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Dissertation/Project Coversheet

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Abstract

Human habitability has been explored in theoretical context till now. According to the recent IPCC report, several parts of the Earth will become uninhabitable by 2050. It is predicted that the barely liveable area of the world will increase from 1% to 20% in next 27 years (Muggah, 2022). NASA and IPCC have emphasised that climate change can be mitigated by reducing the release of greenhouse gases in atmosphere and adaptability can be enhanced by building flood defences, planning for higher temperatures, installing better drainage, and improving water storage and use (NASA, 2023). This paper studies the public perception of habitability in Brazil amidst changing climates. The research draws crucial insights like variance in willingness to live and leave an area based on climatic and non-climatic factors. Key findings of the research elicit the drivers of habitability as floods, landslides, droughts, heatwaves, low air humidity, employability, health services and safety. Public opinion of essentials to thrive is dominated by employment, stability, education, and mental health with little mention of necessities like food, water, land, etc. Brazilians majorly believe that transportation, sanitisation, health care need improvement while some respondents suggest afforestation and reducing fires to mitigate heat and improve air quality.

Keywords: Climate change; Risk Perception and communication; Climate Risk Narrative; Human Habitability; Drivers of human habitability.

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Exploring the limits of human habitability in Brazil and using stakeholder engagement to inform the development of Climate Risk Narratives.

Chapter 1 Introduction

1.1. Background

The maximum wet-bulb temperature to support life is 35-degree Celsius (95-degree Fahrenheit) which may drop to 25-degree Celsius (77-degree Fahrenheit) in humid regions and prolonged exposure to such high temperatures can cause death by hyperthermia (Earth Institute at Columbia University, 2020; Buis, 2022).

Several regions around the globe including South and Southeast Asia, Persian Gulf, Red Sea, Eastern China, and Brazil, are predicted to regularly cross temperatures of 35-degree Celsius within the next 30-50 years (Buis, 2022). However, the risk perception of climate change is not consistent with the steadily rising environment temperature. Studies in the US have reported a decline in the proportion of people considering climate change as a serious problem ((Weber, 2010); (Pew Research Center, 2009)). It may be because of the "boiling frog" effect where the people have become acclimatised to the gradually rising temperature and hence fail to identify the evidence of global warming (Cattani, et al., 2006). Several other factors may contribute to the beliefs of public regarding climate change. According to the construal level theory people tend to respond to those events that are psychologically less distant to them. Psychological distance may be temporal, social, hypothetical, or spatial ((Liberman & Trope, 2003); (Liberman & Trope, 2008)). For example, someone planning for a vacation a year in advance will vaguely plan about fun, relaxation, and entertainment whereas someone planning for a vacation in the next week will plan all minute details like booking travel tickets, accommodation, etc. Some argue that mere psychological distance from climate change is not enough to foster action in public and the judgement of a person depend on the level of fear for proximal climate issues and level of scepticism for distant climatic events (Brügger, et al., 2016). Amidst growing consensus among scientists that climate change is happening now, the public perceptions of climate change vary significantly. Thus, creating a gap between the expert reality and the conceptions of lay man of climate change.

While rising temperature is the most direct impact of climate change, it is not the only way in which global warming is affecting our lives. The global mean surface temperature of the earth has risen by 1.37 to 1.63 degree Celsius since the pre-industrial era where the last 8 years reached the record high temperatures, the global mean sea level is continuously rising by approximately 3.1 to 3.7 mm every year for the past 30 years due to ocean warming and melting glaciers, the global mean ocean PH is dropping due to excessive CO2 in the atmosphere while the absorbing capacity of oceans is limited leading to acidification of oceans causing death of sea organisms (World Meteorological Organization, 2022). This data is backed by satellite images suggesting 1 degree C rise in planet's average temperature, a rise in the global sea-level by 8 inches in the past century, melting icesheets in Antarctica, Greenland and Arctic Sea and an increase in the frequency of extreme weather events such as heat waves, cold spells and intense rainfall (NASA Global Climate Change, 2022). Abundance of evidence of global warming has awakened the world to analyse the current and futuristic climatic conditions around the globe stirring a sense of urgency to improve preparedness and educate the masses about the mitigation methods.

Migration is one of the coping mechanisms used to combat extreme weather events. Prior research indicates two types of climatic events triggering migration: (1) Slow-onset; events like drought and rising temperatures which gradually make people want to migrate (2) Fast-onset; events like floods, landslides, heavy rains that force people to migrate immediately (Cattaneo, et al., 2019). The World Meteorological Organization has identified droughts and floods as the key events that drove displacement of humans in 2022 as 9% of Pakistan was inundated, 7.2 million people displaced in Bangladesh due to floods and 1.2 million people were forced to relocate due to droughts in Somalia (World Meteorological Organization, 2022). It is estimated that 4.2M people will be required to relocate from the continental USA due to sea level rise by 2100 (Hauer, et al., 2016).

Despite growing literature highlighting the severity of climate change on human habitability across the world, research has shown that although people acknowledge the severity of climate change, they think that this is a problem of the distant future, and they will be unaffected by the adverse impacts of climate change ((McDonald, et al., 2015); (Nicholas & Nicholas, 2019); (Steentjes, et al., 2020)). Thus, there is growing research to understand how people perceive the risks of climate change and how they will be affected by the changing climate. For example, according to a recent news article, decrease in deforestation in the Amazonas region of Brazil is reported implying betterment (Buschschlüter & Watson, 2023). But do the citizens of Brazil consider deforestation as an issue strong enough to result in displacement from their current residence or do they understand why reduction in deforestation is important. Since, Amazonas have been threatened by deforestation for a long time, people might have become complacent and ignorant towards the issues.

This investigation aims to understand the key drivers that affect the choice of place of living in Brazil so that this information can be used to develop climate risk narratives to educate the people about the risks of climate change in terms of habitability.

1.2. Objective

Working in collaboration with the Met Office UK and CSSP Brazil, the main objective of this investigation is to elicit the key drivers of human habitability from a Brazilian public perspective and identify key weather and climate influences on human habitability in Brazil. This will then contribute to the development of Climate Risk Narratives for Brazil and guide further in depth focussed scientific research. The agenda of this research involves identifying which areas of Brazil will become uninhabitable and when.

1.3. Organization

This report consists of a literature review of existing work done in the climate risk perception and habitability and builds upon the finding from various regions of the world to provide an insight about what Brazilians consider important for habitability. The research is designed to analyse the willingness to live and willingness to leave an area and identify the major factors behind the migratory decisions and predict the perception of habitability in Brazil. The upcoming sections reflect upon the existing findings with respect to the factors affecting climatic risk perception, perception of necessary criteria of habitability and mitigation methods to combat climate change. The research gap is identified, and research questions are developed. The further sections describe the detailed method of data collection and some salient features of the questionnaire. The next section entails the analyses and supporting explanations. The results are presented in the following section which is followed by the discussion, limitations, and conclusions.

Chapter 2 Literature review

2.1. What is human habitability?

Human habitability in its broadest sense is defined as the suitability of an environment to support life (Méndez, et al., 2021). However, there is no standard definition of human habitability. Most researchers refer to the definition of habitability which considers a planet to be habitable if water can exist on the surface in liquid form (Kasting, et al., 1993). A planet is said to be habitable if it supports life for a significant period and liquid water, energy and nutrients are considered essentials for life (NASA Sellers Exoplanet Environments Collaboration - SEEC, 2023). Another study conceptualises the essentials for habitability by framing the definition as a balance between biological demands and potential of the environment to fulfil these demands (Hoehler, 2007). Hoehler lists the main requirement for habitability as raw material, energy to maintain the raw material in complex molecular form, solvent to help the complex molecules to interact with each other and environmental conditions that allow the complex molecules to persist and interact at appropriate rates. Horton et. al. (2021) defines human habitability as the environmental conditions that assist healthy human life, productive livelihoods, and sustainable intergenerational development.

Some researchers have identified five Habitability Pillars viz. (1) Land, (2) Freshwater, (3) Food or nutrition, (4) Settlements and infrastructure and (5) Economic activities (Duvat, et al., 2020). Contrarily, others argue that habitability is rather a contested concept as people may perceive habitability differently as per the factors that they consider to be most important which may be material or non-material aspects and influenced strongly by cultural and social norms (Farbotko & Campbell, 2022). However, there is lack of empirical data to prove this conceptual assumption.

Even though some literature review has conceptualised the necessary conditions for habitability, the existing literature lacks public elicitation of essentials of habitability. It is vital to understand what public considers important for liveability as it would greatly impact their decision of place of residence and hence will be important when designing effective risk communication strategies to educate people of dangers of uninhabitability.

2.2. Factors affecting climatic risk perception of people

Studies have shown that climatic risk perception depends on factors like, direct and indirect experiences, trust, and spatial differences (Wachinger, 2013). Various experiments have shown that the perception of climate change risk varies with the political orientation of people. For example, people who are more liberal are more concerned about environment and exhibit a higher attention to climate change thus depicting greater sensitivity to climate change stimuli leading to higher climate change risk. Psychologists refer to this extra attention to something due to pre-conceived beliefs as attentional bias and the resulting increased perception of risks to perceptual bias (Luo & Zhao, 2021). Other factors like prior knowledge about climate change, direct and indirect experiences with extreme weather events also amplify the climate risk perception of individuals (Wachinger, 2013).

2.2.1 Personal experiences

Strong positive correlations have been noted between past experiences and damages with future risk perceptions of floods storms and heat waves (Frondel, et al., 2017). A study reviewing 72 existing literatures concluded that personal experience with climatic hazards is the most impactful factor in predicting risk perception in mountain regions (Schneiderbauer, et al., 2021). On one hand literature suggests that experience has a positive effect on adaptive behaviour like improving infrastructure to combat flooding, on the other hand, some studies highlight negative or no effect on mitigating behaviour due to loss of financial abilities (Orlove, et al., 2020). Furthermore, it is also found that when people have witnessed an event and have survived, it is possible that they undermine the risks associated with those events as familiarity with an event without experiencing any negative consequences reduces the riskiness of the event (Fischhoff, et al., 1978).

2.2.2. Indirect experience - Media coverage

Studies have shown that environmental hazard risk perception is low in countries like Hungary where media reports fewer domestic climatic hazards while risk perception is high in USA where the media actively presents climatic disasters (Englander et al., 1986). This behaviour of humans can be explained by the availability heuristic (Tversky & Kahneman, 1973) which refers to the mental shortcut developed by humans to rely on the most recent or readily available information to make judgements. Thus, heavy coverage of climate change and climate disasters in the media leads to indirect visual experience of hazards which affects the risk perception positively. Societal norms also greatly influence the perception of climate change risk. Political inclination towards party that supports environmental agenda increase risk perception in Germany (Frondel, et al., 2017).

2.2.3 Demographic factors

A study in Mexico indicates a relationship between social identity like age, education, and prior knowledge and perceptions of risk (Frank, et al., 2011). According to recent UN article, climate change has impacted women's livelihoods significantly in the Asia-pacific region (Emandi, et al., 2022). More than half of the women in Asia-pacific region work in fisheries, agriculture, and forestry which are directly impacted changing climate, yet women are underrepresented in the ministries. Use of unclean fuels directly affects the quality of air at home thus exposing women to the hazards of air pollution directly. It is found that there is a correlation between increase in the rate of child marriages in some arid regions and the frequency of drought episodes. In several underdeveloped areas where there is lack of multi-hazard early warning systems the primary mode of obtaining meteorological warnings is the internet (UN Women, 2022). However, it is noted that women are less likely to be internet users in certain regions. Furthermore, and additional loss is suffered by women in underdeveloped areas apart from the loss of lives of family members in terms of poverty as women do not have the right to inherit land or property. (UN Women, 2022). In a study conducted in Africa, gender and higher education were non-significant predictors for risk perception but were significant predictors for behavioural willingness (Xie, et al., 2019.). Another study in Uganda has found that floods have a positive effect on Man's land accumulation while droughts have a negative effect on women's non-land holdings (Goh, 2012). Although, these findings are strongly bound to certain areas, there is a need to evaluate other possible ways in which different genders and age groups can be affected by climate change. Studies have shown that people are more likely to assess flood risks greater in flood prone areas ((Hung et al., 2007); (Brilly & Polic, 2005); (Ruin, et al., 2007)). Assessing role of location in habitability perception can be fruitful in Brazil as there are arid regions and urban areas with intense rainfall.

2.1.4. Psychological Factors

Several studies have reported that trust is strongly correlated with risk perception when people's knowledge is limited (Siegrist, 2019). People who believe that they can control the adverse impacts of climatic events rate the risk of those events as low. However, high risk perception and personal experience of climatic hazard may not be enough to foster adaptation in people (Frank, et al., 2011). This gap between risk perception and action is confirmed by several studies.

