



UNIVERSITY OF  
**LIVERPOOL**

**Assessing local opinions on the potential for the use of Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago.**

*Jamala Alexander*

MSc. Environmental Assessment and Management



*Session 2020/2021*

*The University of Liverpool*

*School of Environmental Sciences*

**Jamala Alexander (201443035)**

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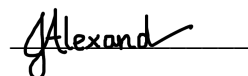
The University of Liverpool

School of Environmental Sciences

Being a dissertation submitted to the University in partial fulfilment of the requirements for the degree of Environmental Assessment and Management.

I declare that this dissertation is my own work.

SIGNED:

A handwritten signature in black ink, appearing to read 'Jamala Alexander', is written over a horizontal line.

Jamala Alexander

DATE: 09.09.2021

## Acknowledgements

*I dedicate this project to myself – as a testimony to my strength and perseverance.*

*A major thank you also goes out to my family and my supervisor, Dr. Sarah Clement, for their support and guidance throughout my academic career.*

*Finally, I am beyond grateful to the Caribbean Catastrophe Risk Insurance Facility (CCRIF) for serving as my sponsor for this Master's programme.*

This project assesses the potential for Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago. The topic was chosen as flooding is the most prevalent issue within the Caribbean state. This issue is worsened by a variety of environmental and human factors, making it a difficult problem to tackle, however, the implementation of Nature-based Solutions is seen as a key concept that can be implemented to make a difference. The study began with an extensive literature review which was used to develop an original conceptual framework, which served as the basis for the methodology used. Aside from documentary analysis, the data collection process included the dissemination of an online questionnaire and the conduction of semi-structured interviews - allowing for 119 individuals to contribute their opinions as research participants.

The results obtained indicated that most participants found both the use of conventional methods and the implementation of Nature-based Solutions to be effective - suggesting that these should be used in combination. Additionally, of the flood adaptation and management strategies covered, the maintenance of existing drainage and irrigation systems, creation of water retention ponds, and implementation of SUDS were seen as being the most effective based on public opinion. It is expected that this data will allow for decision-makers to become aware of how different approaches to flood management are perceived by the public, while also providing evidence for the creation and amendment of flood management and urban planning and environmental management policies. It is also recommended that this project could be extended through further research which should: (1) have an increased sample size, (2) assess areas in Tobago and (3) include detailed case studies to determine exactly how Nature-based Solutions can be incorporated.

**Key words:** Nature-based Solutions, Vulnerability, Flooding, Well-being, Urban Areas.

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Urban centres are at the heart of both compounding environmental challenges and potential solutions. In the past few decades, the world has seen exponential urban growth, and this growth is expected to continue as Kabisch et al. (2017) noted that while 50% of the world's population lived in urban areas in 2007, by the year 2050, that number will increase to 66%. This statistic is concerning as the rapid expansion of urban populations and areas comes with several negative long-term effects such as an increased threat to physical environments (While and Whitehead, 2013). Alongside this, climate change is expected to further aggravate these anticipated issues – putting decision-makers in a precarious position. This study focuses on how decision-makers may rise to the challenge of addressing environmental challenges in urban environments. As there is no preferred definition for an 'urban environment' - for the purposes of this study, it has been defined by the author as 'a human settlement with a relatively high population density and densely built environment'.

Climate change is increasing the 'frequency, intensity, spatial extent, duration, and timing' of weather-related events (IPCC, 2012), including hurricanes, storm surges, heavy rainfall. Such events can lead to a variety of impacts, including flooding, which the island of Trinidad and Tobago faces as its most prevalent natural hazard (Udika, 2010). Flooding can result in various health issues including injury, the spread of disease, loss of life, and declining mental health conditions, all of which can be compounded by and loss of property and/or agricultural goods. Thus, climate change is expected to put the health and well-being of many persons at increased risk, a large portion of which will include persons from Caribbean Small Island Developing States (CSIDS) due to their high susceptibility to climate change (Inter-American Development Bank 2014). While this is concerning, some researchers have noted that there can be more cost-effective solutions to these issues (World Bank, 2019), which can either challenge or complement conventional measures used to improving disaster risk reduction. These solutions, which put nature at the forefront, are referred to as Nature-based Solutions.

The European Commission (2020) defined Nature-based Solutions (NbS) as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience...". Considering the need for rapid adaptation to the effects of climate change, Nature-based solutions are currently being incorporated into government regulations and legislation of Global North countries, as

well as being rapidly implemented in their cities. While one would hope that Caribbean Small Island Developing States (SIDS) - which have an even higher vulnerability to the effects of climate change - would have made similar moves to help reduce vulnerability, there are currently no related policies in many Caribbean countries, including Trinidad and Tobago.

While one can argue that this may be largely due to a lack of knowledge with regards to the potential benefits of Nature-based Solutions on a local scale, it is already clear that such solutions would be especially beneficial to Caribbean states such as Trinidad and Tobago. To explain why we focus on two key terms from the definition provided above: (1) cost-effective and (2) resilience. Noting that Trinidad and Tobago is part of the Global South and has reduced financial capability in comparison to Global North nations, the dual-island nation could potentially benefit most from a cost-effective option like Nature-based Solutions. With regards to resilience, it was already highlighted that Caribbean SIDS have a high susceptibility to climate change, therefore, Nature-based Solutions can be implemented to reduce the vulnerability. The fact that there is funding for such projects from international organisations, and the potential for there to be wide-ranging co-benefits from any methods that are implemented, also places the concept in a positive light.

### ***Key issues to be investigated***

This dissertation will aim to explore the potential role that Nature-based Solutions can play in reducing vulnerability to flooding and improving well-being in urban areas in Trinidad and Tobago. It will take a participatory approach, aiming to incorporate diverse perspectives about the impacts of flooding, the degree of vulnerability, existing coping and adaptation strategies, and the usefulness of Nature-based Solutions. The research focuses directly on the urban areas in Trinidad and Tobago such as the East-West Corridor, where most of the population reside and the risk for flooding is noted to be high.

***Research Question:*** “What are the local opinions on the potential for the use of Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago?”



**Overall Aim:** To assess local opinions on potential for the use of Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago.

**Key Objectives:**

- i. To determine how the public has been affected by flooding, how they perceive their level of vulnerability, and what they consider to be the key environmental and human factors that contribute to flooding.
- ii. To determine the extent to which the public and key decision-makers find conventional coping and adaptation strategies effective.
- iii. To determine the opinion of the public and key decision-makers with regards to the potential implementation of Nature-based Solutions.

**Project Rationale**

This project is relevant to the field of planning and environmental management, as it will provide a clear record of public opinions which can be used as evidence for the future amendment and development of local flood management and planning policies in Trinidad and Tobago. Specifically, an assessment of how effective the local population perceives conventional flooding adaptation methods as being will provide information on if these methods are providing real benefits - allowing for better decisions to be made (should current adaptation methods be modified or left as is?). Additionally, information on how the public perceives the potential effectiveness of Nature-based Solutions can provide reasons for increased political support of such initiatives as, allowing for nature to be put at the forefront. Furthermore, the production of a case study would allow for key decision-makers to see how simple it can be to incorporate Nature-based Solutions into existing areas and will provide recommendations on the best Nature-based Solutions which can be implemented to achieve peak benefits. Moreover, the project can inspire a drive towards the increased implementation of Nature-based Solutions in Trinidad and Tobago, which can be financed through the obtaining of grants provided by the concept's international proponents. Therefore, this study will benefit a range of stakeholders such as planners, policymakers, environmental managers, and local and regional government bodies, such as the Ministry of Planning and Development and the Ministry of Works and Transportation in Trinidad and Tobago.

### *Structure of the project*

This dissertation is organised into 5 chapters. The following chapter examines literature related to vulnerability, conventional coping methods which are used to reduce the risk of flooding, and the current/potential implementation of Nature-based Solutions to reduce flooding in Caribbean SIDS. After this, Chapter 3 explains the process of research design and primary and secondary data collection, which is noted to include various data collection methods such as questionnaires, interviews, the assessment of two case study sites. Results are outlined in Chapter 4 and then, finally, Chapter 5 hosts the project conclusion, recommendations for further study, references, and appendices.

Reviewing existing academia is key to gaining a clear understanding of the topics being researched in this project and the gaps that occur in the literature. As such, I gathered a variety of information from academic journals, books, reports, and other documents - which are explored in this chapter. To begin, the chapter looks at the concept of vulnerability from a general point of view. Then, it focuses more specifically on vulnerability to flooding in Trinidad and Tobago. Next, it highlights the government ministries and agencies that are responsible for flood management in Trinidad and Tobago – outlining their various duties. This is followed by a section that summarises the current adaptation measures which have been put in place. Then it concludes with a section that outlines the development of NBS and discusses how nature-based solutions can be used to reduce vulnerability – with specific options being identified.

