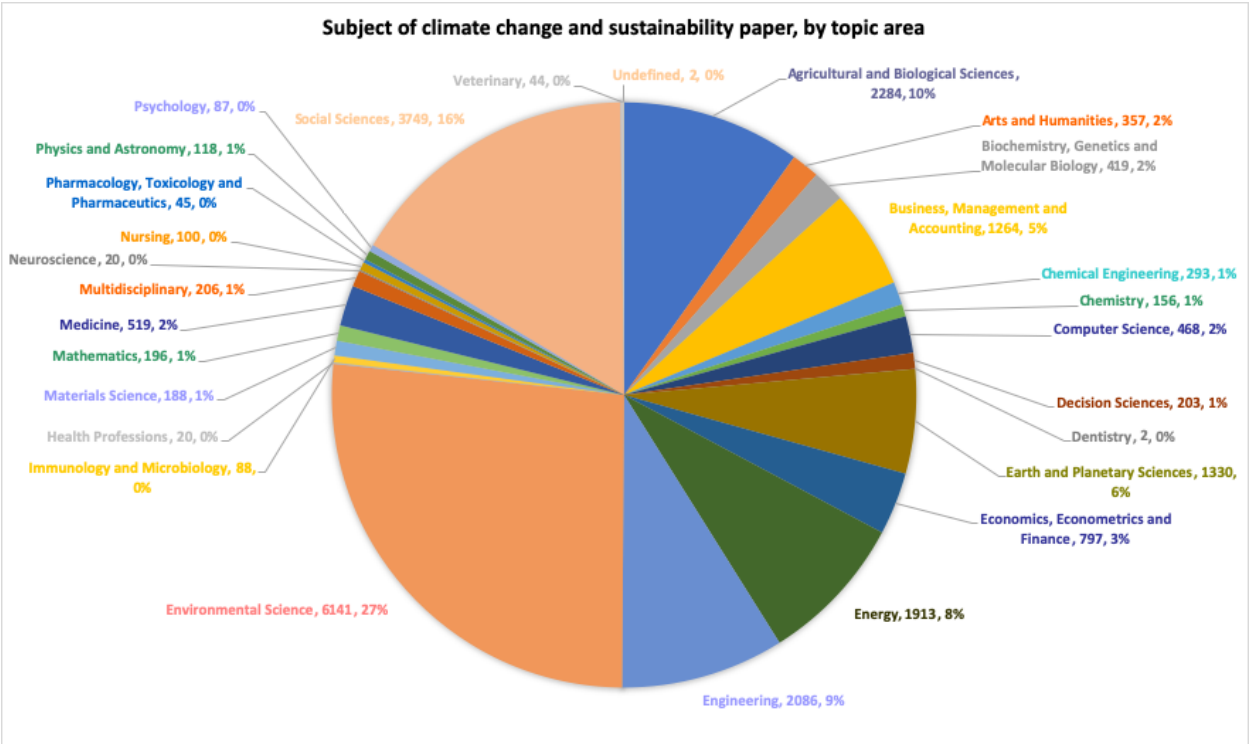

Figure 2: The subject areas of the climate change and sustainability papers by topic area. This figure illustrates that most of the papers relate to environmental science (27% of the papers), social sciences (16%), and agricultural and biological science (10%). But the search also renders papers from energy (8%), business, management and accounting (5%), and even dentistry (0%, or two papers). Data from Scopus.

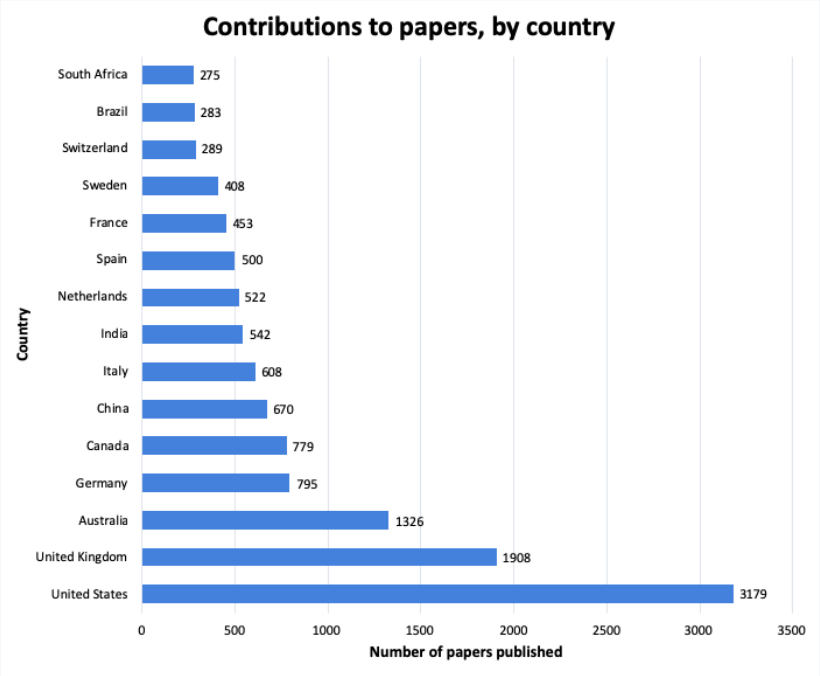

Figure 3: Contribution to total climate change and sustainability papers by country. This figure illustrates that researchers in the US, UK, and Australia are responsible for a large portion of the literature. Data from Scopus.

Figure 4: Top 100 most-cited papers, by journal. This figure illustrates that journal contribution to the top 100 is fairly evenly spread out, with high-impact journals like Science and Nature only accounting for 14% of the papers, while the 51 papers listed under "Other" are papers that only appeared once by many individual journals. Data from Scopus.

Figure 5: The top 10 most-cited papers in climate and sustainability literature. Data from Scopus.

Appendix B: 10 most-cited articles in climate change and sustainability literature

Ranking by citations	Title	Author(s)	Year of publication	Journal
1	The Path Forward for Biofuels and Biomaterials	Ragauskas, A. J.	2006	Science
2	Solutions for a cultivate planet	Foley et al.	2011	Nature
3	A safe operating space for humanity	Rockström et al.	2009	Nature
4	Successful adaptation to climate change across scales	Adger, N. W., Arnell, N. W., & Tompkins, E. L.	2005	Global Environmental Change
5	The emergence of land change science for global environmental change and sustainability	Turner, B. L., Lambin, E. F., & Reenberg, A.	2007	Proceedings of the National Academy of Sciences
6	A global synthesis reveals biodiversity loss as a major driver of ecosystem change	Hooper et al.	2012	Nature
7	Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet	Hoffert et al.	2002	Science
8	Sustainable biochar to mitigate global climate change	Woolf et al.	2010	Nature Communications
9	Adaptation, Plasticity, and Extinction in a Changing Environment: Towards a Predictive Theory	Chevin et al.	2010	PLoS Biology
10	Ecosystem services: From eye-opening metaphor to complexity blinder	Norgaard, R. B.	2010	Ecological Economics