2.3. Mitigation methods

A survey conducted in Houston and Portland has shown that virtually all participants (92% and 80%) were aware of climate change and the majority (47% and 63% of them agree to adopt mitigation methods like reducing electricity usage. However, out of the proportion of sample admitted to not using any mitigation methods, the most common reason was not knowing how to change behaviour. Similarly, Siegrist and Gutscher argue that the gap between risk perception and action could be because they "did not know what to do?". Such paradoxical behaviour of people accepting the risks of climate change but not indulging in corrective behaviours is explained by reasons like psychometric paradigm of risk where people tend to trade the climatic risks prevalent in an area with other gains like income, transfer of responsibility of action to someone else and a lack of resources.

Most prior literature has asserted that there is significant positive correlation between personal experience of floods and mitigation behaviour. Contrarily, some research shows weak positive correlation (Thieken et al. et al.) while some show no intent (Botzen et al.) to adopt mitigation measures despite high level of risk perception (Bubeck, et al., 2012). Although a large amount of research has focused on whether people will adopt mitigation methods, there is not enough evidence indicating whether people understand that mitigation is possible and how it can be achieved. Existing literature is also mostly confined to climate related mitigation methods whereas, it has been established through several studies that the decision of migration rarely only depends on climatic factors. It is indeed a combination of multiple factors including economy, safety, infrastructure, political stability and so on. This paper attempts to identify the awareness levels of public of Brazil regarding possibility of mitigation methods and through open-ended questionnaire aims to elicit what people think can improve habitability of their state in general. This allows for a comprehensive comparison between the climatic and not-climatic factors responsible for uninhabitability of a region.

2.4. Literature gap

The existent literature provides several conceptual models of essentials for habitability. However, there is no significant research done to understand the factors that are considered essential for habitability by lay public. It is important to understand what might drive mobility of people from their current location or what factors people would weigh highest when deciding a habitat.

While existing literature has touched upon the necessity of adopting mitigation methods to dampen the impacts of climate change, the work assumes that people believe that climatic impacts can be mitigated. Further, non-climatic factors which are recognised as more prominent drivers of migration are ignored. It will be interesting to know if people understand what might improve the habitability of an area irrespective of climatic or non-climatic factors as some non-climatic factors are indeed indirect consequences of climatic events. For example, floods may cause damage to infrastructure. People might consider infrastructure to be an essential for life, and yet be unaware that floods can be mitigated by better preparedness and curbing the amount of greenhouse gas emission into the atmosphere.

Although, existing literature has identified that risk perceptions affect the adaptation and mitigation actions, least proportion of the literature has explored the communication methods of climate risks to enhance sensitivity and encourage mitigation actions (Schneiderbauer, et al., 2021). Stakeholder engagement has been suggested by some researchers as an effective technique to generate effective risk communications for climate change ((Sprengel & Busch, 2011); (Gardner, et al., 2009)). This paper draws upon this idea and lays a foundation for developing Climate Risk Narratives in a subsequent project to inform the public in a fun and engaging way.

Past research in parts of Brazil has indicated high migration rates from the northeast to the southeast are a result of long periods of droughts and better labour opportunities (Barbieri & Confalonieri, 2011). The North Region of Brazil is one of the five political subdivisions of Brazil. This region is formed of seven states: Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins. Few climate risk perception studies have also been conducted in certain parts of Brazil ((Ardaya, et al., 2017); (Albuquerque, et al., 2023)). However, not much work has been done for overall Brazil in the context of migration due to climate change.

2.5. Research Questions

Aligning with the objective of this research designed by the MetOffice to elicit the perceived essential factors for habitability of inhabitants of Brazil and to determine whether people know how the liveability can be improved, the following research questions are broadly analysed in this paper.

1. What is essential in terms of human habitability for Brazilians?
2. What could improve human habitability as per the public of Brazil?

People may choose their place of living based on various factors which may or may not be climatic. There are two possible dimensions of what people consider essential for human habitability. First, the push factors: specific factors that affect the willingness of people to leave their current residence. For example, questions that ask how much a particular factor like floods or lack of income opportunities makes someone want to leave their current location? Second, pull factors: specific factors that affect the decision to choose a place of living or the willingness live in an area. Thus, the research questions can be specifically improvised as follows:

1. What factors affect the willingness to live in terms of human habitability for Brazilians?
2. What factors affect the willingness to leave in terms of human habitability for Brazilians?
3. What people think could improve human habitability in Brazil?

Chapter 3 Method

3.1. Data

Working with the Met Office and CSSP Brazil, data was collected from Brazil through questionnaire designed to encourage stakeholder participation in development of Climate Risk Narratives to inform public of the risks associated with uninhabitability of regions in Brazil due to changing climate. A total of 178 responses was received across seventeen states of Brazil.

3.2. Participants

178 respondents across seventeen states of Brazil participated in the survey with most responses from urban areas like Sao Paulo (83), Rio de Janeiro (18) and Minas Gerais (15). The age of respondents was above 18 years with most respondents (38) in the range of 45 – 54 years of age. The gender distribution indicates 63.3% Females and 35.5% Males. There are 77 Whites 16 Browns and 5 Blacks and 1 Yellow among the respondents. The sample is a convenience sample where the responses were collected online through questionnaires.

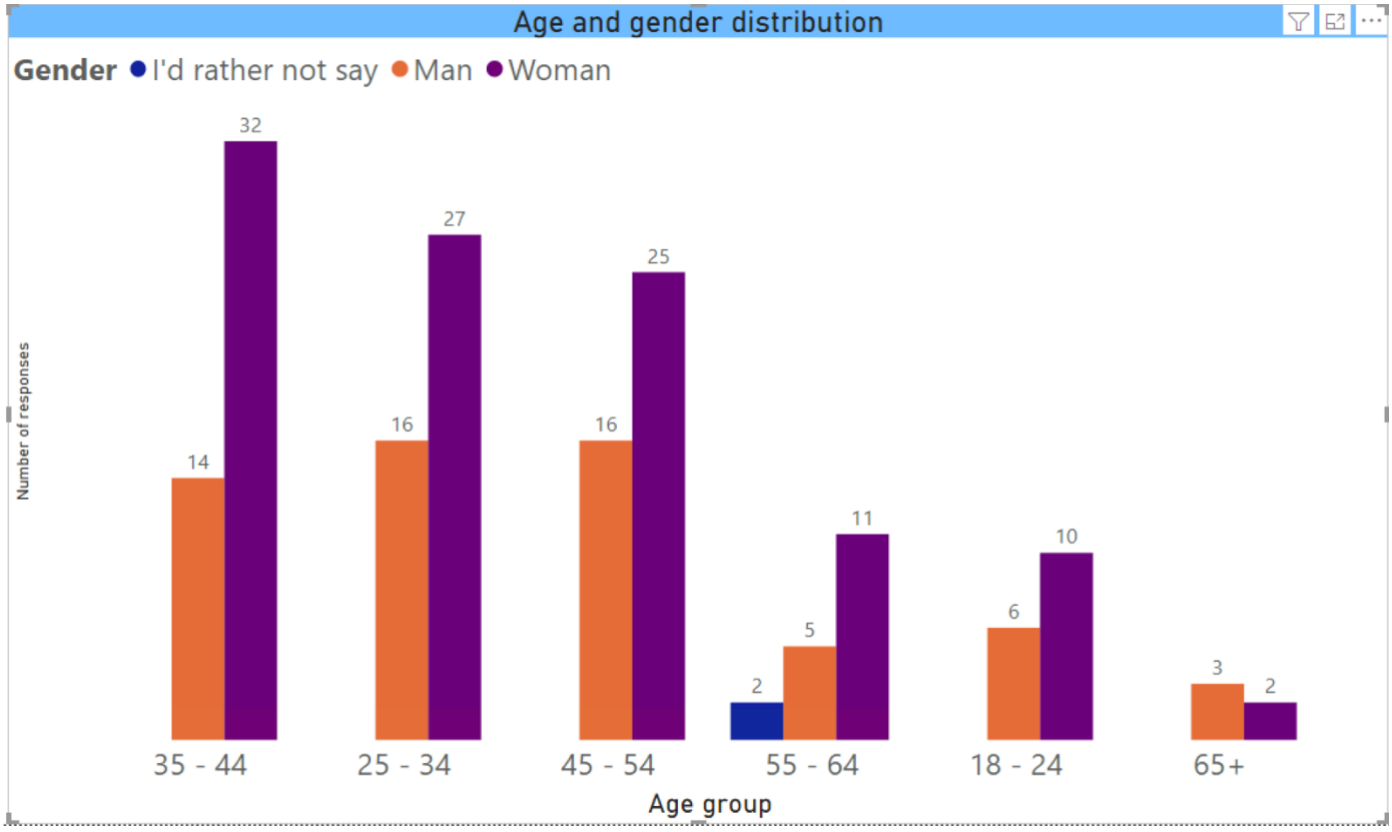

Figure 3.1 Gender and age distribution.

Figure 3.2 Heatmap showing concentration of responses in urban states of Brazil.

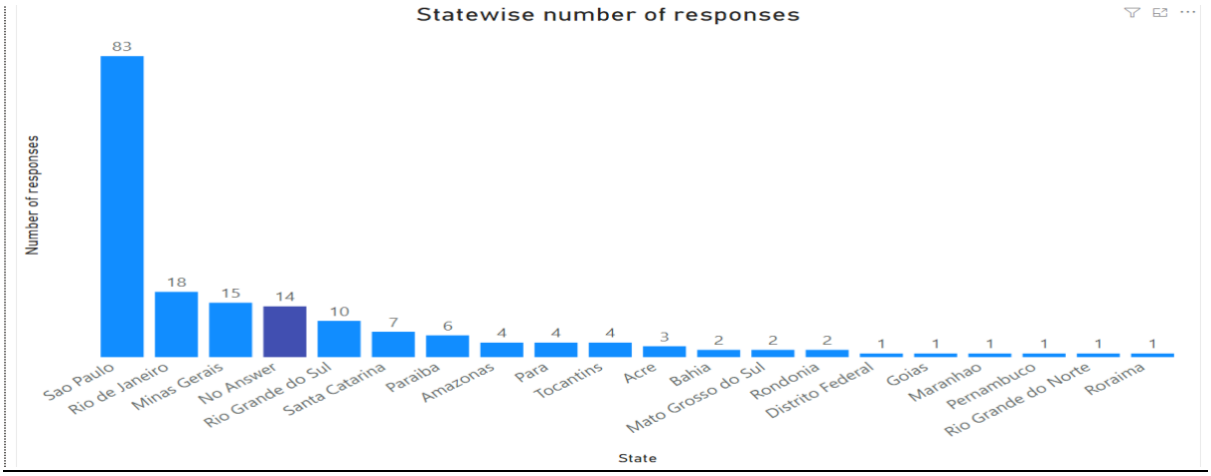

Figure 3.3 State wise responses.

3.3. Questionnaire design

The questionnaire is designed to obtain a maximum stakeholder participation to develop effective communication strategy for apprising the public with the risks of uninhabitability associated with climate change. The questionnaire is divided into five logical parts where part 1 plainly states the objective and importance of the survey while providing least information to avoid the anchoring effects in the responses. Part 2 captures the consent of respondents, part 3 pertains with the human habitability questions. Part 4 asks open-ended questions to encourage public to think about the most impactful events they remember and how those events have impacted their daily lives. The next section asks more generic open-ended questions like "What do you need to thrive?" so that people have the freedom to record their thoughts about essentials for habitability without any constraints (Questionnaire).

3.4. Likert scale

The questionnaire uses 5- and 7-point Likert scales to assess the level of impact of various climatic and non-climatic factors and degree of willingness to choose a place of living. These questions attempt to establish the psychological distance of humans to the impacts of weather disasters in order create Climate Risk Narratives that will bridge the gap between the expert model and lay model of climate change risk perception.

3.5. Open ended questions

Public elicitation research is based on the idea of understanding what people already know about the topic. This is a significant step in the mental model approach (Johnson-Laird, 1983) which compares the lay-man's knowledge with the expert model of appropriate facts and designs a suitable communication to improve the understanding of public or provoke necessary actions. While MCQ type questions are useful in determining the most sought options among a group of options that the surveyors think is important, they deprive the respondents from adding new diverse perspectives to the research. Open-ended questions allow respondent to uncover useful insights that the survey designers may have missed or may have been unaware of while crafting the questionnaire with closed-ended questions (Tourangeau, et al., 2000).

Chapter 4 Methodology

4.1 Analysis 1: Variable reduction.

The questionnaire gathers scores of willingness to live and willingness to leave based on 25 different factors like "No jobs", "Droughts", "Floods", etc. To simplify the analyses and draw logical interpretations, these variables were reduced using factor reduction. There are two prominent ways of reducing dimensionality in a diverse dataset; FA and PCA. FA or Factor Analysis estimates the theoretical underlying structure of a group of variable based on mathematical models accounting for only the shared variance whereas PCA or Principal Component Analysis is a variable reduction technique that converts a larger set of variables into a smaller set of linear uncorrelated components where all the variance among the original variables is completely used (Pallant, 2016). With an aim to utilize the all the variance in the variables, PCA was selected to reduce the 25 variables. The survey questions 13 and 18 (Questionnaire) were used to obtain the reduced variable structure.