### ***2.1: Exploring Vulnerability***

'Vulnerability' a key concept in disaster risk reduction research has been defined in a multitude of ways over time. For example, natural scientists may prefer to define vulnerability in the context of risk as it is more likely to be able to quantify it (Nur and Shrestha, 2016). In contrast, social scientists tend to prefer definitions that are based on more qualitative aspects. For this study, the IPCC (2001) definition of vulnerability - 'the extent to which a natural or social system is susceptible to sustaining damage...' - will be used. In order to fully understand vulnerability, however, one should view it as resulting from the interaction of various parameters, which were listed by Adger (2006) as being: (1) exposure – the nature and degree to which a system experiences stress, (2) sensitivity - the degree to which a system is modified or affected by perturbations, and (3) adaptive capacity - the ability to evolve to accommodate environmental hazards or policy change and to expand the range of variability with which it can cope.

Considering this, Lankao and Qin (2011) add impacts and responses into the parameter interactions, suggesting that vulnerability is shaped by different factors which inhibit or enhance these parameters. As such, one can assume that any human or environmental factor which leads to increased exposure, increased sensitivity, and/or reduced adaptive capacity

within a social-ecological system would lead to increased vulnerability to hazards. For example, Nur and Shrestha (2016) suggest that socioeconomic, cultural, and political stresses in cities can heighten exposure and sensitivity while negative political dynamics can affect an individuals' capacity to adapt. However, the vulnerability of different individuals and communities is shaped by different factors. Noting this, in this project, we will be discussing the various factors which can lead to changes in vulnerability parameters in general, and then specifically in Trinidad and Tobago - giving a better understanding of the baseline situation for this study.

## ***2.2 Exploring the connections between Urban Areas, Climate Change and Vulnerability***

In recent history, the world has seen exponential growth in the global population, along with a process of rapid urbanisation. Both trends are predicted to continue, with almost three-quarters of the global population forecasted to live in urban environments by 2050 (Sinnott et al., 2015). Unfortunately, population growth and urbanisation have resulted in several socio-economic and environmental issues such as reductions in biodiversity, degradation of water supplies, and poor sanitation. Alongside these issues, there has also been the rise of anthropogenic climate change, leading to issues such as sea-level rise and increased storm frequency and intensity. These three key issues have influenced the creation of various environmental and human factors which can be said to increase vulnerability. Therefore, urban areas across the globe must consider the ways in which traditional land use and planning techniques are lacking (Dorst et al. 2019) and aim to find new techniques to counteract negative urban impacts and increased vulnerability.

## ***2.3 Vulnerability to flooding in Trinidad and Tobago and its contributing factors***

As mentioned previously, this dissertation focuses on Trinidad and Tobago – a twin-island republic in the Caribbean that experiences a tropical climate, strongly influenced by the northeast trade winds (Office of Disaster Preparedness and Management, 2014). The country's natural and anthropogenic characteristics make it prone to many hazards, however, in recent years the nation's most prevalent hazards have been hydro-meteorological events such as flooding (Office of Disaster Preparedness and Management, 2014). Flooding results in extreme economic and social costs such as property loss and health problems (Trinidad and Tobago

Parliament, 2020). This issue is multi-dimensional (Shrivastava, 2003), being caused by a combination of environmental and social factors, which will be highlighted in this section. As with other global areas, human factors such as population increase, and rapid urbanisation have made local flood management a challenge. In fact, Shrivastava (2003) stated that one of the three key anthropogenic factors that contributes to flooding in Trinidad and Tobago is the need for increased space for settling. Indeed, population growth has led to the local urbanisation of flood plains, and because urban areas are often designed to create impervious surfaces which change run-off patterns, there has been increased susceptibility to flooding. This increases the pressure places on drainage systems, leading many scholars to highlight the need for increased drainage and water storage capacity (Zhou, 2014).

Moreover, as a Caribbean SIDS, Trinidad and Tobago is especially vulnerable to the effects of climate change. In fact, in 2017 and 2018 Trinidad and Tobago experiences instances of extreme flooding that was caused by unprecedented rainfall and storm conditions (Trinidad and Tobago Parliament, 2020) leading to many cases of loss and disease. While Trinidad and Tobago exist within a tropical wet climate zone that is prone to high-intensity rainfall during the wet or 'rainy' season: June to November every year (Maingot, 2015). According to the Ministry of Works and Transport (MoWT), the 2018 floods occurred due to a 'continuous heavy rainfall' period, during which the island of Trinidad received a month's worth of rainfall during a two-day period from 18 to 19 October. Due to this extraordinary rainfall, Trinidad's natural watercourses were not effectively and quickly able to drain the stormwater (Trinidad and Tobago Parliament, 2020). This was further backed by data from the University of the West Indies (UWI) which attributed the flooding to extreme rainfall and high streamflow as catchment areas became saturated, leading to high runoff coefficients. There was also the fact that several rivers exceeded their capacity, spilling onto existing floodplains, leading to the flooding of settlements (Trinidad and Tobago Parliament, 2020).

On the anthropogenic side, there are a variety of other factors which contribute to the issue of flooding, including: (1) the need for improved flood risk data, (2) the need for improved research, allowing for improved planning and decision-making, (3) the indiscriminate disposal of solid waste and derelict objects (Shrivastava, 2003), (4) the persistence of inappropriate agricultural practices, (5) unplanned and improper housing development, and (6) deforestation (Udika, 2010). In the case of the 2018 floods, the Ministry of Works and Transport (MoWT) and Ministry of Planning and Development (MoPD) also listed the following human factors as key contributors: (7) the backfilling and illegal diversion of watercourses, (8) the indiscriminate

dumping of garbage, (9) insufficient drainage capacity, (10) blocked drainage channels, (11) informal settlements/construction, (12) conversion of reserved lands to housing, (13) unauthorised clearing and excavation of hillsides, (14) quarrying, and (15) inadequate legal enforcement (Trinidad and Tobago Parliament, 2020).

Noting the large variety of potential contributors to the issue of flooding, the question is raised – whose responsibility it is to manage and regulate these factors?

#### ***2.4 Responsibility for Flood Management in Trinidad and Tobago***

In February 2019, the decision was made to have an inquiry into ‘flood alleviation and control measures for major river basins and drainage catchments in Trinidad and Tobago’ (Trinidad and Tobago Parliament, 2020). In this inquiry, it was noted that there are multiple government ministries and agencies responsible for flood alleviation and control to varying degrees. Their related responsibilities, as outlined in the inquiry, are summarised in the table below:

<b><i>Ministry / Agency</i></b>	<b><i>Division / Unit</i></b>	<b><i>Responsibilities</i></b>
Ministry of Works and Transport (MoWT)	Drainage Division	<ul style="list-style-type: none"> <li>• the maintenance of natural watercourses and drainage structures along highways and major roadways.</li> <li>• the provision of advisory services to ensure “efficient and effective flood erosion and sedimentation control, drainage, irrigation, and reclamation, in a cost-effective manner”.</li> <li>• constructing, rebuilding, or altering any controlled structure over, in or under any controlled channel.</li> <li>• altering the banks or bed of a controlled channel.</li> </ul>
	Coastal Protection Unit	<ul style="list-style-type: none"> <li>• the mitigation of coastal flooding through the development of relevant policies and plans related to coastal preservation and rehabilitation.</li> </ul>
Ministry of Rural Development and Local	Municipal Corporations	<ul style="list-style-type: none"> <li>• the construction and maintenance of local roads, drains, irrigation systems, and watercourses - ensuring that they are clean and in good condition.</li> <li>• the identification of standards for development.</li> </ul>

Government (MoRDLG)		<ul style="list-style-type: none"> <li>the implementation of preparedness procedures, mitigation procedures, and procedures for before and after an emergency.</li> </ul>
Ministry of Planning and Development (MoPD)	Town and Country Planning Division (TCPD)	<ul style="list-style-type: none"> <li>the enforcement of land use policies that stipulate setback distances from rivers and watercourses.</li> <li>the establishment of no-build zones.</li> <li>the development of spatial planning guidelines.</li> <li>the identification of areas where: development should be prohibited due to flood risk, the watershed needs to be protected, and the slippage of the soil can be anticipated.</li> <li>the taking of action against unapproved and unplanned development (through its enforcement role).</li> </ul>
Ministry of Public Utilities (MPU)	Water Resource Agency (WRA) - WASA	<ul style="list-style-type: none"> <li>monitors rainfall, surface water, and groundwater systems</li> </ul>
	Meteorological Services Division (MET)	<ul style="list-style-type: none"> <li>provides meteorological information and advice</li> </ul>
	Solid Waste Management Company Limited (SWMCOL)	<ul style="list-style-type: none"> <li>monitors pre-warning flood alerts and prepares the landfills to receive post-flood debris</li> </ul>

***Table 1. Local ministries and agencies responsible for flood alleviation and their responsibilities.***

### ***2.5 Current adaptation in Trinidad and Tobago***

In the 2019 inquiry (mentioned above), it was recommended that all the responsible agencies and ministries that were listed above work towards doing more. However, as expanded on in the section above, while the flooding problem in Trinidad and Tobago is multi-dimensional, the approaches used have been mainly centred on traditional engineering-based approaches (Shrivastava, 2003; Braithwaite, 2012). Specifically, experts from the University of the West

Indies (UWI) have stated that Trinidad and Tobago's existing drainage infrastructure consists of lined and unlined channels, levees, hydraulic structures, and their control works, sumps, pumps, ancillary works, and detention basins - all of which are aged. Along with this, it was also highlighted that the existing drainage and pump and gate infrastructure were built to accommodate rainfall patterns from the 1960s - making them obsolete (Trinidad and Tobago Parliament, 2020).