4.2 Dividing spatial zones.

The responses are spread across 17 states of Brazil with most states having number of responses in single digits. To preserve the analytical strength of the data during the analyses while adhering to the Met Office's requirement of state wise insights, the dataset was divided into five spatial zones; zone 1: Sao Paulo, Zone 2: Rio de Janeiro, Zone 3: Minas Gerais, Zone 4: Rest of Brazil, Zone 5: Overall Brazil. The survey question 8 (Questionnaire) was used for this.

4.3 Analysis 2: Identifying the key drivers for willingness scores.

The responses to the questions "Imagine experiencing each of the following events. For each event, please indicate how much this would make you want/need to leave the region where you currently live (or are answering for)" collected on a 5-point Likert scale and "Which of the following weather and climate events could affect your decision about where you might want to live?" collected on a 7-point Likert scale were used to analyse the key drivers of willingness scores wanting to leave an area or live in an area. To understand the difference in the mean willingness scores for various factors One-way repeated measures ANOVA was used on the five components derived from PCA for each of the four spatial zones. For zone 5 (overall Brazil), the component loadings were used to get an idea of the most impactful events within a component. The survey questions 13 and 18 (Questionnaire) were used to identify the most significant factors affecting the decision to choose place of living or migrate.

4.4 Analysis 3: Variance in the willingness scores among the slow onset, fast onset, and non-climatic factors.

One-way repeated measures ANOVA was performed to find if there is a significant difference between the willingness scores based on whether the event is slow onset climatic event, fast onset climatic event or non-climatic factor.

4.5. Analysis 4: Does the willingness to leave depend on the way in which people are impacted?

Regressions are widely used to determine relationships between variables and estimate the effect of predictor variables on a dependent variable in data due to simplicity and interpretability (IBM). Based on the type of data various types of regressions can be used. Usually, the best suited method for categorical responses on a Likert scale is logistic regression. However, this requires the data to be collected on same scales. Due to the disparity in the scales used for the different questions in questionnaire, it was decided to convert the 5-point and 7-point Likert responses to a percentage scale. Thus, the rescaled scores were on the same scale to support regression analyses. The percentage scale and the composite scores obtained from PCA after variable reduction caused the values to become rather continuous. Hence, linear regression was chosen to determine if there is any relation between the readiness of people to leave an area and the way in which they are impacted. The questions 13 and 17 from the questionnaire (Questionnaire) were used to identify the predictors

4.6. Analysis 5: Analysing open ended questions.

The questionnaire gathers the responses to open-ended questions that provoke the respondents to record their thoughts on what they consider essential for habitability and how the conditions can be improved, in their own words to allow elicitation of the key terminologies used by the public. These terminologies will be used to develop Climate Risk Narratives in a subsequent project. The tm library in R along with other relevant libraries was used to identify major themes in the responses. The similar themes were then grouped together, and the frequency of themes was updated. The open-ended questions 20-23 (Questionnaire) were used to analyse the themes and sentiment.

4.7. Analysis 6: Analysing difference in the willingness scores based on push or pull factors.

With an aim to understand whether the mean willingness scores differ between willingness to leave and willingness to live for similar factors like experiencing droughts, floods, landslides and other slow onset or fast onset climatic events, multiple paired samples t-tests were conducted. Paired samples t-test are a simple way to understand if the means of two samples are significantly different to each other or not. The survey questions 13 and 18 (Questionnaire) were used.

4.8 Analysis 7: Demographic factors affecting perception of habitability.

Two way between-groups ANOVA was used to determine any significant variance between 6 age-groups and 3 genders in the dataset as it is a well-established robust method with high statistical power. It can detect variance a dependent variable influenced by two categorical variables. Hence, the coded categorical variables age and gender were used against the willingness to live and willingness to leave for slow onset and fast onset climatic events, non-climatic factors. The survey questions 13, 18, 24 and 25 (Questionnaire) were used.

Chapter 5 Results

5.1. Analysis 1: Principal Component Analysis.

The 13 items of willingness to leave for climatic factors, 4 items for willingness to leave for non-climatic factors and 8 items of willingness to live were subjected to separate Principal Component Analyses using SPSS version 29. Prior to the PCA the suitability of data was assessed by checking the correlation coefficients. The correlation matrix depicted several coefficients above 0.3. The Kaiser-Meyer Olkin values for the tests were 0.878, 0.803 and 0.892 respectively which were greater than the recommended value 0.6 (Kaiser 1970, 1974) and Bartlett's Test of Sphericity (Bartlett, 1954) was statistically significant (<0.01) suggesting factorability of the variables. The analyses uncovered five coherent groups namely "willingness to live for slow onset climatic events", "willingness to live for fast onset climatic events", "willingness to leave for slow onset climatic events", "willingness to leave to fast onset climatic events" and "willingness to leave for non-climatic factors".

PCA 1: Willingness to leave for climatic factors.

67% of the variance was explained by two components and the scree plot suggested a possibility of 2-3 components with a clear break at 2. Using three components caused just two factors (cold spell and storm surge) to be pushed to a third component. Using two components the variables could be grouped into logically coherent groups of climatic events causing immediate displacement and long-term climatic events gradually affecting the choice of relocation. Thus, for simplicity and logical coherence, two components were chosen and named "willingness to leave for slow onset climatic events" and "willingness to leave for fast onset climatic events". Varimax rotation was used to avoid dual loading.

	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	6.997	53.826	53.826
2	1.649	12.687	66.513
3	1.117	8.592	75.105
4	.632	4.865	79.970
5	.490	3.772	83.742
6	.452	3.478	87.220
7	.410	3.157	90.378
8	.352	2.711	93.089
9	.291	2.238	95.327
10	.208	1.603	96.930
11	.199	1.530	98.460
12	.103	.795	99.255
13	.097	.745	100.000

Table 5.1 Variance for willingness to leave for climatic factors. (Refer appendix D)

	Component	
	1	2
LEAVE_BadAirQuality	.630	.439
LEAVE_TooManyExtremeWeatherEvents	.520	.554
LEAVE_TooHot	.870	.194
LEAVE_TooDry	.896	.216
LEAVE_TooWet	.722	.276
LEAVE_Windstorms	.707	.416
LEAVE_RiverFlooding	.331	.819
LEAVE_FlashFlooding	.316	.822
LEAVE_StormSurge	.143	.707
LEAVE_Landslides	.127	.884
LEAVE_Wildfires	.352	.731
LEAVE_ColdSpell	.602	.170
LEAVE_LowAirHumidity	.782	.173

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 3 iterations.

Table 5.2 Rotated component matrix.

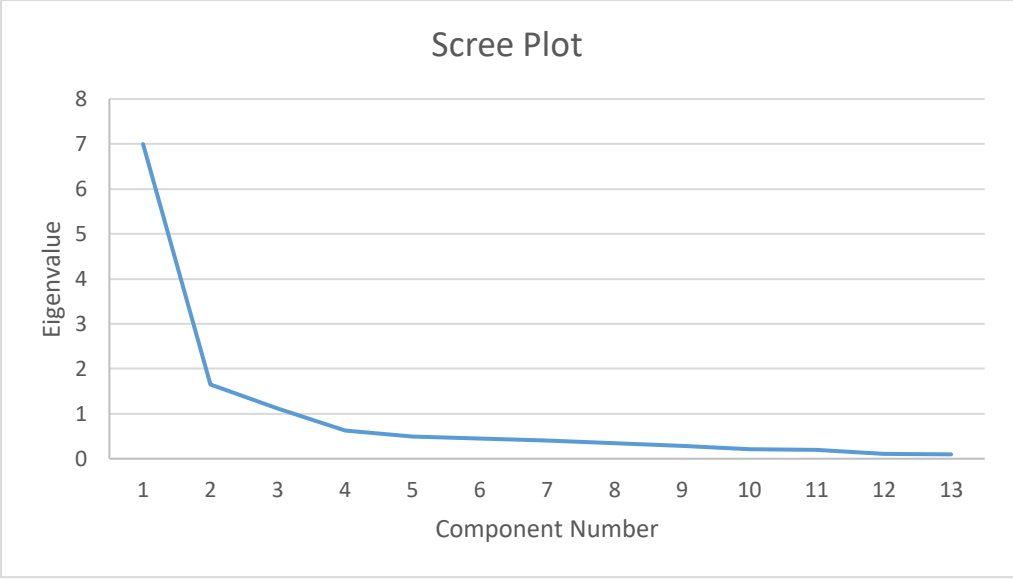

Figure 5.1 Scree plot for willingness to leave.

PCA 2: Willingness to live for climatic factors.

Based on Eigen values, one component was best suited for the willingness to live for climatic events. 71.475% of the total variance was explained by a single component and two components explained 80.352% of variance. The scree plot suggested 1-2 components. To maintain similarity with the logic of slow onset events and fast onset events, two components were selected with varimax rotation, and the following structure was obtained. As evident, similar climatic events like drought, intense rainfall, heatwaves, windstorms, low air humidity were grouped into the slow onset component and events like flooding, landslides and wildfires were grouped into fast onset component in both PCA for willingness to live and willingness to leave bolstering the appropriateness of the structure.

	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	5.718	71.475	71.475
2	.710	8.877	80.352
3	.438	5.481	85.833
4	.354	4.429	90.262
5	.301	3.767	94.029
6	.211	2.636	96.665
7	.153	1.913	98.577
8	.114	1.423	100.000

Table 5.3 Variance for Willingness to live. (Refer appendix D)

	Component	
	1	2
LIVE_Flooding	.872	.334
LIVE_Drought	.579	.661
LIVE_IntenseRainfall	.503	.665
LIVE_Heatwaves	.437	.778
LIVE_Landslides	.907	.296
LIVE_Wildfires	.762	.453
LIVE_Windstorms	.558	.654
LIVE_LowAirHumidity	.193	.905

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]
a. Rotation converged in 3 iterations.

Table 5.4 Rotated Component Matrix for willingness to live.

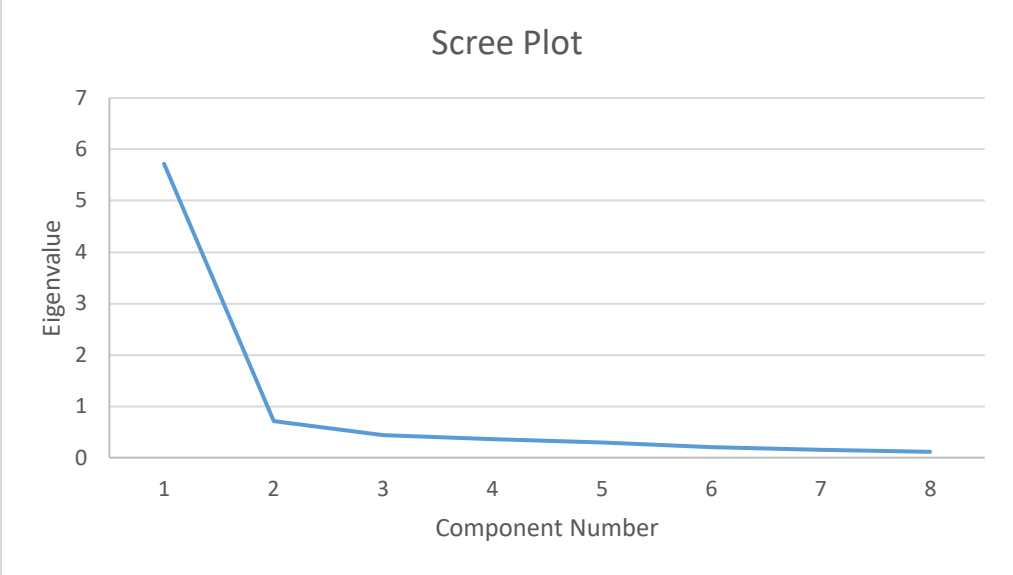

Figure 5.2 Scree plot for Willingness to live.

PCA 3: Willingness to leave for non-climatic factors.

The four non-climatic factors (No jobs, not safe, no health service and negative political situation) assessing the willingness to leave, were subjected to a PCA which resulted in a single component, based on eigen values, that explained 68.425% of the total variance. The scree plot clearly indicated 1 component as the best outcome with a sharp bend. Thus, the component was retained and named "willingness to leave for non-climatic factors"

	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	2.737	68.425	68.425
2	.540	13.504	81.929
3	.445	11.136	93.065
4	.277	6.935	100.000

Table 5.5 Variance for willingness to leave for non-climatic factors. (Refer appendix D)

Component Matrix[a]

	Component 1
LEAVE_NoJobs	.788
LEAVE_NotSafe	.866
LEAVE_NoHealthService	.879
LEAVE_NegativePolitical Situation	.771

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Table 5.6 Component matrix for willingness to leave for non-climatic factors.

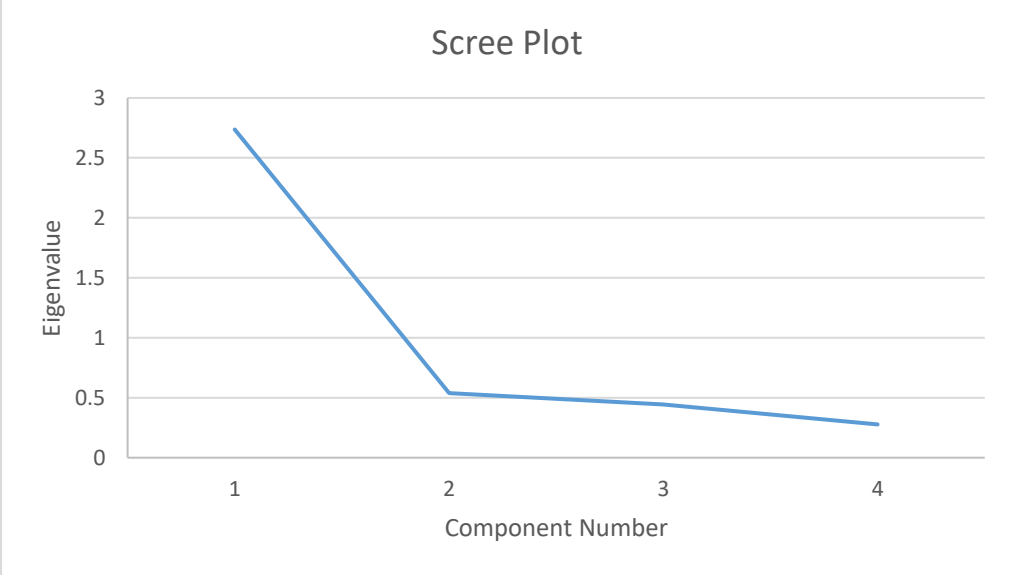

Figure 5.3 Scree plot for willingness to leave for non-climatic factors.

The following tables provide an overview the structure thus obtained (PCA Output).

Willingness to leave for fast onset climatic events.	**Willingness to leave for slow onset climatic events.**	**Willingness to Live for fast onset climatic events.**	**Willingness to live for slow onset climatic events.**	**Willingness to leave for non-climatic factors.**
Too many extreme weather conditions	Bad air quality	Flooding	Drought	No Jobs
River flooding	Too hot	Landslides	Intense rainfall	Not safe
Flash flooding	Too dry	Wildfires	Heatwaves	No health service
Storm surge	Too wet		Windstorms	Negative political situation
Landslides	Windstorms		Low air humidity	
Wildfires	Cold spell			
	Low air humidity			

Table 5.7 Reduced variables post Principal Component Analysis.

5.2. Analysis 2: Key driver elicitation.

5.2.1. Overall

The component loadings were assessed which imparted an idea of the key drivers of willingness to live and leave scores among the various climatic and non-climatic factors for the overall dataset including all states of Brazil. The top factors affecting the willingness to leave among fast onset climatic events were landslides (0.884), flash flooding (0.882) and river flooding (0.819). Among the slow onset climatic events, too dry (0.896), too hot (0.870), and low air humidity (0.782) were the major drivers. As for the non-climatic factors,

no health service (0.879) and not safe (0.866) were the top drivers. Whereas the key drivers for willingness to live were low air humidity (0.905) and heatwaves (0.778) for slow onset climatic events while landslide (0.907) and floods (0.872) for fast onset climatic events.

5.2.2. Key drivers in Sao Paulo.

A one-way repeated measures ANOVA was conducted to compare scores on the willingness to Live for the three fast-onset climatic events; (1) Flooding, (2) Landslides, and (3) Wildfires. The means and standard deviations are presented in Table 1. There was a significant moderate effect of event type, Wilks' Lambda = .88, F (2, 77) = 5.247, p = .007, multivariate partial eta squared = 0.12.

	Mean	Std. Deviation	N
LIVE_Flooding	5.75	1.951	79
LIVE_Landslides	5.66	1.894	79
LIVE_Wildfires	5.32	1.878	79

Table 5.8 Willingness to live for fast onset climatic events.

The major driver for willingness to live for fast onset climatic events were Flooding and Landslides. The pairwise comparisons (See table 2) suggest that the mean difference is not significant between Flooding and Landslides implying both these events almost equally drive the willingness to live for fast onset events in Sao Paulo. While the willingness to live for wildfires is significantly lower than landslides and floods implying a lesser contribution to the willingness score.

FastOnsetClimaticEvents	**FastOnsetClimaticEvents**	**Mean Difference**	**Sig.**
1 Flooding	2 Landslides	.089	1.000
	3 Wildfires	.430*	.009
2 Landslides	1 Flooding	-.089	1.000
	3 Wildfires	.342*	.010
3 Wildfires	1 Flooding	-.430*	.009
	2 Landslides	-.342*	.010

Table 5.9 Pairwise comparisons

One-way repeated measures ANOVA for willingness to live for slow onset climatic events suggests that Drought, Intense rainfall, Heatwaves, and Windstorms almost equally drive the willingness to live for slow onset events in Sau Paulo as the mean difference among these variables is not significant. The weakest driver among the slow onset climatic events was Low-air humidity. There was a significant large effect of event type, Wilks' Lambda = .721, F (4, 71) = 6.881, p < 0.001, multivariate partial eta squared = 0.279. The tables below depict the variances in willingness scores across the slow onset events.

	Mean	Std. Deviation	N
LIVE_Drought	4.77	1.850	75
LIVE_IntenseRainfall	4.67	2.009	75
LIVE_Windstorms	4.64	1.963	75
LIVE_Heatwaves	4.63	1.844	75
LIVE_LowAirHumidity	3.99	1.797	75

Table 5.10 Willingness to live for slow onset events in Sao Paulo.

SlowOnsetClimaticEvents	SlowOnsetClimaticEvents	Mean Difference	Sig.b
1 LIVE_Drought	2 LIVE_IntenseRainfall	.107	1.000
	3 LIVE_Heatwaves	.147	1.000
	4 LIVE_Windstorms	.133	1.000
	5 LIVE_LowAirHumidity	.787*	<.001
2 LIVE_IntenseRainfall	1 LIVE_Drought	-.107	1.000
	3 LIVE_Heatwaves	.040	1.000
	4 LIVE_Windstorms	.027	1.000
	5 LIVE_LowAirHumidity	.680*	.001
3 LIVE_Heatwaves	1 LIVE_Drought	-.147	1.000
	2 LIVE_IntenseRainfall	-.040	1.000
	4 LIVE_Windstorms	-.013	1.000
	5 LIVE_LowAirHumidity	.640*	<.001
4 LIVE_Windstorms	1 LIVE_Drought	-.133	1.000
	2 LIVE_IntenseRainfall	-.027	1.000
	3 LIVE_Heatwaves	.013	1.000
	5 LIVE_LowAirHumidity	.653*	.003
5 LIVE_LowAirHumidity	1 LIVE_Drought	-.787*	<.001
	2 LIVE_IntenseRainfall	-.680*	.001
	3 LIVE_Heatwaves	-.640*	<.001
	4 LIVE_Windstorms	-.653*	.003

Table 5.11 Pairwise Comparisons

The willingness to leave for fast onset and slow onset events is as follows.

Among the fast onset events, Flash flooding and River flooding majorly drive the willingness to leave while Bad Air Quality, Too Dry and Too Hot are the key drivers among slow onset climatic events. The weakest factors among fast onset and slow onset events were Storm surge and cold spell respectively. There was a significant large effect of event type, Wilks' Lambda = .516, $F(2, 77) = 11.803$, $p < 0.001$, multivariate partial eta squared = 0.484.
The following tables show the means and mean differences statistics.

Descriptive Statistics

	Mean	Std. Deviation	N
LEAVE_FlashFlooding	3.75	1.250	68
LEAVE_RiverFlooding	3.66	1.265	68
LEAVE_TooManyExtremeWeatherEvents	3.54	1.239	68
LEAVE_Landslides	3.40	1.437	68
LEAVE_Wildfires	3.29	1.372	68
LEAVE_StormSurge	2.40	1.517	68

Table 5.12 Willingness to leave for fast onset climatic events.

(I) FastOnsetClimaticEvents	(J) FastOnsetClimaticEvents	Mean Difference (I-J)	Sig.b
1 LEAVE_TooManyExtremeWeatherEvents	2 LEAVE_RiverFlooding	-.118	1.000
	3 LEAVE_FlashFlooding	-.206	1.000
	4 LEAVE_StormSurge	1.147*	<.001

	5 LEAVE_Landslides	.147	1.000
	6 LEAVE_Wildfires	.250	1.000
2 LEAVE_RiverFlooding	1 LEAVE_TooManyExtremeWeatherEvents	.118	1.000
	3 LEAVE_FlashFlooding	-.088	1.000
	4 LEAVE_StormSurge	1.265*	<.001
	5 LEAVE_Landslides	.265	.900
	6 LEAVE_Wildfires	.368	.295
3 LEAVE_FlashFlooding	1 LEAVE_TooManyExtremeWeatherEvents	.206	1.000
	2 LEAVE_RiverFlooding	.088	1.000
	4 LEAVE_StormSurge	1.353*	<.001
	5 LEAVE_Landslides	.353	.155
	6 LEAVE_Wildfires	.456	.066
4 LEAVE_StormSurge	1 LEAVE_TooManyExtremeWeatherEvents	-1.147*	<.001
	2 LEAVE_RiverFlooding	-1.265*	<.001
	3 LEAVE_FlashFlooding	-1.353*	<.001
	5 LEAVE_Landslides	-1.000*	<.001
	6 LEAVE_Wildfires	-.897*	<.001
5	1 LEAVE_TooManyExtremeWeatherEvents	-.147	1.000
	2 LEAVE_RiverFlooding	-.265	.900
	3 LEAVE_FlashFlooding	-.353	.155
	4 LEAVE_StormSurge	1.000*	<.001
	6 LEAVE_Wildfires	.103	1.000
6	1 LEAVE_TooManyExtremeWeatherEvents	-.250	1.000
	2 LEAVE_RiverFlooding	-.368	.295
	3 LEAVE_FlashFlooding	-.456	.066
	4 LEAVE_StormSurge	.897*	<.001
	5 LEAVE_Landslides	-.103	1.000

Table 5.13 Pairwise comparisons

	Mean	Std. Deviation	N
LEAVE_BadAirQuality	3.38	1.041	65

LEAVE_TooDry	3.23	1.222	65
LEAVE_TooHot	3.22	1.269	65
LEAVE_LowAirHumidity	2.92	1.241	65
LEAVE_Windstorms	2.91	1.308	65
LEAVE_TooWet	2.65	1.243	65
LEAVE_ColdSpell	2.25	1.173	65

Table 5.14 Willingness to leave for slow onset events.

(I) SlowOnsetClimaticEvents	(J) SlowOnsetClimaticEvents	Mean Difference (I-J)	Sig.b
1 LEAVE_BadAirQuality	2 LEAVE_TooHot	.169	1.000
	3 LEAVE_TooDry	.154	1.000
	4 LEAVE_TooWet	.738*	<.001
	5 LEAVE_Windstorms	.477	.114
	6 LEAVE_ColdSpell	1.138*	<.001
	7 LEAVE_LowAirHumidity	.462*	.018
2 LEAVE_TooHot	1 LEAVE_BadAirQuality	-.169	1.000
	3 LEAVE_TooDry	-.015	1.000
	4 LEAVE_TooWet	.569*	<.001
	5 LEAVE_Windstorms	.308	.587
	6 LEAVE_ColdSpell	.969*	<.001
	7 LEAVE_LowAirHumidity	.292	.440
3 LEAVE_TooDry	1 LEAVE_BadAirQuality	-.154	1.000
	2 LEAVE_TooHot	.015	1.000
	4 LEAVE_TooWet	.585*	<.001
	5 LEAVE_Windstorms	.323	.326
	6 LEAVE_ColdSpell	.985*	<.001
	7 LEAVE_LowAirHumidity	.308	.098
4 LEAVE_TooWet	1 LEAVE_BadAirQuality	-.738*	<.001
	2 LEAVE_TooHot	-.569*	<.001
	3 LEAVE_TooDry	-.585*	<.001
	5 LEAVE_Windstorms	-.262	1.000
	6 LEAVE_ColdSpell	.400	.110
	7 LEAVE_LowAirHumidity	-.277	1.000
5 LEAVE_Windstorms	1 LEAVE_BadAirQuality	-.477	.114
	2 LEAVE_TooHot	-.308	.587
	3 LEAVE_TooDry	-.323	.326
	4 LEAVE_TooWet	.262	1.000
	6 LEAVE_ColdSpell	.662*	.002
	7 LEAVE_LowAirHumidity	-.015	1.000
6 LEAVE_ColdSpell	1 LEAVE_BadAirQuality	-1.138*	<.001
	2 LEAVE_TooHot	-.969*	<.001
	3 LEAVE_TooDry	-.985*	<.001
	4 LEAVE_TooWet	-.400	.110
	5 LEAVE_Windstorms	-.662*	.002

	7 LEAVE_LowAirHumidity	-.677*	<.001
7 LEAVE_LowAirHumidity	1 LEAVE_BadAirQuality	-.462*	.018
	2 LEAVE_TooHot	-.292	.440
	3 LEAVE_TooDry	-.308	.098
	4 LEAVE_TooWet	.277	1.000
	5 LEAVE_Windstorms	.015	1.000
	6 LEAVE_ColdSpell	.677*	<.001

Table 5.15 Pairwise Comparisons

Thus, there is a significant effect of event type on the willingness scores. The following table summarizes the key drivers in Sao Paulo.