Their response to these findings was to make several recommendations including the updating and finalisation of the National Flood Contingency Plan (2003) and the IWRM (2018) with current data and the creation of a Flood Management Act and/or National Drainage and Water Management Plan (Trinidad and Tobago Parliament, 2020). However, it is likely that, without some form of intervention, these policies will also be created from a one-dimensional point of view - leaving limited room for the consideration and inclusion of new approaches. While such limited approaches have proven to be unsuccessful, only providing temporary and symptomatic relief, they are visible and can be quickly mobilised, making them politically expedient with the ability to temporarily soothe public resentment (Shrivastava, 2003). This is likely a core reason why more contemporary methods such as the use of Nature-based Solutions, which will be clearly defined in the following section, have not been extensively considered, despite being known to have beneficial impacts.

## ***2.6 Defining Nature-based Solutions***

The concept of Nature-based Solutions (NbS), like many other environmental management concepts, evolved from early examples of 'urban experimentation' (O'Sullivan et al., 2020). That is, Nature-based Solutions can be said to have evolved from the work in the late nineteenth and early twentieth centuries, which promoted the use of nature as a tool to respond to urban issues. While the work in previous centuries was in response to the effects of technological advancement and growth in global cities - poor living conditions, air quality and drinking water, and increased disease (Eisenmann, 2013) - Nature-based Solutions initially entered mainstream literature in the early 2000s as a potential solution for agricultural problems. However, in the late 2000s, it began to be used when considering how nature could contribute to tackling challenges such as climate change (O'Sullivan et al., 2020).

While it is still relatively new, this concept has evolved rapidly, with many different definitions being applied. In many cases, Nature-based Solutions is defined solely in terms of the benefits



it can provide, for example, the IUCN (2016) defined it as “actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits”. Dorst et al. (2019) also took a similar approach, defining NbS as “interventions based on nature that are envisaged to address sustainability challenges such as resource shortages, flood, and heat risks and ecosystem degradation caused by processes of urbanisation and climate change”. However, definitions which only focused on the benefits have often been critiqued as being too vague, leaving three important questions unanswered; ‘What constitutes ‘nature’?’, ‘How should nature be incorporated?’ and ‘Who are the key actors?’.

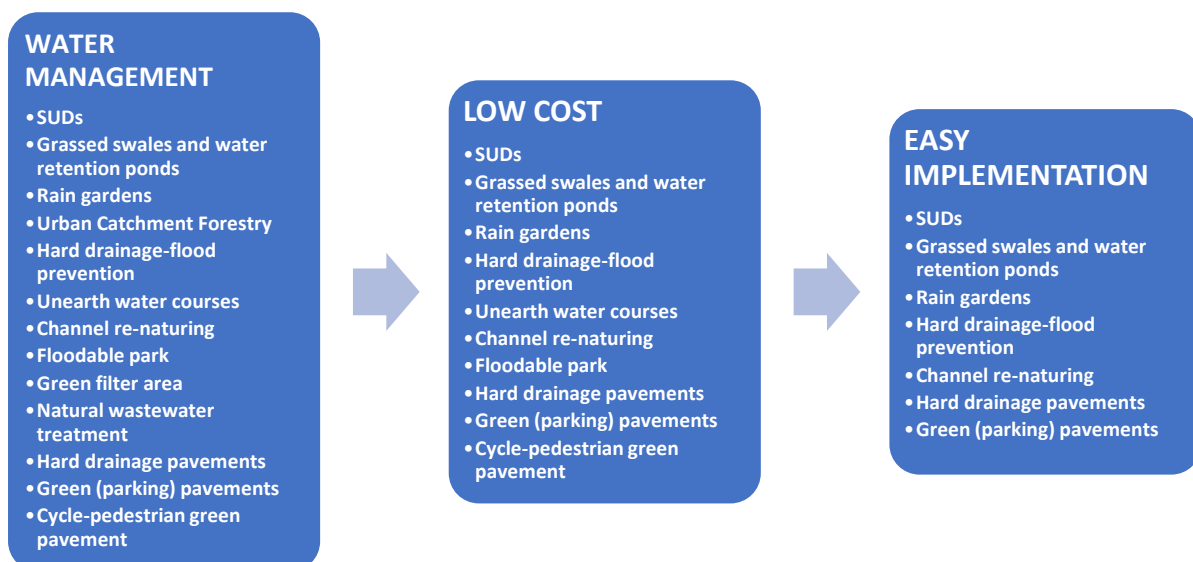
A different perspective, however, was brought by the European Commission and Directorate-General for Research and Innovation (2015), who defined Nature-based Solutions as “living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits”. This definition answers some of the previously unanswered questions, suggesting that nature means ‘living’ and that Nature-based Solutions should not only use resources efficiently but also be adaptable. However, the argument could be made that humans are also living - so it is still a bit unclear. Albert et al. (2020) also produced a rather well-rounded definition: “actions that (i) alleviate a well-defined societal challenge, (ii) utilize ecosystem processes of spatial, blue and green infrastructure networks, and (iii) are embedded within viable governance or business models for implementation”. Aside from just highlighting NbS as a solution, this definition insinuates that ‘nature’ refers to blue and green infrastructure and indicates that the practice should be incorporated within government and business models – suggesting that they are some of the key players.

While a variety of definitions were discussed above, the main definition that will be used in this study was created by the European Commission (2020), stating that Nature-based Solutions “are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience...”. This is firstly because of the use of the term “resilience” in the definition - a word that directly aligns with the field of disaster management. Nature-based Solutions are often seen as being able to contribute to the improved resilience of social-ecological systems as they help to build the capacity of an area to adapt to and resist future shocks (Kabisch et al., 2017). This definition was also chosen due to the incorporation of the word “cost-effective” which is extremely

relevant to the financial context of Trinidad and Tobago. Indeed, there is a general belief that Nature-based Solutions present more cost-effective solutions than existing approaches (Laforteza et al., 2018). Moreover, there is a multitude of funding options available from international organisations such as the World Bank for projects related to Nature-based Solutions - which countries that may have reduced financial capability, such as Trinidad and Tobago, can apply for. Now that the concept of Nature-based Solutions has been clearly defined, the next section will explain how it can be used to reduce vulnerability at a local level.

### ***2.7 The use of Nature-based Solutions to reduce vulnerability to flooding***

The term Nature-based Solutions can be used to describe the improvement of existing green space, the addition of new green space, or the greening of existing surfaces (e.g., green roofs), or water features (e.g., wetlands). Therefore, discussions around the implementation of Nature-based Solutions raises many questions surrounding which types of solutions would be most suitable for Caribbean SIDSs? To answer this question, the list of NbSs from the Urban GreenUP NBS Catalogue (2018) was narrowed down, firstly based on the solutions that focused on water management (resilience), and secondly, based on those with a low estimated cost (cost-effective), and lastly based on the ease of implementation (see process – Figure 1).



***Figure 1. The selection process for the Nature-based Solutions assessed in this study.***

### ***2.7.2 Water retention ponds***

These are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events (Urban GreenUP, 2021). They are usually created by converting an existing depression or newly excavated depression into a permanently wet pond and constructing embankments around it to provide temporary additional storage. Aside from assisting with storm water attenuation, they can also remove urban pollutants, improve the quality of surface runoff, support wetland planting and providing ecological, and amenity benefits (Urban GreenUP, 2018).

### ***2.7.3 Green roofs***

These refer to the external upper covering of a building for which the main aim is to favour the growth of vegetation (Urban GreenUP, 2021). To allow for this to be done while preserving the habitability of the rooms below, the green roof should be built with a variety of layers: (1) a waterproof layer that is resistant to roots, (2) a separating layer to protect the waterproof layer, (3) a draining layer, (4) a water retention layer, (5) a filtering layer, an absorbent layer, (6) substrate - to support the - (7) vegetation. Specifically, Braithwaite (2012) suggested that green roofs can serve as a good starting point as they retain significant amounts of rainfall from storm events which would otherwise flow quickly into the nearest receiving water body or drainage system – one of the main reasons for urban flooding.

### ***2.7.4 Rain gardens***

This is defined as a bioretention shallow basin designed to collect, store, filter and treat water runoff (Urban GreenUP, 2021). These often consist of a perforated pipe in a gravel pipe bed, which is placed below a draining soil mixture (50% sand, 20-30% compost, and 20-30% topsoil). It should also include vegetation with deep roots (e.g., Vetiver grass in the local context) and some plants that are capable of phytoremediation, and a curb and gutter with curb cuts to allow for water to enter the garden (Urban GreenUP, 2018).