	Willingness to live for fast onset climatic events.	**Willingness to leave for fast onset climatic events.**	**Willingness to live for slow onset climatic events.**	**Willingness to leave for slow onset climatic events.**	**Willingness to leave for non-climatic factors.**
Key drivers (In descending order)	Flooding and Landslides	Flash flooding, river flooding, too many extreme weather events and landslides	Drought, Intense rainfall, windstorms, and Heatwaves	Bad air quality, Too Dry, Too Hot, Windstorms and low air humidity	No jobs, not safe and no health service
Wilk's Lambda	0.88	0.516	0.721	0.478	0.696
Significance	0.007	<0.001	<0.001	<0.001	<0.001
Partial eta squared	0.12	0.484	0.279	0.522	0.304
Effect of event type	Moderate	Large	Large	Large	Large

Table 5.16 Key drivers of willingness scores for Sao Paulo.

5.2.3. Key drivers in Rio de Janeiro.

Most ANOVA tests for willingness to live and willingness to leave for slow onset, fast onset and non-climatic factors were insignificant meaning that the means for the events within a component were not significantly different to each other. Thus, there was no evidence of significant difference between the events driving the willingness scores. However, as per the absolute mean scores, top drivers of willingness to live were flooding and landslides for fast onset events while drought and intense rainfall for slow onset events. The only significant ANOVA test was for willingness to leave for fast onset events where Landslides, flash flooding and river flooding significantly drove the willingness scores. Following is a summary of the key drivers in Rio de Janeiro.

Test for willingness to	**Wilk's Lambada**	**P-value**	**Significance**	**Partial eta squared (Effect)**	**Key drivers**
Live fast onset	0.899, (2,16) =0.901	0.426	Insignificant	0.101	Flooding and landslides

Live slow onset	0.631, (4,14) = 2.045	0.143	Insignificant	0.369	Drought and intense rainfall
Leave fast onset	0.414, (5,12) = 3.394	0.038	Significant	0.586 (Large)	Landslides, flash flooding and river flooding
Leave slow onset	0.516, (6,12) = 1.873	0.167	Insignificant	0.484	Bad air quality, too dry, too hot, and windstorms
Leave non-climatic	0.901, (3,14) = 0.510	0.682	Insignificant	0.099	No jobs

Table 5.17 Key drivers for Rio de Janeiro.

	Mean	Std. Deviation	N
LIVE_Flooding	6.00	1.680	18
LIVE_Landslides	6.00	1.495	18
LIVE_Wildfires	5.67	1.572	18

Table 5.18 Willingness to live for fast onset events.

	Mean	Std. Deviation	N
LIVE_IntenseRainfall	5.22	1.734	18
LIVE_Drought	5.17	1.886	18
LIVE_Windstorms	4.94	1.830	18
LIVE_Heatwaves	4.61	2.004	18
LIVE_LowAirHumidity	4.44	2.121	18

Table 5.19 Willingness to live for slow onset events.

	Mean	Std. Deviation	N
LEAVE_FlashFlooding	4.24	1.033	17
LEAVE_Landslides	4.24	1.091	17
LEAVE_RiverFlooding	4.18	1.074	17
LEAVE_TooManyExtremeWeatherEvents	4.00	1.061	17
LEAVE_Wildfires	3.59	1.278	17
LEAVE_StormSurge	2.82	1.425	17

Table 5.20 Willingness to leave for fast onset events.

	Mean	Std. Deviation	N
LEAVE_BadAirQuality	3.06	1.305	18
LEAVE_TooDry	2.78	1.437	18
LEAVE_TooHot	2.72	1.406	18
LEAVE_Windstorms	2.72	1.526	18
LEAVE_TooWet	2.56	1.247	18
LEAVE_ColdSpell	2.56	1.381	18
LEAVE_LowAirHumidity	2.22	1.114	18

Table 5.21 Willingness to leave for slow onset events.

	Mean	Std. Deviation	N
LEAVE_NoJobs	3.76	1.480	17
LEAVE_NotSafe	3.71	1.359	17

LEAVE_NoHealthService	3.71	1.404	17
LEAVE_NegativePoliticalSituation	3.35	1.222	17

Table 5.22 Willingness to leave for non-climatic factors.

5.2.4. Key drivers in Minas Gerais.

The willingness scores for the push factors in Minas Gerais were significantly different from each other. However, the pull factors did not differ much in driving the willingness to live. Hence, the absolute mean scores were used to identify the top drivers of willingness to live. Here is a summary of the results followed by the mean scores for all factors.

Test for willingness to	**Wilk's Lambada**	**P-value**	**Significance**	**Partial eta squared (Effect)**	**Key drivers**
Live fast onset	0.983, (2,12) =0.101	0.904	Insignificant	0.017	Landslides and wildfires
Live slow onset	0.481, (4,11) = 2.971	0.069	Insignificant	0.519	Heatwaves and low air humidity
Leave fast onset	0.105, (5,7) = 11.921	0.003	Significant	0.895 (Large)	Too many extreme weather conditions, landslides, and wildfires
Leave slow onset	0.066, (6,6) = 14.090	0.003	Significant (However, there were no significant differences in pairwise comparisons)	0.934 (Large)	Bad air quality, too hot, and too dry
Leave non-climatic	0.273, (3,9) = 7.975	0.007	Significant	0.727 (Large)	No jobs and no health service

Table 5.23 Key drivers for Minas Gerais.

	Mean	Std. Deviation	N
LIVE_Landslides	4.93	1.979	14
LIVE_Wildfires	4.86	2.107	14
LIVE_Flooding	4.79	2.190	14

Table 5.24 Willingness to live for fast onset events.

	Mean	Std. Deviation	N
LIVE_Heatwaves	4.93	1.981	15
LIVE_LowAirHumidity	4.33	1.952	15
LIVE_Drought	4.27	1.668	15
LIVE_IntenseRainfall	4.00	1.732	15
LIVE_Windstorms	3.73	1.907	15

Table 5.25 Willingness to live for slow onset events.

	Mean	Std. Deviation	N

LEAVE_TooManyExtremeWeatherEvents	3.67	1.155	12
LEAVE_Landslides	3.25	1.357	12
LEAVE_Wildfires	3.25	1.138	12
LEAVE_FlashFlooding	3.17	1.586	12
LEAVE_RiverFlooding	3.08	1.676	12
LEAVE_StormSurge	2.08	.996	12

Table 5.26 Willingness to leave for fast onset events.

	Mean	Std. Deviation	N
LEAVE_TooHot	3.25	1.357	12
LEAVE_TooDry	3.08	1.311	12
LEAVE_BadAirQuality	3.00	.953	12
LEAVE_Windstorms	2.92	1.084	12
LEAVE_TooWet	2.75	1.138	12
LEAVE_LowAirHumidity	2.58	1.165	12
LEAVE_ColdSpell	1.75	.866	12

Table 5.27 Willingness to leave for slow onset events

	Mean	Std. Deviation	N
LEAVE_NoJobs	4.58	1.165	12
LEAVE_NoHealthService	3.58	1.564	12
LEAVE_NotSafe	3.50	1.314	12
LEAVE_NegativePoliticalSituation	3.17	1.115	12

Table 5.28 Willingness to leave for non-climatic events

5.2.5. Key drivers for Rest of Brazil.

Test for willingness to	**Wilk's Lambada**	**P-value**	**Significance**	**Partial eta squared (Effect)**	**Key drivers**
Live fast onset	0.993, (2,48) =0.166	0.847	Insignificant	0.007	Landslides and flooding
Live slow onset	0.914, (4,46) = 1.088	0.374	Insignificant	0.086	Drought and heatwaves
Leave fast onset	0.567, (5,40) = 6.099	<0.001	Significant	0.433 (Large)	Too many extreme weather conditions, flash flooding, wildfires, river flooding, and landslides
Leave slow onset	0.497, (6,39) = 6.585	<0.001	Significant (However, there were no significant differences in pairwise comparisons)	0.503 (Large)	Bad air quality, too hot, too dry and windstorms

Leave non-climatic	0.666, (3,45) = 7.537	<0.001	Significant	0.334 (Large)	No jobs and no health service

Table 5.29 Key drivers in rest of Brazil.

	Mean	Std. Deviation	N
LIVE_Landslides	5.26	2.155	50
LIVE_Flooding	5.24	2.076	50
LIVE_Wildfires	5.14	2.080	50

Table 5.30 Willingness to live for fast onset events.

	Mean	Std. Deviation	N
LIVE_Drought	4.64	1.967	50
LIVE_Heatwaves	4.62	1.978	50
LIVE_IntenseRainfall	4.30	1.982	50
LIVE_Windstorms	4.28	2.214	50
LIVE_LowAirHumidity	4.22	1.909	50

Table 5.31 Willingness to live for slow onset events.

	Mean	Std. Deviation	N
LEAVE_TooManyExtremeWeatherEvents	3.51	1.272	45
LEAVE_FlashFlooding	3.22	1.347	45
LEAVE_Wildfires	3.20	1.502	45
LEAVE_RiverFlooding	3.11	1.481	45
LEAVE_Landslides	2.91	1.490	45
LEAVE_StormSurge	2.27	1.498	45

Table 5.32 Willingness to leave for fast onset events.

	Mean	Std. Deviation	N
LEAVE_BadAirQuality	3.09	1.294	45
LEAVE_TooHot	3.00	1.225	45
LEAVE_TooDry	2.96	1.331	45
LEAVE_Windstorms	2.82	1.386	45
LEAVE_LowAirHumidity	2.44	1.501	45
LEAVE_TooWet	2.40	1.176	45
LEAVE_ColdSpell	2.04	1.296	45

Table 5.33 Willingness to leave for slow onset events.

	Mean	Std. Deviation	N
LEAVE_NoJobs	4.04	1.352	48
LEAVE_NoHealthService	3.67	1.358	48
LEAVE_NotSafe	3.52	1.271	48
LEAVE_NegativePoliticalSituation	3.19	1.363	48

Table 5.34 Willingness to leave for non-climatic events.

5.3 Variance in willingness scores based on the type of event.

Repeated measures ANOVA was performed to check the variance of willingness to live and willingness to leave for fast onset events, slow onset climatic events and non-climatic factors. The results suggest that Brazilians are significantly most likely to choose a place of living or leave their current location based on non-climatic factors, less likely for fast onset climatic events and least likely for slow onset climatic events.

5.3.1. Pull factors.

The willingness to live was analysed among three categories; 1. Fast onset climatic events, 2. Slow onset climatic events and 3. Essentials to live (non-climatic factors). The Wilk's Lambada (0.396) was significant

($p<0.001$) with a large effect (multivariate partial eta squared = 0.604). The descriptive statistics show that the mean scores the willingness to live for fast onset events (76.1473) is greater than slow onset events (62.2426). The pairwise comparisons show that all the mean values were significantly different from each other with $p<0.001$. Therefore, Brazilians are more likely to choose a place of living based of fast onset climatic events like floods, landslides, and wildfires than slow onset climatic events like droughts, intense rainfall, heatwaves, windstorms, and low air humidity.

5.3.2. Push factors.

The willingness to leave was analysed among three categories; 1. Fast onset climatic events, 2. Slow onset climatic events and 3. non-climatic factors. The Wilk's Lambada (0.589) was significant ($p<0.001$) with a large effect (multivariate partial eta squared = 0.411) of type of event on the willingness to leave score. The descriptive statistics suggests that the Brazilians are most likely to leave their current location for non-climatic factors like no jobs, no health service, not safe or negative political situation than the climatic factors. Among the climatic factors, people exhibit a higher willingness to leave for fast onset events like floods, landslides, wildfires, storm surge and extreme weather than the slow onset events such as too hot, too dry, too wet, bad air quality, windstorms, low air humidity and cold spell. The pairwise comparisons show significant ($p<0.001$) difference among all pairs.

5.4. Linear regressions

Linear regressions were performed to analyse what factors define the willingness to leave for Brazilians. The results show that Impact to the activities of going to School/University/Work significantly explain the willingness to leave for non-climatic factors (21.6%), fast onset climatic factors (22.9%) and slow onset climatic factors (16.3%). Thus, there is a relationship between disruption of commutation to school/university/work and people's choices of living or leaving an area.

5.5. Text analysis

From the open-ended questions regarding best and worst imaginable futures, the sentiment analysis suggests a mix of hope for best cases and worry for worst cases. The respondents are most concerned about water scarcity among the negative themes while they are most optimistic about the reforestation and increasing greenery to mitigate heat and raise humidity. Following is a summary of the themes and their frequencies.

Figure 5.4 Best future word cloud.

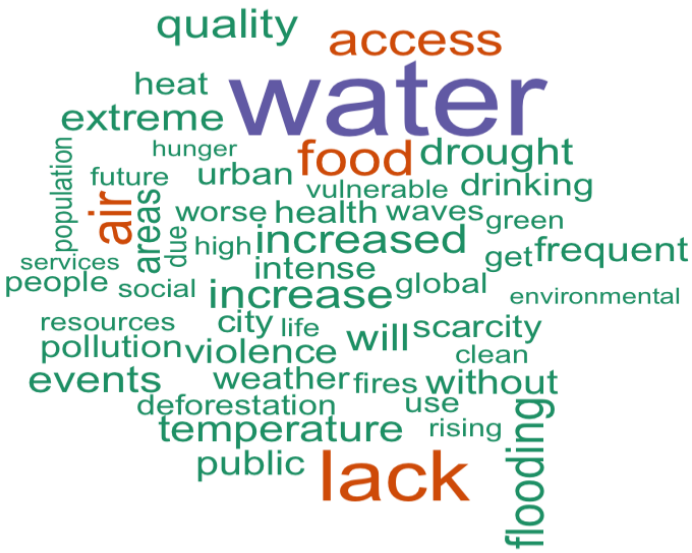

Figure 5.5 Worst future word cloud.

Best case themes	
Themes	**Counts**
Reforestation/green spaces	29
Clean water access	21
Infrastructure adaptation/resilience	19
Temperature moderation	9
Social equality	6
Forest preservation	6
Education/awareness	4
Worst case themes	
Themes	**Counts**
Water scarcity/drought	34
High temperatures/heat waves	29
Floods/landslides	24
Fires/burning	20
Air pollution	11
Food scarcity/hunger	10
Poverty/inequality	10
Displacement/migration	6
Sea level rise	4
Disease	4

Table 5.35 Frequency table for best and worst future themes.

The most mentioned needs for thriving were related to employment, financial/economic stability, education, health, political stability, access to basic services like food/water/sanitation, and quality of life factors like leisure and culture. The following is a summary of the themes noted in the responses and their frequencies.

Figure 5.6 Essentials to thrive word cloud.

Themes	**Counts**
Employment/Jobs	41

Political stability	30
Education/Educational system	29
Health/Mental health	24
Financial/Economic stability	23
Basic services (food/water/housing etc)	20
Quality of life/Leisure/Culture	14
Public policies	12
Access to opportunities/Social mobility	11
Transportation/Mobility	7
Safety/Security	6
Environmental sustainability	5
Income/Wages	5
Equity/Equality	5
Corruption	4
Sanitation	4
Democracy	4
Energy	2
Technology/Internet Access	2
Housing	2
Social inclusion	2
Justice	1
Infrastructure	1
Legal certainty	1

Table 5.36 Frequency of essentials to thrive.

Regarding improvement measures, respondents have identified measures to improve issues like transportation, sanitisation, health services, etc. Few respondents have mentioned that reducing fires and deforestation can improve environmental issues like air and water quality.

Figure 5.7 What can improve habitability – word cloud.

Here are the main themes from the data and the number of times each was mentioned:

Themes	**Counts**	**Improvements suggested**

Public transportation/mobility	41	Better public transport is needed, including more options, affordability, and connectivity.
Sanitation/Sewage/Waste management	25	Sewage treatment, drainage systems, and waste management are lacking.
Healthcare/Health services	22	More facilities, better equipment, more coverage, and specialized care are needed.
Infrastructure/Roads/Housing	19	Paving, asphalt, drainage issues were flagged.
Environment/Air quality/Water quality	17	Reducing fires and deforestation was suggested.
Safety/Security	14	Crime prevention and more personnel needed.
Education/Schools	10	Better quality and access emphasized.
Public policies/Governance	9	Effective management and enforcement of laws needed.
Leisure/Culture/Parks	9	More public spaces for recreation desired.
Employment/Jobs	8	More opportunities locally.
Urban heat mitigation.	7	Afforestation/Trees/Green spaces
Technology/Internet	2	Access to internet/technology

Table 5.37 Frequency of improvement methods.

5.6. People are reluctant to leave an area for the same factors that they consider important to live.

Multiple paired samples t-tests were conducted to analyse the difference in willingness to live and willingness to leave for similar factors. The tests confirm that there is a significant difference between the willingness to live and willingness to leave for similar factors for 4 out of 5 zones. The results show that people are significantly less likely to leave than chose a place of living based on fast onset climatic events and slow onset climatic events for zone 1, zone 2, zone 4 and zone 5. For zone 3 (Minas Gerais), the mean willingness to live was higher than the mean willingness to leave. However, the t-tests were insignificant hence we cannot conclude that the willingness to live is significantly greater than the willingness to leave for Minas Gerais. Following is a summary of t-tests performed zone-wise.

Zone		**1**	**2**	**3**	**4**	**5**
Sample size (N)		**75**	**18**	**12**	**49**	**154**
States		**Sau Paulo**	**Rio de Janeiro**	**Minas Gerais**	**Rest of Brazil**	**Overall Brazil**
Fast onset climatic events	**Willingness to live**	M=0.8128, SD=0.25038	M=0.8429, SD=0.21402	M=0.6898, SD=0.28472	M=0.7560, SD=0.26183	M=0.7890, SD=0.24764
	Willingness to leave	M=0.6228, SD=0.25754	M=0.7498,	M=0.6146,	M=0.5849,	M=0.6249,

			SD=0.20938	SD=23440	SD=0.24263	SD=0.24764
	Mean difference	0.18995	0.09310	0.0752	0.17112	0.16416
	T(N-1)	7.210	3.920	1.048	5.501	9.437
	2-tailed Sig(p)	<0.001	=0.001	=0.317	<0.001	<0.001
	95% CI Range	0.13746 to 0.24244	0.07745 to 0.24373	-0.08275 to 0.23305	0.10857 to 0.23367	0.12979 to 0.19852
	Eta squared statistic	0.4126	0.4748	-	0.3866	0.3664
	Effect	Large	Large	-	Large	Large
Slow onset climatic events	**Willingness to live**	M=0.6378, SD=0.23504	M=0.6915, SD=0.24225	M=0.6046, SD=0.22704	M=0.6421, SD=0.24263	M=0.632844, SD=0.241564
	Willingness to leave	M=0.5577, SD=0.22322	M=0.5309, SD=0.23158	M=0.4945, SD=0.24103	M=0.5248, SD=0.21852	M=0.530608, SD=0.23032
	Mean difference	0.8012	0.16059	0.11004	0.11725	0.1022356
	T(N-1)	3.615	4.075	1.725	4.161	6.684
	2-tailed Sig(p)	<0.001	<0.001	=0.108	<0.001	<0.001
	95% CI Range	0.03595 to 0.12428	0.07745 to 0.24373	-0.02774 to 0.24783	0.06060 to 0.17390	0.06872 to 0.12981
	Eta squared statistic	0.1501	0.4941	-	0.2651	0.2111
	Effect	Large	Large	-	Large	Large

Table 5.38 Summary of multiple t-tests for willing to live vs willingness to leave.

5.6 Demographic factors affecting habitability perception.

Contrary to the prior research (Ardayaa, et al., 2017), no significant difference was observed between the 6 age-groups and 3 genders (Detailed output is attached to the appendix). Prior research in other countries have found higher risk perception for floods in aged population and females. However, no such significant difference was seen in this sample. Since, the sample was skewed with majority of the respondents being females, it is difficult to derive generalizable results in terms of demographics from this sample.

Chapter 6 Discussion

6.1. General discission

This paper explores the public perception to elicit the factors that the lay people of Brazil consider essential for habitability of a region and what they know about the ways to improve habitability of a region amidst changing climates. The research answers the following questions:
(RQ-1) What factors affect the willingness to live in terms of human habitability for Brazilians?
(RQ-2) What factors affect the willingness to leave in terms of human habitability for Brazilians?
(RQ-3) What people think could improve human habitability in different states of Brazil?

Recent studies in Rio de Janeiro, north-eastern and rural parts of Brazil have shown that factors like income, past experiences and demographic factors significantly influence the climatic disaster risk perceptions like flood risk perception and drought risk perception of public ((Ardaya, et al., 2017); (Albuquerque, et al., 2023)). This paper builds on these ideas and attempts to answer questions in the context of liveability and mobility with an aim to determine the key drivers of habitability in various regions of Brazil. Aligning with the findings of WMO recognising droughts and floods as key drivers of mobility around the world (World Meteorological Organization, 2022), this study finds landslides, flash flooding and river flooding to be the key drivers for willingness to leave and live for fast onset climate events for overall Brazil and the slow onset events like drought, low air humidity, heatwaves, too hot as major drivers of the willingness to leave and live.

In the past, Brazilians were most likely to migrate for economic reasons according to research done by Sahota (Sahota, 1968). While Brazilians still consider jobs as a strong driver of willingness to leave, they also consider health services to be equally significant driver in Sao Paulo, Minas Gerais, and zone 4 (states like Maranhão, Rio Grande do Norte, Paraíba, Bahia, Acre, Amazonas, etc.) states. The fear of recent pandemic may have sensitised the public towards health facilities in the state. A survey done in the UK finds a decline in the public perception of health care services since the Covid-19 pandemic with 69% of the public believing that the standard of health care services has worsened since 2021 (Buzelli, et al., 2022). The public sentiment may be affected by the availability heuristic (Tversky & Kahneman, 1973) as people have been repeatedly exposed to pandemic news and it is a rather recent occurring. The lack of health services during pandemic possibly generated a negative affect towards health services which as per the affect heuristic (Tversky & Kahneman, 1982), may lead to biased risk assessments. Furthermore, Sau Paulo also considers safety as a significant factor along with jobs and health services for mobility. Thus, this paper adds to the existing literature by confirming the climatic events that are most likely to displace masses specifically in the different states of Brazil. Most, earlier work has been either done in the context of mobility or to understand the risk perception of various large impact climatic events. This paper brings the two dimensions in a single perspective and asks questions about which events make people want to move from or to a certain location. The study also uses a broader suite of slow onset climatic events and non-climatic factors and compares the variation in the willingness scores across different types of events.

Furthermore, it was believed that people rarely decide migration based on climatic reasons (Gonzalez, 2020) however, while the willingness to leave was highest (70.14) for non-climatic factors, the sample displayed high willingness scores for fast onset (62.49) and slow onset (54.54) climatic events too. Although, prior literature review done in this context (Kaczan & Orgill-Meyer, 2020) suggests that people are more likely to migrate for long-term slow onset events rather than rapid onset events, it is empirically determined that fast onset events like floods, landslides, and wildfires, that have an immediate impact, are significantly more likely to induce a sense of mobility as compared to the slow onset events in Brazil.

Additionally, the drivers were analysed across different states in Brazil, to assess the variance in public perception between states. In zone 4, comprising of rural and north-eastern (semi-arid), zone 2 and zone 3 no jobs and no health service were a significant predictor of willingness to leave. While in Sau Paulo safety along with no jobs and no health service was a significant predictor.

There is non-significant difference between the willingness to live for all pairs of climatic events for all state-wise zones except Sau Paulo where Drought, Intense rainfall, windstorms, and Heatwaves were significant

drivers of willingness to live at 95% confidence interval and floods and landslides were significant drivers of willingness to live at 90% confidence interval.

Furthermore, this research finds a novel insight indicating difference in attitudes of people while considering a place of living and leaving their current home. People tend to consider all possible factors when thinking of choosing a new place to live but they will not leave their current home if they are affected by the same events. For instance, it is observed that more than 50% of the sample considers suitable temperature to be essential for habitability and is willing to choose a place of residence based on temperature condition. However, people might not leave their current location readily for extreme temperatures. Thus, indicating reluctance in migrating away from their current residence. It was found that there is a significant difference in the willingness to live and willingness to leave an area due to similar factors. This means that people are more likely to choose a place of living based on the floods, droughts or jobs in a region than leave their current place for the same factors. Such inconsistency in responding to the same factors in different question frames like "what makes you need/want to leave" and "what affects your choice of where you might want to live" can be explained by the endowment effect (Thaler, 1980) and reason-based choice (Shafir, et al., 1993). The reason-based choice framework emphasises on the role of accessible information and mental shortcuts in decision-making. Decision-makers rely on accessible information in the wordings of the question to make choices. For instance, when people were presented the question in a positive frame i.e., "where you might want to live?", they tend to behave in a liberal fashion and rate the factors exceedingly. However, when the same factors are presented in a negative frame like "what makes you want/need to leave?", they opt for more conservative choices and thus, are likely to rate the same factors lower. This mental shortcut is known as framing effect (Tversky & Kahneman, 1981).

Another reason for lower willingness to leave may be that people assign higher value to their present home or town and hence, are reluctant to give away what they possess easily. This phenomenon where people overvalue things they own is known as endowment effect and is widely implied in economics and behavioural science. Undermining the climatic events that may lead to displacement may be because people don't want to relocate. An analysis conducted in a village in Fiji depicted how people refuse to believe in adverse effects of climate change and seek religious fable of Noah's Ark to assume that the earth will never be uninhabitable just because they don't want to relocate and hence refuse to accept any future that may displace them (Bertana, 2020).