### ***2.7.5 Channel re-naturing***

This entails the removal of the existing concrete riverbanks of channel and replace it with Terramesh walls that stabilise earth embankment and create green slopes by requiring vegetation (Urban GreenUP, 2021). Terramesh is a soil reinforcement system that consists of panels of double twist hexagonal woven heavy zinc and PVC coated wire mesh (Jayswal et al., 2014).

### ***2.7.6 Hard drainage pavements***

This is a combination of built and impervious surfaces and permeable material - a combination of hard (engineered) and an ecological surface (Urban GreenUP, 2021). Essentially, they consist of smaller areas of impermeable surface which are interspersed with open or grassed areas. These allow for the increased infiltration and retention of rain and surface water through paved surfaces before it is released into managed water systems. Commonly, hard drainage pavements are made of porous concrete or asphalt, permeable interlocking concrete pavers, or polymer-based grass pavers, grids, and geocells. Such innovations are suitable for pedestrian areas, cycling paths, car parks, and areas of standing water (Urban GreenUP, 2018).

### ***2.7.7 Green pavements***

Green pavements have “gaps, which will be filled with smart soil and with specific creeping grass species with a short growing and minimum maintenance period” (Urban GreenUP, 2021). They have large recesses to establish a green scene and ensure that water is either evaporated or absorbed. They are also appropriate for pedestrian, bike, and motor travel, while also providing other benefits such as: the provision of a growable surface (Urban GreenUP, 2018).

### ***2.7.8 Sustainable Urban Drainage (SUDS)***

This is a sequence of management practices, control structures, and strategies designed to drain surface water efficiently and sustainably while minimising pollution and managing the impact on water quality of local water bodies (Urban GreenUP, 2018). Woods-Ballard et al. (2015) noted that SUDS are meant to maximise the opportunities for surface water management. While they manage water quantity in a similar way to traditional drainage systems, they also assist with reducing water pollution because they naturally filter and treat water so that it can

be slowly released as new blue infrastructure (Zhou, 2014). This directly contradicts conventional urban drainage systems which can often lead to the disruption or contamination of existing ecosystems through the leakage of untreated water (Marlow, 2014). Regardless of these benefits, however, the use of SUDS for adaptation purposes has still been a slow process - a feature that may be because traditional cost-benefit calculations do not always favour Nature-based Solutions, making it difficult for investors to see the rewards of their implementation.

## ***2.8 Conclusion***

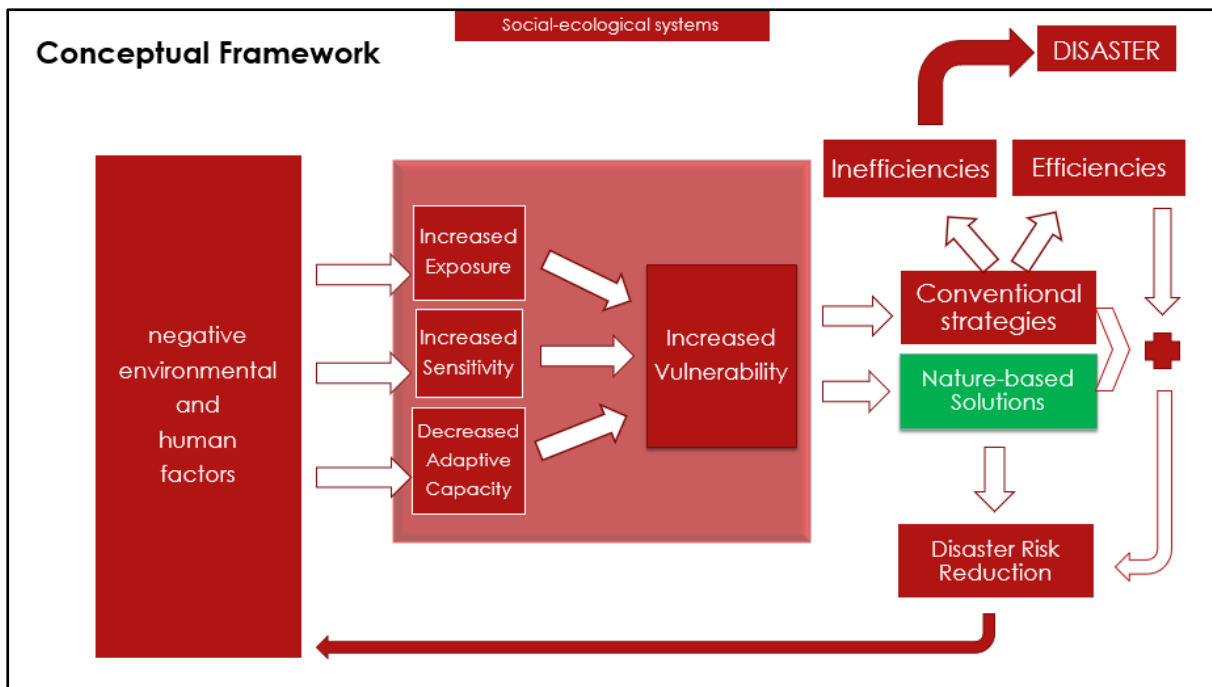
This research examines the potential for the use of Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago. This assessment began with the completion of a literature review that identified how the key themes of urbanisation, climate change, vulnerability, flooding, wellbeing, and Nature-based Solutions have been addressed in academic research. Based on this assessment, urban flooding in Trinidad and Tobago can be reduced through the implementation of a combination of Nature-based Solutions which can also lead to a variety of environmental, social, and economic co-benefits. The gaps identified during this part of the study, however, prove that further research is required to understand the potential for Nature-based Solutions to be effectively used across the country. The next section outlines the methodology that was used to further examine the key themes and knowledge gaps that were identified in this chapter.

This chapter explains the project's methodology, using relevant literature to explain how different data collection techniques have been employed to meet the research objectives.

### ***Research Design***

The research paradigm used in this project was post-positivist realism. Realism recognises that there is an external reality that consists of interdependent, complex structures and that different individuals have different perceptions of this said reality (Sobh and Perry, 2006). That is, this approach knows that there is reality, and there is a person's view on it – aiming to evaluate the different views of the existing reality and select the ones which are contextually relevant (Yeung, 1997). As stated above, the specific aim of this study is 'to assess the potential for the use of Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago'. For example, it is understood that different individuals will have different opinions about the potential impact that Nature-based Solutions can have on reducing vulnerability to flooding. Such understanding has influenced the research design of the study, while also being largely influenced by the conceptual framework (Figure 2) that was created by the researcher.

The conceptual framework was developed based on aspects of the literature reviewed above, related to vulnerability and Nature-based Solutions. The framework firstly emphasises that certain environmental and human factors can affect the parameters of vulnerability, as discussed in the literature reviewed. This leads to increased vulnerability to hazards such as flooding, which will trigger either the implementation of conventional mitigation or adaptation strategies or Nature-based Solutions. The framework highlights that while conventional strategies can only prevent disaster if they remain efficient, some degree of disaster risk reduction can always be achieved through either the sole implementation of Nature-based Solutions, or through a combination of conventional strategies with Nature-based Solutions. This dissertation focuses on most elements of this framework, except: (1) the parameters of vulnerability, and (2) the individual efficiencies and inefficiencies of conventional strategies.



**Figure 2. Conceptual Framework for this project.**

Recognising that data collection techniques should complement project objectives (Peters, 2017), the first step of creating the research plan was to clarify the relationship between the research objectives and selected methods – outlined in Table 1 below.

<b>Objectives</b>	<b>Methods Used</b>
i. To determine how the public has been affected by flooding, how they perceive their level of vulnerability and what they consider to be the key environmental and human factors that contribute to flooding.	Questionnaires
ii. To determine the degree to which the public and key decision-makers find conventional coping and adaptation strategies effective.	Questionnaire Interviews
iii. To determine the opinion of the public and key decision-makers with regards to the potential implementation of Nature-based Solutions.	Interviews

**Table 2. The relationships between research objectives and selected methods**

## ***Data Collection***

For this study, research was conducted using both primary and secondary data collected during the period from March to August 2021. As shown in the table above, the project focused on a mixed method approach, however, qualitative data collection techniques were primarily used. This aligns with the research paradigm as qualitative data collection can allow for one to uncover multiple perspectives. There is also a consensus that moving away from traditional quantitative methods would be beneficial for planning research (Sandercock, 1998).

### ***Secondary Data Collection - Document Analysis***

Being defined as “a systematic procedure for reviewing or evaluating documents” – this method aims to elicit meaning and understanding (Bowen, 2009). This process entails the finding, selecting, appraising, and synthesising of data from these documents, leading to the extraction of key excerpts and quotations (Bowen, 2009). This was a key component in this study – with the data used coming mostly from academic journals, policy documents, books, and reports that were sourced through online services, the Sydney Jones Library, or conversations with supervisors and interviewees. These sources not only helped with the identification of the main research gaps at the beginning of the study but have also allowed for the gathering of data on the issue of flooding in Trinidad and Tobago, the conventional measures that have been used to respond to the issue, and the degree to which Nature-based Solutions have been considered or implemented thus far. On the other hand, while quantitative (numerical) secondary data is often free to access, and less time consuming to collect (White, 2010), it was very difficult to obtain. As such, primary data was collected in its stead. This allowed for the determination of the (perceived) effect of flooding in Trinidad and Tobago. Indeed, document analysis is often used in tandem with other research methods to allow for triangulation, that is, to show that the study’s findings are not a result of bias or a single data source (Bowen, 2009).

### ***Primary Data Collection***

The collection of primary data, to facilitate the completion of all project objectives, took place through the completion of several tasks which were conducted at varying times throughout the (aforementioned) study period. These tasks were divided as follows:



### ***Part 1: Online, Self-Administered Questionnaire***

The use of questionnaires is known to have several advantages including low cost, minimal training for administration, the ability to reach large numbers of a target population and the potential to be delivered in a variety of ways ranging from verbal methods or web links (Jones et al. 2008). Thus, this method will be expected to allow for the successful completion of the first two objectives: (i.) to determine how the public has been affected by flooding, how they perceive their degree of vulnerability and what they consider to be the key environmental and human factors that contribute to flooding and (ii.) to determine the degree to which the public finds conventional coping and adaptation strategies effective. It will also contribute to the third objective by assessing the public opinion with regards to the potential implementation of Nature-based Solutions.

To address these objectives, the questionnaire began with a section that allowed for respondents to confirm that they currently live, work or study in an urban area. After this, respondents were provided with a listing of the past five years (including 2021) and were asked to indicate when there were affected by flooding events during this period. Survey respondents were then asked to identify exactly how they were affected: (1) during or immediately after the flood and, (2) in the weeks and months after flooding events. This was done by providing a list of psychological and physical effects - taken from a paper by Tunstall et al. (2016) which examined the extent to which flooded residents reported suffering physical and psychological health effects during and after the event - and asking participants to select all of those which applied. The option was also left open for participants to include any other effects which were not listed (see Appendix 1).

After the flooding section, a definition of vulnerability was provided, and the respondents were asked to state how vulnerable they believed their respective communities, workplaces, and educational facilities were to flood. To do this, respondents were asked to rank the vulnerability of these areas on a Likert scale which ranged from 'Very High Vulnerability' to 'Very Low Vulnerability'. Following this, respondents were provided with a list of environmental and human factors and were asked to select the factors that they thought contributed to flooding vulnerability. Another option was also provided to allow for the respondent to include any other factors which may not have been listed.

In the next section, respondents were provided with a list of typical coping and adaptation strategies that are used to tackle flooding in Trinidad and Tobago and were asked if they

recognised any of the measures as being used in their area(s). The list of measures provided was based on a variety of research papers, but mainly Shrivastava (2003) and Braithwaite (2012). The participants were then asked to assess the effectiveness of these measures using a Likert scale wherein 5 indicated that the method is 'Very effective', 1 indicated that the method is 'Very ineffective' and 3 indicated that the respondent is unsure.

In the second-to-last section, survey participants were provided with a definition of 'Nature-based Solutions' and were asked: (1) if they were familiar with the term, and (2) if they believed that Nature-based Solutions can help to moderate the issue of flooding in Trinidad and Tobago. Then they were provided with a list of Nature-based Solutions and were asked to state how effective they believe these methods could be if implemented locally. Once again, this was done using a Likert Scale, which used the same values outlined in the previous section. This section then closed by asking the respondents if they recognised any of the Nature-based Solutions as already being used in Trinidad and Tobago, and to state where they recalled seeing them. Then, finally, the survey was closed by asking a series of demographic questions.

Once the questionnaire (Appendix 1) was complete, it was pre-tested with a sample group of five persons. Pre-testing refers to testing a questionnaire or set of questions on members of the target audience (Czaja, 1998). This is usually done to address problems related to: (1) respondent comprehension, burden, and interest; (2) interviewer tasks; (3) other questionnaire issues e.g., do the questions have a logical flow?; (4) sampling e.g., are there any issues with completeness and accuracy?; and (5) coding and analysis (Czaja, 1998). In this study, the first, third and fourth issues were focused on during pre-testing and the main technique was the use of follow-up probes which, according to Czaja (1998), can allow for an analysis of comprehension, information retrieval and the adequacy of close-end answer categories.

Then the final questionnaire was disseminated to the public in Trinidad and Tobago by sharing the form on varying social media platforms. Due to the COVID-19 pandemic, this electronic sharing was the only seeding option available. While this led to concerns about being able to achieve a diverse group of respondents, there are various benefits that are known to be associated with online questionnaires. For example, Jones et al. (2008) noted that web questionnaires can allow for data entry to be controlled through real-time error checking, ensuring that the questionnaire is completed properly before it is submitted. It can also be configured to allow for it to be directly transferred to the analysis software with no need for re-keying (Jones et al., 2008) – a feature which allowed for the smooth transfer of data to the

Microsoft Excel software, which was used to produce clear, comprehensive graphs to support data analysis.

## **Part 2: Semi-structured Interviews**

Interviews, which can take place in a structured, semi-structured, and unstructured manner, are one of the most common forms of data collection (Whiting, 2008). This occurs when questions are pre-planned, but the interviewee also has the freedom to diverge from predetermined questions and use other open-ended questions to allow for the interviewee to elaborate on intriguing aspects, as needed (Alsaawi, 2014), that is, semi-structured interviews provide more flexibility than structured interviews (Whiting, 2008). Semi-structured interviews were chosen as the preferred method for this study as they are more in-depth than structured interviews, allowing for direct questions to be used to elicit detailed responses (Whiting, 2008). Thus, this method allowed for the successful completion of the second and third objectives – with a focus on the opinions of professionals - and provided anecdotal evidence to support the quantitative survey data (Vaughn and Turner, 2016).

While the aim was to interview a range of 6-10 persons who are key thinkers, influencers, and decision-makers in the realm of planning, environmental management, and disaster management, contacting persons in relevant fields proved difficult. Instead, a total of four individuals engaged in a formal, semi-structured interview. Of the three interviewees, two were men, helping to increase the incorporation of the male perspective into the survey data (as only 37% of questionnaire respondents were male). Due to the COVID-19 pandemic, all interviews were conducted online, using Zoom, and all interviewees provided verbal and written consent for their interviews to be recorded to facilitate verbatim transcription at the end of the data collection period, so that direct quotations could be used in the main text.

As mentioned previously, the interviews aimed to meet objectives two and three, so, two of the key questions that were asked to all interviewees were (1) “Do you find conventional methods used for coping with and adaptation to flooding effective?” and (2) “Are you familiar with the notion of Nature-based Solutions for flood risk reduction? If yes, what is your opinion on its implementation?”. Once these interviews were transcribed, the qualitative analysis process began. This was done using “thematic coding” - a very common approach used in qualitative data analysis (Alsaawi, 2014). The thematic coding process followed the procedure outlined by Vaughn and Turner (2016) by beginning with the review of each question, and identification

of relevant themes, then creating a coding system and using it to code the interview transcripts. Due to time constraints, however, it was found that some of the interview data could not be properly analysed, and thus, practical decisions were made to limit the analysis to the most useful data obtained.

### ***Limitations***

It must be stated that the entirety of this study was interrupted by the COVID-19 pandemic, during which movement was more strictly regulated. This limited the scope of research that could be carried out, and limited data collection methods to those which could be carried out digitally. The size of the survey group also did not allow for a statistical representation of the local population, limiting options for data analysis. While social researchers such as Jowett (2020) and Townsend (2020) have shown concern about project viability due to the pandemic, the research was still conducted successfully, with interviews being conducted on Zoom, and the questionnaire being distributed across social media platforms.

### ***Ethical Concerns***

This dissertation received ethical approval from the Central Human Research Ethics Committee and all ethical guidelines were followed to ensure that the rights of all participants are upheld. The ethics application also included a special amendment to allow for the researcher to engage participants who reside outside of the United Kingdom. This amendment was considered minor, especially as the researcher is a citizen of Trinidad and Tobago.

For this paper, a total of 116 individuals were surveyed. Of the respondent group, 62% were female while 37% were male and one respondent preferred not to disclose their gender. In the case of age, 47% of respondents were 18-24 years of age, while 34% were 25-34 years old and 16% were in the 35-44 age group. It is recognised that this is still a rather young survey group, a factor this is anticipated to be because the survey was carried out online. Furthermore, 36% regarded themselves as being of East Indian descent while 34% identified as being of African (Black) descent and the rest stated that they were mixed race. Most respondents put their current education level as ‘Bachelor’s degree or equivalent’ and were either students (22%) or involved in some form of employment, be it temporary, permanent, or self-employed (58%). As highlighted in Table 3 below, the urban areas which were most represented by the survey respondents were San Fernando, Port of Spain, and Curepe/St. Augustine.