The responses to open ended questions show that respondents seldom mention the environmental factors as essentials to live and rarely talk about improving the environmental conditions to make their state more habitable while never mentioning any climatic conditions. The most essential factors for habitability are employment, political stability, education, health, and finance. The most mentioned improvements are in the transportation domain and some respondents have mentioned afforestation as a measure to mitigate urban heat and some have mentioned reducing forest fires to improve air/water quality. The theoretically considered essentials for habitability, like land, water, food, are mentioned only 20 out of 178 times by the Brazilians. Thus, there is a certain rift in perceptions of habitability between experts and lay people.

6.2. Limitations

Although, this paper provides robust empirical evidence of perception of habitability, few limitations must be noted.

1. The sample is a convenience sample which is skewed in terms gender and concentrated in the urban regions. As a result, the sample does not completely represent the population of Brazil (Babbie, 2015).
2. For simplicity of analyses and to maintain the statistical strength of the data, the states with fewer responses have been grouped into a single zone (zone 4) which limits the comparability of results across individual states.
3. The responses on 5-point and 7-point Likert scales have been converted to scores out of 100 to compare the willingness to live and willingness to leave. Thus, there is a possibility of loss of scale sensitivity (Shaughnessy, et al., 2000). Therefore, it is recommended that the same scales be used to collect data in future.

6.2. Recommendation and future scope

This study draws crucial insights regarding essentials and improvement measures of habitability with an aim to support the formation of Climate Risk Narratives (Jacka, et al., 2020) to educate the population of Brazil about the approaching uninhabitability of various regions and fostering a need for adopting mitigation methods to increase preparedness for future situation. Based on the findings, this report recommends the following points for developments of CRN.

1. Interconnectedness: The people of Brazil are not prominently concerned about the climatic events that might displace them in future. Instead, they consider employment and health as most essential for habitability. Hence, linking climate change with impacts to jobs or health or fatality might reinforce the importance of suitable climate for habitability.

2. FRACTAL emphasizes on subjective and contextual messaging instead of overwhelming data to avoid confusion and enhance receptivity of the message (Scott & Taylor, 2019). Thus, illustrating the impacts in subjective scenarios would be better than quoting data.

3. Positive message: The imaginary future for the Brazilians is not completely pessimistic, thus indicating hope for a better environment with afforestation, access to clean water and temperature moderation. It might help to demonstrate how the suggested improvement measures can lead to a favourable future with cleaner water or temperature moderation, etc. Moreover, studies have established that fearful messages may attract attention, but fear is ineffective in motivating individual engagement (O'Neill & Nicholson-Cole, 2009).

4. Human stories: Including anecdotes or personal stories indicating impact to daily life activities such as travel to school/work/universities might increase climate change awareness as it is seen that people are likely to leave an area if their travel to school/work/university is affected (Global Network of Civil Society Organization for Disaster Reduction, 2023).

5. As people are most concerned about lack of clean water in future, it may be fruitful to suggest some measures that associate with cleaner water.

6. People are also concerned about drainage systems and show high willingness to live, and leave based on floods. Hence, it might be helpful to associate floods, drainage, and climate change.

Future scope:

This research has presented the key drivers for habitability in the perception of public of Brazil. Although, results clearly indicate the most prominent events and factors that the public consider when deciding a place of living or migration, confirming these findings with a more representational sample is required. The findings indicate an overall low willingness to leave hence, it will be useful to know how the willingness varies among different income groups of Brazil as past studies have shown low-income groups and aged population to be most vulnerable to forced migration due to climatic disasters (Delazeri, et al., 2022; Sahotra, 1968). Furthermore, the past research suggests employability as a major driver of habitability perception, it will be essential to know how education plays a role in driving the willingness to leave for various factors as varied levels education can indicate variety of professions and climate change affects some professions like agriculture directly and others indirectly (Delazeri, et al., 2022). The open-ended responses show a mix of hope and worry for future. It will be essential to know the timeframe the public considers for such responses as it can indicate the temporal distance people consider when they think about future climatic condition.

Chapter 7 Conclusion

This study finds that Brazilians are most likely to decide out-migration based on employability, health services and safety while they are more likely to leave due to fast onset events like landslides, flash floods, and river floods than slow onset events like hot and dry weather and low air quality. Thus, the findings lay emphasis on the need to communicate the possibility of unfavourable climate causing forced displacement in future. The lay man is prominently more concerned about improving public services like transportation,

education, employability, and health service for a better future rather than a sustainable climate and predominantly worries about water scarcity. Although, the public rates the climatic events as important factors while choosing a new location, they are reluctant to leave their current home for the same factors.

Overall, this study elicits the key drivers of habitability in terms of willingness to live and willingness to leave in Brazil. It lays the foundation for development of Climate Risk Narratives by establishing the underlying beliefs of the society about essentials to thrive, sentiments about future climate condition and improvement measures. Policy makers are recommended to consider these results and insights to design robust Climate Risk Narratives based on the public elicitation to achieve better receptiveness. The study acknowledges its limitations in terms of sample generalisability and data manipulations like conversion of discrete Likert scales to continuous scales for comparative analyses. Nevertheless, the research adds significant findings of public elicitation of essentials for habitability in Brazil and relevant insights to the body of literature concerned with human habitability during climate change.

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Chapter 10 Appendix – A: Glossary of technical/unfamiliar terms.

Sr. No.	Term	Meaning
1	Availability Heuristic	Mental shortcut where decision-makers rely on most recent or most easily available information to make judgements.
2	Affect Heuristic	Mental shortcut where decision-makers rely on affect or emotion to make judgements.
3	Framing effect	Mental shortcut where decisions are affected by positive or negative frames or words used in a question.
4	Boiling frog effect	If a frog is gradually heated in boiling water, it will die slowly. But if it is placed into already boiling water it will jump out.
5	Mental model	A cognitive structure in the mind which forms the basis of decision-making. (Jones, et al., Mar 2011)
6	Attentional bias	Giving extra attention to a particular topic due to personal traits.
7	Perceptual bias	Over estimation of risks due to attentional bias.
8	Human habitability	The environmental conditions that assist healthy human life, productive livelihoods, and sustainable intergenerational development.
9	Migration	The act of moving from one location to other.
10	Slow onset event	Gradually impacting events that create problems in long-term.
11	Fast onset event	Catastrophic events that cause severe impacts leading to immediate displacement.
12	Willingness to live	Willingness of a person to decide a place of living.

13	Willingness to leave	Willingness of a person to decide migrating away from an area.

Chapter 11 Appendix B: Ethics form.

Chapter 12 Internal research ethics application form

For module LUBS5579M (Business Analytics and Decision Sciences Dissertation) covered by University of Leeds ethical approval reference AREA 17-055[1].

Student ID	201681784
Student Name	Srishtee Sinha
Degree Programme	MSc Business Analytics and Decision Sciences
Title / topic area	Exploring the limits of human habitability in Brazil and using stakeholder engagement to inform the development of Climate Risk Narratives.
Name of dissertation supervisor	Andrea Taylor

Are you planning to work with (data on) human participants for your dissertation?	Please tick the relevant box
Yes (This includes interviews, surveys and secondary data analysis of social media or internet data).	✓
No, I am conducting an in-depth literature review with analysis.	

If you ticked 'No' you do not need to take further action in respect of ethical approval. Please proceed to the declarations on page 7.

If you ticked 'Yes' you need to complete the rest of this form.

You MUST discuss your research design and the ethical issues it raises with your dissertation supervisor and receive their signed approval before you approach any participants or collect any data.

You MUST include a copy of your ethics form (signed by your supervisor) as an appendix to your final dissertation submission (both the electronic and paper copies).

[1] Ethical approval valid until 31/12/2027.

Ethical review is required for **all research involving human participants**. Further details of the University of Leeds ethical review requirements are provided in the *Research Ethics Policy* available at: http://ris.leeds.ac.uk/ResearchEthicsPolicies and www.leeds.ac.uk/ethics.

1. **Will your dissertation involve any of the following?**	**Yes**	**No**
New data collected by administering interviews for analysis		✓
New data collected by administering questionnaires for analysis		✓
New data collected from observing individuals or populations		✓
Working with secondary aggregated or population data	✓	
Using open data		✓
Using data given to you by a company	✓	
Any other research methodology, please specify:		✓

2. **Will any of the participants be from any of the following groups?** (Tick as appropriate)	**Yes**	**No**
Children under 16		✓
Adults with learning disabilities		✓
Adults with other forms of mental incapacity or mental illness		✓
Adults in emergency situations		✓
Prisoners or young offenders		✓
Those who could be considered to have a particularly dependent relationship with the investigator, e.g. members of staff, students		✓
Other vulnerable groups, please specify:		✓

3. **Will the project/dissertation/fieldwork involve any of the following:** (You may select more than one)	**Yes**	**No**
Patients and users of the NHS (including NHS patients treated under contracts with private sector)		✓

Individuals identified as potential participants because of their status as relatives or carers of patients and users of the NHS		✓
The use of, or potential access to, NHS premises or facilities		✓
NHS staff - recruited as potential research participants by virtue of their professional role		✓
A prison or a young offender institution in England and Wales (and is health related)		✓

If you have answered 'Yes' to **ANY of the above statements in questions 2 or 3** then you will need to apply for full ethical approval which is a faculty committee level process. This can take up to 6-8 weeks, so it is important that you consult further with your supervisor and/or program director for guidance with this application as soon as possible. Please now complete and sign the final page of this document. The application form for full ethical review and further information about the process are available at http://ris.leeds.ac.uk/uolethicsapplication.

If you answered **'No' to ALL of the statements in Questions 2 and 3** please continue to part B.

4. Will the research touch on sensitive topics or raise other challenges?	Yes	No
Will the study require the cooperation of a gatekeeper for initial access to groups or individuals who are taking part in the study (eg students at school, members of self-help groups, residents of a nursing home)?		✓
Will participants be taking part in the research without their knowledge and consent (eg covert observation of people in non-public places)?		✓
Will the study involve discussion of sensitive topics (eg sexual activity, drug use)?		✓
Could the study induce psychological stress or anxiety or cause harm or have negative consequences beyond the risks encountered in normal life?		✓
Are there any potential conflicts of interest?		✓
Does any relationship exist between the researcher(s) and the participant(s), other than that required by the activities associated with the project (e.g., fellow students, staff, etc)?		✓
Does the research involve any risks to the researchers themselves, or individuals not directly involved in the research?		✓

If you have answered 'Yes' to any of the statements above please describe the ethical issues raised and your plans to resolve them on a separate page. Agree this with your supervisor and submit it with this form.
You MAY be referred for light touch or full ethical review.

5. International Research Does your research involve participants outside of the UK?	Yes	No
Are any of your research participants located outside of the UK? For example: will you be gathering data through Skype interviews with participants located overseas?		✓
Will any of the fieldwork or research require you to travel outside of the UK to collect data?		✓

If you have answered 'Yes' to any of the statements above please describe the ethical issues raised with: gaining consent and gathering data from participants located overseas, securely storing and transferring data from the field back to the UK, any cultural issues that may be relevant. Please outline your plans to resolve this on a separate page and ensure that you have completed a risk assessment form (available from LUBS student education). Agree this with your supervisor and submit it with this form.
You MAY be referred for a light touch or full ethical review if you are unable to demonstrate that you have resolved the ethical issues relating to international research.

6. Personal safety Where will any fieldwork/ interviews/ focus groups take place?	Yes	No
At the university or other public place (please specify below).		✓
At my home address		✓

At the research subject's home address		✓
Some other location (please specify below).		✓

If you conduct fieldwork anywhere except at the university or other public place you need to review security issues with your supervisor and have them confirmed by the Module Leader who may refer you for a light touch or full ethical review. Write a brief statement indicating any security/personal safety issues arising for you and/or for your participants, explaining how these will be managed. Agree this with your supervisor and submit it with this form. Please note that conducting fieldwork at the research subject's home address will require strong justification and is generally not encouraged.

7. Anonymity	**Yes**	**No**
Is there any potential for data to be traced back to individuals or organisations, for instance because it has been anonymised in such a way that there remains risk? for example: highlighting people's positions within an organisation, which may reveal them		✓

If you have answered 'Yes' to question 7, please discuss this further with your supervisor. You need to provide a strong justification for this decision on a separate sheet. This application will need to be reviewed by the dissertation Module Leader and may require a full ethical review.

8. Data management issues

Will the research involve any of the following activities at any stage (including identification of potential research participants)?	**Yes**	**No**
a. Examination of personal records by those who would not normally have access		✓
b. Sharing data with other organisations		✓
c. Use of personal addresses, postcodes, faxes, e-mails or telephone numbers		✓
d. Publication of direct quotations from respondents		✓
e. Publication of data that might allow identification of individuals to be identified		✓
f. Use of audio/visual recording devices		✓

g. Storage of personal data on any of the following:			✓
	FLASH memory or other portable storage devices (e.g. USB storage)		✓
	Home or other personal computers		✓
	Private company computers		✓
	Laptop computers		✓

If you have answered 'Yes' to any of the questions above you must ensure that you follow the University of Leeds Information Protection Policy: http://www.leeds.ac.uk/informationsecurity and the Research Data Management Policy: http://library.leeds.ac.uk/research-data-policies#activate-tab1_university_research_data_policy.