Urban Area	Number of Respondents that live in this area	Number of Respondents that work in this area	Number of Respondents that study in this area
San Fernando	27	17	13
Curepe/St. Augustine	14	15	37
Port of Spain	3	21	4

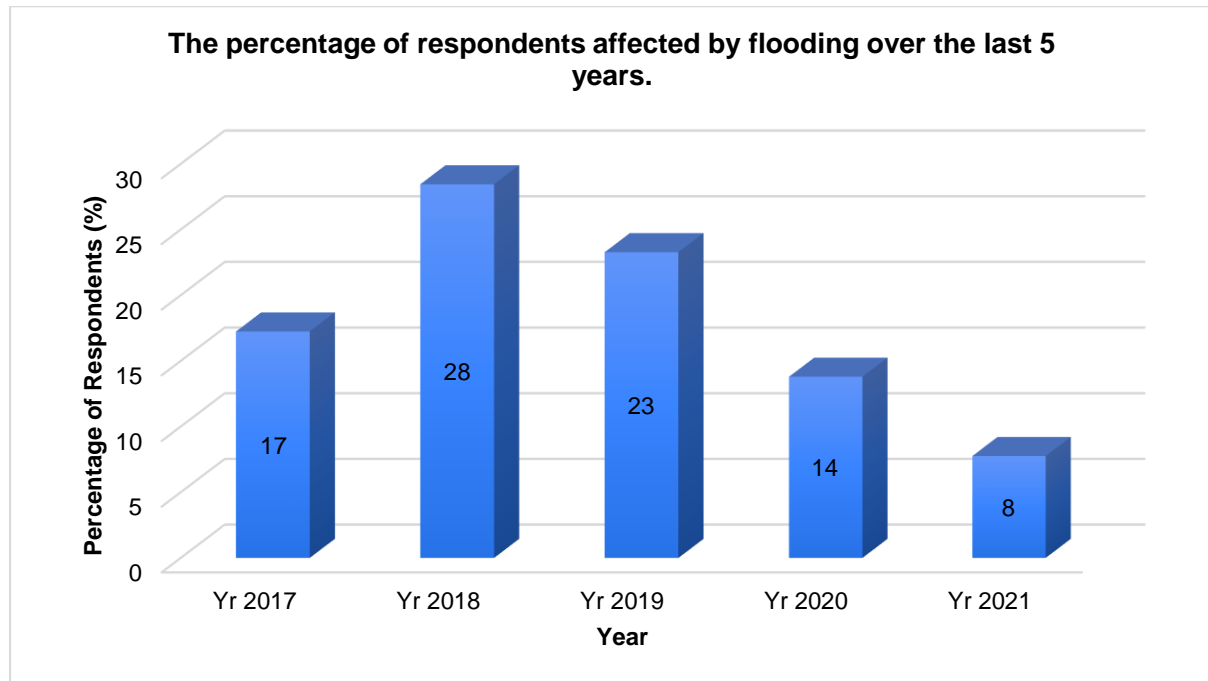
*Table 3. The most popular urban areas represented by responded.*

In contrast, interviewees were mainly men (2/3) with all interviewees falling within the age range of 25-54, thereby somewhat making up for the prevalence of young survey respondents.

### **FLOODING:**

A pool of questionnaire items was developed to examine if and how the respondents were affected by flooding in the past five years. Specifically, this section of the questionnaire began by asking respondents to indicate exactly when over the last five years they were affected by flooding. While it was anticipated that the number of persons affected by flooding would increase progressively with time, the results (Figure 3) showed otherwise. While the low value recorded for the year 2021 can be explained by the fact that the data for this study was collected before the rainy season, when instances of flood would be higher, it is unclear as to why there

was a lower value for the year 2020. Unfortunately, quantitative data was not available to see if this aligned with the actual degree of flooding that year, however, it is noted that the qualitative data that was reviewed made no note of any major flooding incidences during 2020 (in comparison to 2018).



**Figure 3. The percentage of respondents affected by flooding over the last 5 years.**

Next, the questionnaire moved into identifying exactly how respondents were affected during or immediately after the flood and then how they were affected in the weeks and months after flooding events. This was done by providing a list of potential emotional and physical effects and asking respondents to select all of those which applied. The list that was provided was roughly based on the list of 'Self-reported physical and psychological health effects: flooded sample' that was presented in the paper 'The health effects of flooding: social research results from England and Wales' (Tunstall et al., 2016). The option was also left open for respondents to include any other effects which were not listed.

Figure 4, below, highlights the most common effects experienced by participants during or immediately after flooding events. Based on the bar chart, the most common effect experienced was the disruption of transportation services, which prevented individuals from commuting to or from home, work and/or school. This result was the only 'surprise' on the chart, as this was not listed in the survey as a potential effect but was experienced by numerous participants. It

should also be noted that while this chart only showed the effects that were reported by more than 5 respondents, there were other lesser reported effects.

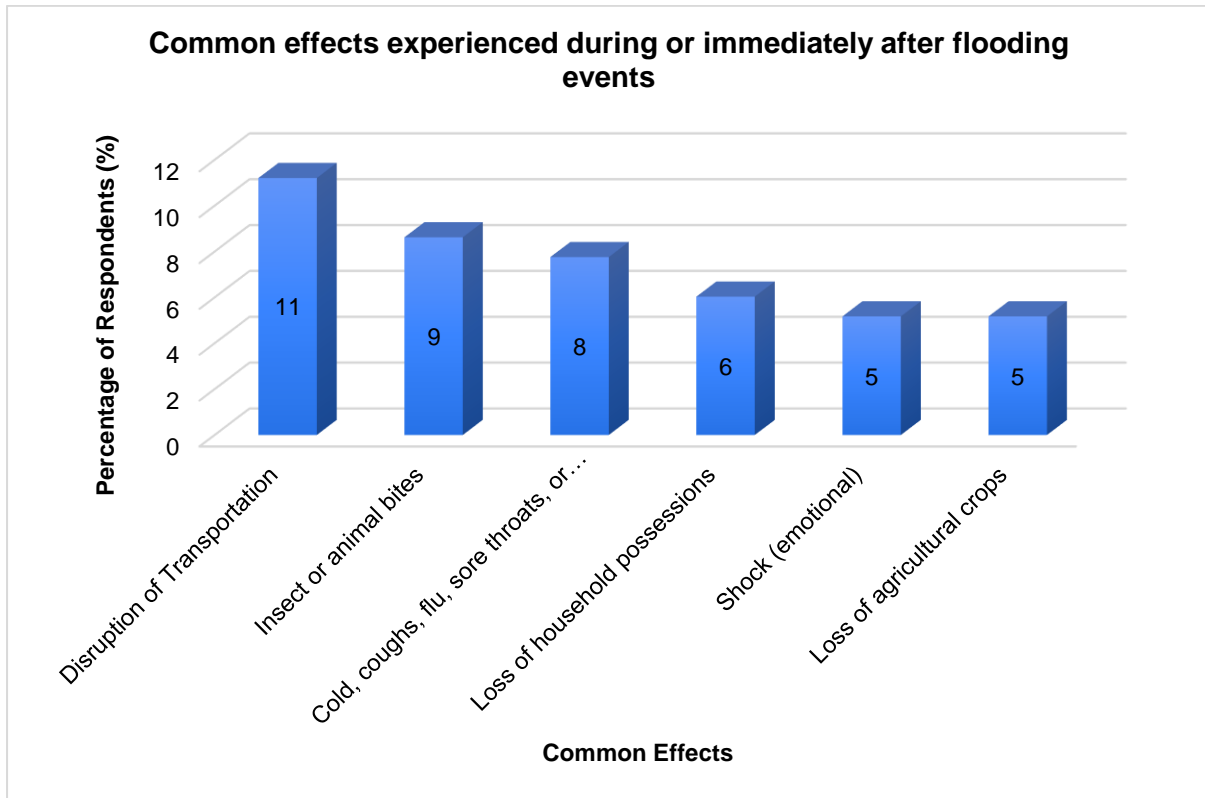
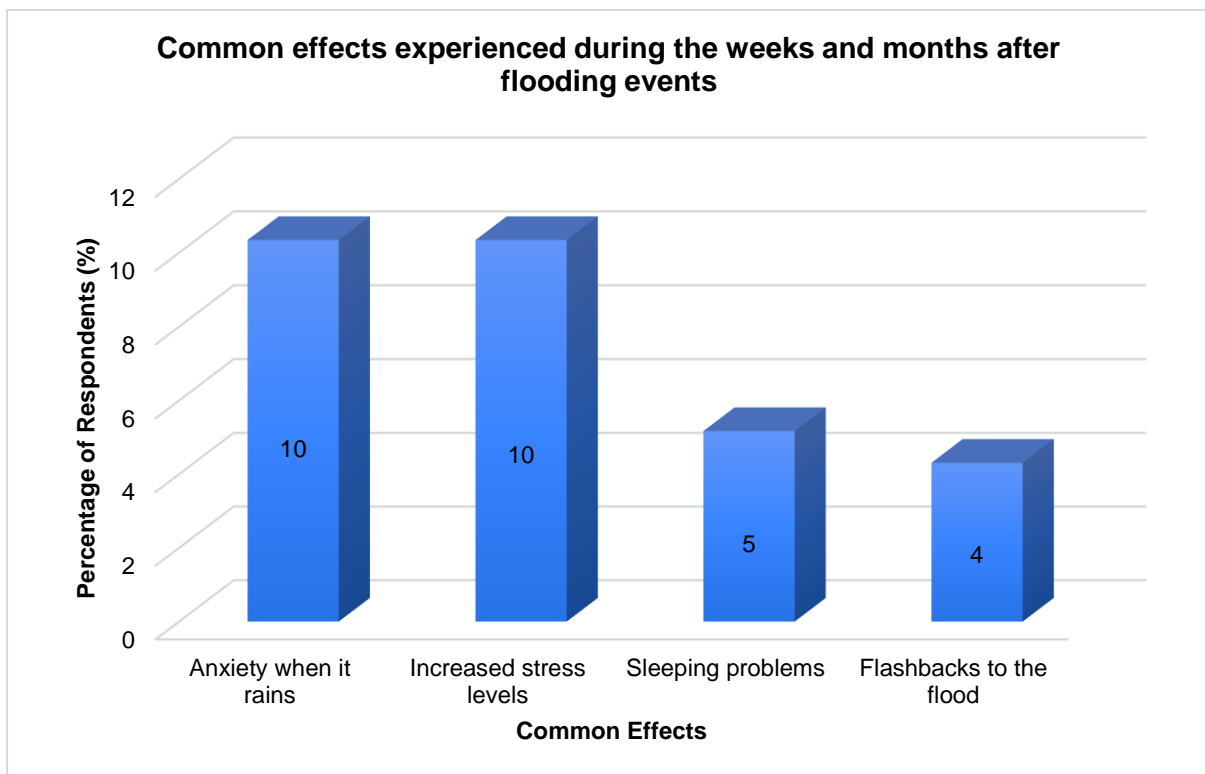


Figure 4. Common effects experienced during or immediately after flooding events.



**Figure 5. Common effects experienced during the weeks and months after flooding.**

Figure 5, above, highlights the most common effects experienced by respondents in the weeks and months after flooding events. The chart showed that all the common effects were emotional in nature, with the most popular effects being a feeling of anxiety when it rains and increased stress levels. Once again, it should be acknowledged that this chart only showed the effects that were reported by more than 5 respondents, there were other lesser reported effects.

**VULNERABILITY**

In this questionnaire section, respondents were asked to rank the vulnerability of their communities, workplaces, and educational facilities on a 5-point Likert scale which ranged from ‘Very High Vulnerability’ to ‘Very Low Vulnerability’ – the results of which are seen below:

<b>Urban Area</b>	<b>Average</b>	<b>Mode</b>
If you live in an urban area, how vulnerable do you believe your community is to flood?	2.3	2
If you work in an urban area, how vulnerable do you believe your workplace is to flood?	3.1	3
If you study in an urban area, how vulnerable do you believe your educational facility is to flood?	3.1	3

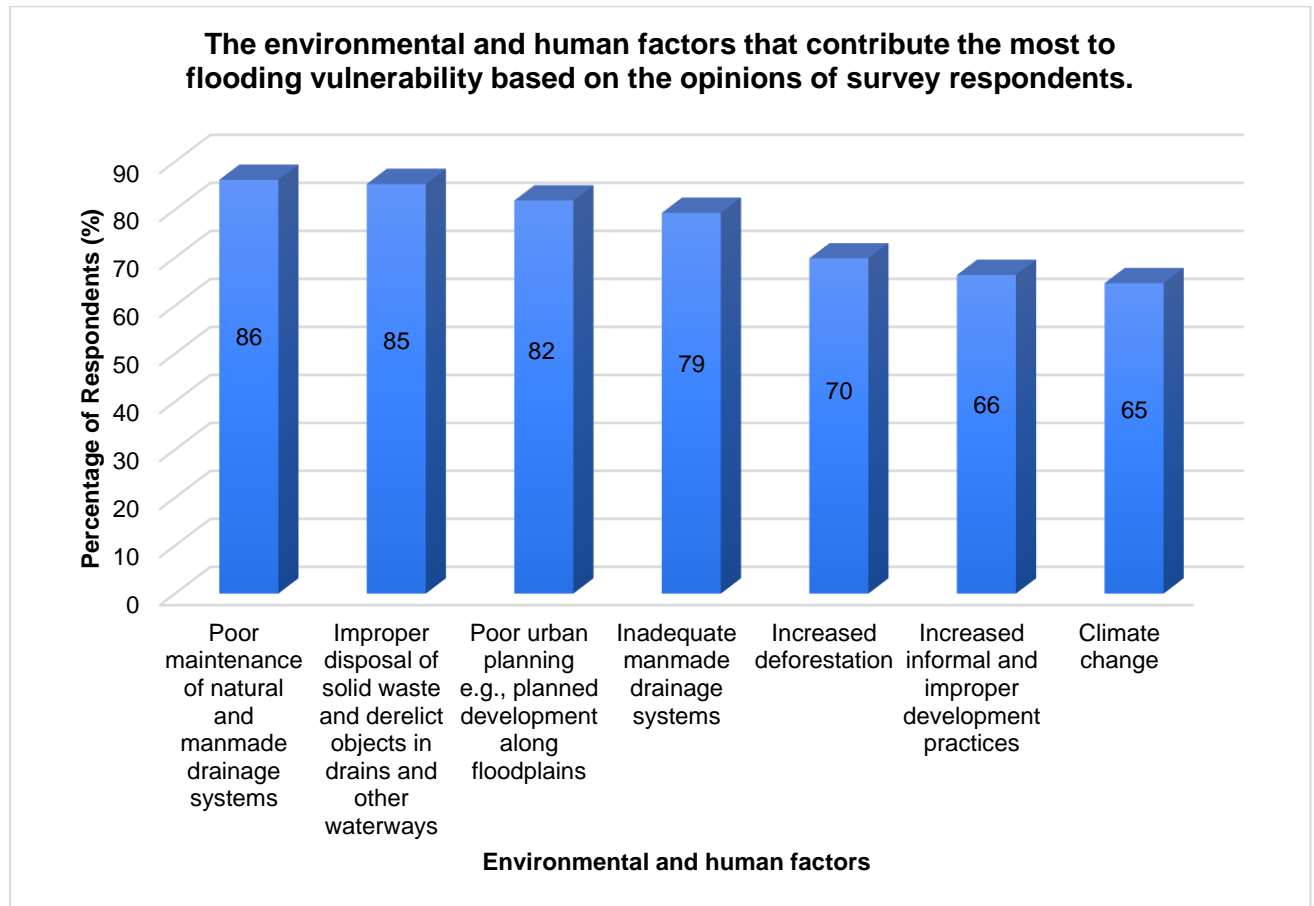
***Table 4. Perceived vulnerability to flooding by survey respondents.***

Table 4 shows the average and mode response values to the questions listed. It should be noted that the mode was used rather than the median, as it provides the most common response for Likert scale questions. In this case, the average and mode values were very close, with the results showing that most participants ranked their community as having a low level of vulnerability, and their workplaces/educational facilities as having a medium level of vulnerability to flooding. This was not surprising considering that 65 participants stated that their homes, workplaces, and educational facilities had not been affected by flooding during the last five years. However, it is surprising considering the prevalence of flooding in Trinidad and Tobago.

This section of the questionnaire ended by asking respondents what environmental and human factors they thought contributed to flooding vulnerability. These results showed that most



participants seemed to blame human factors for prevalence of flooding, instead of natural factors. The four most popular factors were all human in nature, with the most popular reasons being: (1) poor maintenance of natural and manmade drainage systems and (2) improper disposal of solid waste and derelict objects in drains and other waterways.



**Figure 6. The main factors contributing to flooding vulnerability based on the opinions of respondents.**

These ratings were not surprising considering the statements made by interviewees such as one of the *Environmental Biologists* at the Ministry of Planning and Development who said:

“You have to look at what are the causes of the flooding...and it is probably because you have compromised your drainage system. In that, your drainage network now is unable to accommodate the volume of water...”

In addition to this, he also made note of “Uncontrolled, unregulated development”. Both of his responses aligned with the first and third more common factors that were highlighted by survey respondents.

Another interviewee who works within the PURE Division of the Ministry of Works and Transport stated that in his opinion:

“The biggest issue is unplanned development...with development comes an increase in surface runoff and I don’t think we’ve been treating with that as well as we should...I don’t think people realise how much we increase the surface runoff by development. We don’t have a policy here for people controlling their own, how they develop their own land...there is nothing stopping you from paving your entire yard with concrete...”

This aligns with “Increased informal and improper development practices”.