You are obliged to provide a copy of your anonymised data to your supervisor for their records and to destroy other copies of your data when your degree has been confirmed.

Dissertation Research Ethical Approval: Declaration

For students	*Please tick as appropriate*
Option 1: I **will NOT** conduct fieldwork with (data on) human participants for my dissertation.	✓
Option 2: I **will** conduct fieldwork with (data on) human participants for my dissertation.	

For **options 1 and 2 -** I confirm that:

- The research ethics form is accurate to the best of my knowledge.
- I have consulted the University of Leeds Research Ethics Policy available at http://ris.leeds.ac.uk/ResearchEthicsPolicies.
- I understand that ethical approval will only apply to the project I have outlined in this application and that I will need to re-apply, should my plans change substantially.

For **option 2** only:

- I am aware of the University of Leeds protocols for ethical research, in particular in respect to protocols on **informed consent**, **verbal consent**, **reimbursement for participants and low risk observation**. If any are applicable to me, signing this form confirms that I will carry out my work in accordance with them. http://ris.leeds.ac.uk/PlanningResearch

Student's signature: ……Brightee…….....……

Date: ……..……18/07/2023……..…….....……..

For supervisors	**Yes**	**No**
No further action required		
I confirm that the dissertation is in line with the module's block ethical approval (Part A & question 8).	X	
I have discussed the ethical issues arising from the research with the student and agree that these have been accurately and fully addressed.	X	
I have reviewed the student's research proposal.	X	
I have reviewed the student's Risk Assessment Form (*if necessary*).		
Further actions required		
Refer to dissertation Module Leader for further review / discussion.		X
The dissertation falls outside the module's block ethical approval and the student was advised to apply for full ethical review.		X

Supervisor's signature: ……A. L Taylor.....…….....

Date: ……18th July 2023…….....……...

Chapter 17 Appendix C: Questionnaire (English).

Follow this link to view the questionnaire:
https://docs.google.com/forms/d/1esLigyedPa3coC8rqIzKjFlVqgvaAqASRa3qhct9ItE/edit

Human Habitability Questionnaire / Questionário de Habitabilidade Humana

~~* Indicates required question~~

1. Language / Idioma

Mark only one oval.

- English
- Português (BR)

Skip to section 8 (***Questionário de Habitabilidade - Encerramento 30 de junho de 2023*** *)*

Exploring the limits of human habitability in Brazil, using stakeholder engagement to inform the development of Climate Risk Narratives

In this study, we are exploring how climate change may influence where people live in Brazil as the world warms and if taking strong mitigation action to prevent the worst effects of climate change could also improve lives in the shorter term. We are interested in the zone between the absolute essentials for human life (e.g. water, food, shelter etc) and liveability (e.g. somewhere being a desirable place to live) – what we call 'human habitability'.

This research will help us identify areas in Brazil that may be sources of outward or inward migration in the future. This questionnaire will provide us with essential information to feed into the development of Climate Risk Narratives for Brazil – future, evidence-based stories of what life in Brazil could look like as the world warms.

Information Sheet

We are Inika Taylor, Liana Anderson, Andy Hartley and Anna Bradley, members of staff at the Met Office, UK and the National Centre for Monitoring and Early Warning of Natural Disasters (CEMADEN), Brazil. *If you would like to discuss any aspect of this research with us, you can contact us by email at inika.taylor@metoffice.gov.uk or liana.anderson@cemaden.gov.br*

Your participation in this study will provide essential information for the development of Climate Risk Narratives for Brazil and help us understand the key drivers of human habitability in Brazil

If you decide to take part, you will be presented with a mixture of multiple choice and open ended/text based questions. You will also be asked some demographic information. This should take approximately 15 minutes. We do not anticipate that participation in this study will result in psychological distress or harm. It is up to you to decide whether or not to take part. Even after agreeing to take part, you can also leave out any questions that you do not wish to answer and can still withdraw at any time and without giving a reason, simply by closing your browser. Nobody except members of the research team will be allowed to see your questionnaire and in the study, you will be known only by number, so the information is completely confidential.

Results from this project may be written up for publication or used in presentations at conferences. Your involvement in the study will not be made apparent and all data is fully anonymised.

Informed Consent

In this section you will fill in the information about Informed Consent: this is one of the founding principles of research ethics. We want to make sure that you are entering this research freely (voluntarily) with full information about what it means to take part, and that you give us consent **before** starting the questionaire.

2. I have read the information about the study on the previous page and **understand the risks and benefits involved.** *

Mark only one oval.

- Yes
- No

3. I have been given the opportunity to ask the researchers questions in **person/via email.** *

Mark only one oval.

- Yes
- No

4. I have got satisfactory answers to my questions. *

Mark only one oval.

- Yes
- No
- I have no questions

5. I understand that all my personal information will remain confidential and that *

my data gathered in the study will be stored anonymously and securely. It will not be possible to identify me in any publications:

Mark only one oval.

- ◯ Yes
- ◯ No

6. I understand that I am free to withdraw from the study at any time, without *

giving a reason and without penalty if I so wish, simply by closing my browser:

Mark only one oval.

- ◯ Yes
- ◯ No

7. I consent to participate in this research study: *

Mark only one oval.

- ◯ Yes
- ◯ No

Human habitability questions

8. What state do you currently live in? Note: if you have been living in your current state for less than a year please answer for your previous state

Mark only one oval.

- Acre
- Alagoas
- Amapa
- Amazonas
- Bahia
- Ceara
- Distrito Federal
- Espirito Santo
- Goias
- Maranhao
- Mato Grosso
- Mato Grosso do Sul
- Minas Gerais
- Para
- Paraiba
- Parana
- Pernambuco
- Piaui
- Rio de Janeiro
- Rio Grande do Norte
- Rio Grande do Sul
- Rondonia
- Roraima
- Santa Catarina
- Sao Paulo
- Sergipe
- Tocantins
- Prefer not to say

9. Which of the following climate and weather events have a big impact where you live (or where you are answering for)? Please choose all that apply

Tick all that apply.

- [ ] Drought
- [ ] Wildfire
- [ ] River flooding
- [ ] Flash flooding
- [ ] Landslides
- [ ] Heatwaves
- [ ] Low air quality
- [ ] Windstorms
- [ ] High temperature
- [ ] Low temperature
- [ ] Intense rainfall
- [ ] Storm surge
- [ ] Low air humidity
- [ ] Cold spell
- [ ] Prefer not to say
- [ ] Other: _____

10. If you had to choose just one climate or weather event that has the most impact where you live (or where you are answering for) what would it be? Please choose only one of the following options

Mark only one oval.

- Drought
- Wildfire
- River flooding
- Flash flooding
- Landslides
- Heatwaves
- Low air quality
- Windstorms
- High temperature
- Low temperature
- Intense rainfall
- Storm surge
- Low air humidity
- Cold spell
- Other: _____

11. To what extent do the following political, economic or socio-cultural issues affect you most where you live (or where you are answering for)?

Mark only one oval per row.

	1. This does not affect me at all	2.	3.	4.	5. This affects me a great deal
Aiirr pollllutiion					
Fiinanciiall criisiis					
Ilmmiigrrattiion					
Miigrrattiion					
Confliictt and viiollence					
Pandemiic					
Endemiic diiseases e.g mallarriia„ yellllow feverr„ dengue					
No access tto heallttth serrviices					
Pestts and diiseases (pllantts and aniimalls)					
Land/forrestt degrradattiion					
Land use change					
Unpllanned urrban grrowtth					

Water contamination					

12. If you had to choose just one political, economic or socio-cultural issue that affects you most where you live (or where you are answering for) what would it be? Please choose only one from the following options

Mark only one oval.

- Air pollution
- Financial Crisis
- Immigration
- Migration
- Conflict and violence
- Pandemic
- Endemic diseases e.g malaria, yellow fever, dengue
- No access to health services
- Pests and diseases (plants and animals)
- Land/forest degradation
- Land use change
- Unplanned urban growth
- Water contamination
- Other: _____

13. Imagine experiencing each of the following events. For each event please indicate how much this would make you want/need to leave the region where you currently live (or are answering for)

Mark only one oval per row.

	1. I would definitely stay (doesn't impact me)	2.	3.	4.	5. I would definitely leave (impacts me a lot)
No jjobs					
Nott safe					
No heallttth serrviice					
Negattiive polliittiicall siittuattiion					
Bad aiirr qualliitty					
Too many exttrreme weattherr eventts					
Too hott					
Too drry					
Too wett					
Wiindsttorrms					
Riiverr Flloodiing					
Fllash floodiing					
Sttorrm surrge					

Landslides Landslides	⬭	⬭	⬭	⬭	⬭
Wildfires Wildfires	⬭	⬭	⬭	⬭	⬭
Cold spell Cold spell	⬭	⬭	⬭	⬭	⬭
Low air humidity Low air humidity	⬭	⬭	⬭	⬭	⬭

Thinking back over the last 10 years, can you think of any events that have made normal life hard to continue where you live (or where you are answering for)? For each event please give an indication of when this occurred (month/year) and the type of event (e.g. flooding, landslides, drought, wildfire, heatwaves etc)

14. Event 1

15. Event 2

16. Event 3

17. Thinking about weather and climate events that you have experienced in the past (e.g. drought, flooding, heatwaves, wildfires, landslides etc) how have these affected your daily life?

Mark only one oval per row.

	1. Not affected at all	2.	3.	4.	5. Very affected
Goiing tto schooll/uniiverrsiitty/worr k					
Beiing concerrned forr yourr own orr lloved ones lliives					
Damage tto iinfrrasttrructturre					
Meettiing up wiitth frriiends and famiilly					
Accessiing basiic necessiittiies lliike food,, watterr and ellecttrriciitty					
Menttall heallttth and rresiilliience					

18. Which of the following weather and climate events could affect your decision about where you might want to live?

Mark only one oval per row.

	1. This would not affect my decision at all	2.	3.	4.	5.	6.	7. This would greatly affect my decision
Flloodiing (eiittherr rriiverr orr flash floodiing)							
Drroughtt							
Ilnttense rraiinfallll							
Heattwaves							
Landslliides							
Wiilldfirres							
Wiindsttorrms							
Low aiirr humiidiitty							

19. To what extent do you class the following essential for you to live?

Mark only one oval per row.

	1. Not at all essential for me to live	2.	3.	4.	5.	6.	7. Completely essential for me to live
Access tto cllean watterr							
Shellltterr							
Food							
Cllean aiirr							
Heallttth							
Suiittablle ttemperratturre							
Publliic serrviices							
Goverrnance and Democrracy							

20. What do you need to thrive? This might relate to anything from having access to an education system to political stability

21. What resources/services would improve where you live? This could include cleaner air, cleaner water, better public transport etc

22. What is the best future you can imagine for where you live as the world gets hotter?

23. What is the worst future you can imagine for where you live as the world gets hotter?

The following demographic questions are to measure the reach of our questionnaire but will not be used to personally identify you

24. What gender do you identify as? *

Mark only one oval.

- Male
- Female
- Non-binary
- Prefer not to say

25. Which age group band do you fall into? *

Mark only one oval.

- Under 18
- 18 - 24
- 25 - 34
- 35 - 44
- 45 - 54
- 55 - 64
- 65+
- Prefer not to say

26. How do you identify yourself

Mark only one oval.

- White
- Black
- Yellow
- Mixed race
- Indigenous

Chapter 18 Appendix D: Relevant Outputs.

PCA 1

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.997	53.826	53.826	6.997	53.826	53.826	4.592	35.325	35.325
2	1.649	12.687	66.513	1.649	12.687	66.513	4.054	31.188	66.513
3	1.117	8.592	75.105						
4	.632	4.865	79.970						
5	.490	3.772	83.742						
6	.452	3.478	87.220						
7	.410	3.157	90.378						
8	.352	2.711	93.089						
9	.291	2.238	95.327						
10	.208	1.603	96.930						
11	.199	1.530	98.460						
12	.103	.795	99.255						
13	.097	.745	100.000						

Extraction Method: Principal Component Analysis.

PCA 2

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.718	71.475	71.475	5.718	71.475	71.475
2	.710	8.877	80.352			
3	.438	5.481	85.833			
4	.354	4.429	90.262			
5	.301	3.767	94.029			
6	.211	2.636	96.665			
7	.153	1.913	98.577			
8	.114	1.423	100.000			

Extraction Method: Principal Component Analysis.

PCA 3

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.737	68.425	68.425	2.737	68.425	68.425
2	.540	13.504	81.929			
3	.445	11.136	93.065			
4	.277	6.935	100.000			

Extraction Method: Principal Component Analysis.

Note: Full outputs of ANOVA tests, PCA, regressions, raw and transformed datasets, R code for text analytics are attached to the additional files.