One interviewee who works in disaster management highlighted the fact that environmental factors also play a large role with regards to the flooding issue. Aside from her making mention of informal settlements, improper land use planning, and development and unsustainable land use practices, she also stated that:

“The hazards are...intense rainfall over a brief period - leading to flash flooding, prolonged rainfall - light to moderate - that could lead to riverine flooding, coastal flooding...we also have tropical cyclone systems and we have weather patterns or climatic features that result in flood...”

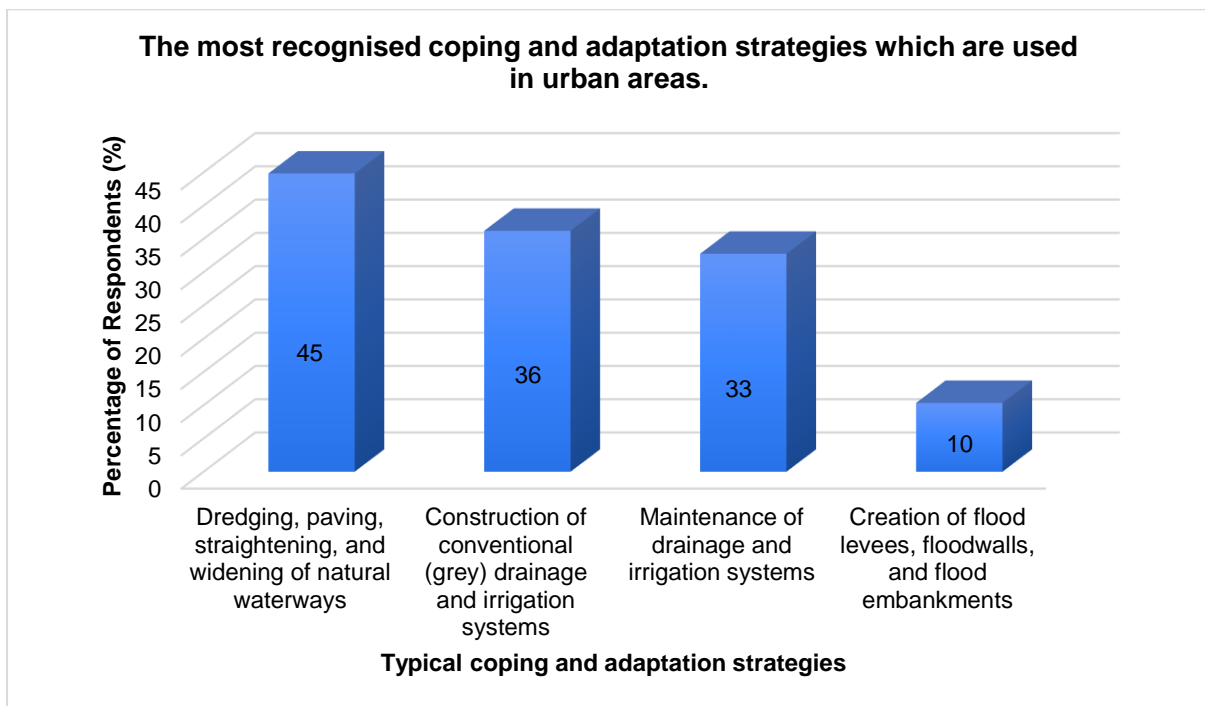
In the next section of this chapter, we will look at what has been done to respond to these environmental and social factors.

## **PUBLIC OPINIONS ON THE TYPICAL COPING AND ADAPTATION STRATEGIES FOR FLOODING**

Proposed solutions for flooding in Trinidad and Tobago have been centred on traditional engineering-based approaches. This section therefore opened by providing the respondent with a list of typical coping and adaptation strategies for flooding in Trinidad and Tobago and asking the respondents if they recognised any of the measures as being used in their area(s). The list of measures was based on research completed by a variety of researchers, but mainly by Shrivastava (2003) and Braithwaite (2012).

The results of this exercise showed that most respondents have witnessed the ‘Dredging, paving, straightening, and widening of natural waterways’ in their area, along with the

construction and maintenance of conventional drainage and irrigation systems. However, many of the listed responses got very low recognition and therefore were not included on the graph below. Some of these strategies included: ‘Restricting development along flood plains’, ‘Restricting the removal of vegetation cover such as trees’, and the ‘Creation of concrete reservoirs’. It is also interesting that 38% of respondents indicated that they could not recognise any of the strategies listed as occurring in their urban area.



**Figure 7. The common coping and adaptation strategies used in urban areas, as recognised by survey respondents.**

The effectiveness of the measures which have been commonly implemented was assessed in the questionnaire using Likert scale questions, the results of which are presented below:

**Scale: 1 – Very ineffective, 2 – Ineffective, 3 – Unsure, 4 – Effective, 5 – Very effective**

	Average	Mode
Dredging, paving, straightening, and widening of natural waterways	3.5	4
Construction of conventional (grey) drainage and irrigation systems	3.4	4
Maintenance of drainage and irrigation systems	3.8	4
Restricting development along flood plains	3.7	5

Restricting the removal of vegetation cover such as trees	3.7	5
Creation of flood levees, floodwalls, and flood embankments	3.6	4
Creation of concrete reservoirs	3.3	3
<b>Overall</b>	<b>3.6</b>	

*Table 5. Likert scale effectiveness ratings for typical flooding coping and adaptation strategies.*

These results show that, overall, the respondents find conventional methods to be generally effective (3.6/5.0). When looking at the individual methods, the method which was seen as being the most effective was the maintenance of drainage and irrigation. In contrast, the ‘Creation of concrete reservoirs’ (3.3/5.0) and ‘Construction of conventional (grey) drainage and irrigation systems’ (3.4/5.0) had the lowest ratings. This may be because some respondents who may have these occurring in their areas still deal with the issue of flooding, and thus may see them as less effective.

With regards to the opinions of the interviewees, when asked if they find conventional methods (alone) to be effective, they shared the following:

“It’s hard to say...But, from my perspective, what we currently are doing, it isn’t sufficient.” – *Employee at the PURE Division of the MOWT.*

“Explicitly my answer is no ...I would not advocate for the Ministry of Works to stop what they are doing; I just think that that needs to be done in tandem with other things.” – *Environmental Biologist at the Ministry of Planning and Development.*

“I think the evidence speaks for itself in terms of why not...Our methods clearly have not been working because our risk has been evolving...maybe it has lowered the impacts but...the aftermaths of flood [still] have us significantly impacted” – *Disaster Management and Health Specialist.*

## PUBLIC OPINIONS ON NATURE-BASED SOLUTIONS

Nature-based Solutions (NbS) put nature at the forefront when aiming to tackle environmental and societal challenges. It is defined by the European Commission (2020) as “solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience...”. All respondents were provided with the previous definition and were asked if they were familiar with the term ‘Nature-based Solutions’, to which most respondents (59%) responded positively. The respondents were also asked if, based on the definition provided, they think that Nature-based Solutions can help to moderate the issue of flooding and improve well-being in Trinidad and Tobago - in response to which, 89% of respondents said yes. These positive responses were backed up by statements such as:

“I believe that it will improve the flooding and wellbeing because it would reduce water pollution and increase vegetation. In my opinion, grey engineering has done more harm than good, in the sense that it creates a solution to the problem for one area but in turn, it creates a problem for another area.”

“Within the context of flooding, Nature-based Solutions (NbS) can moderate the issue of urban area flooding. A major issue within urban areas [is] the increased concretization of what was previously natural surfaces, which reduces water infiltration, thereby augmenting surface runoff. In this regard, Nature-based Solutions can provide increased green infrastructure or spaces that can aid in reducing runoff via increased water retention within the soil.”

“Removing of nature highly contributes to the flooding problems in Trinidad so implementing techniques that incorporate nature at the forefront of the solution is a great approach to tackling the issues and a more natural approach that restricts further concrete development”

However, other respondents disagreed with this. For example, some respondents said:

“Truthfully, I strongly believe the flooding issue which occurs in Trinidad is heavily due to Pollution and I do not think NBs can help if pollution continues to increase. What we need is to find more ways to decrease Pollution. Drainage can only do so much if they are not clogged by waste and garbage.”

“The level of flooding being experienced in Trinidad over the past 5-10years requires much more drastic flood mitigation plans than NBS offers. While it will work for moderate rainfall, it will be of no use during periods of heavy, prolonged, frequent rainfall.”

With regards to the opinions of the interviewees, when asked their opinion on the potential for Nature-based Solutions to be implemented in Trinidad and Tobago, they shared the following:

“I endorse the use of Nature-based Solutions here in T&T...we have a wide expanse of risk that we are exposed to, we have all these characteristics that are synonymous with Small Island Developing States...yet still the application of green infrastructure in any way, or Nature-based Solutions has been minimal... Do I think Nature-based Solutions as a whole is enough to manage flood risk in Trinidad and Tobago? I don't see it happening, but I think we can come up with joint solutions.” - *Disaster Management and Health Specialist*.

The Environmental Biologist at the Ministry of Planning and Development also agreed with the use of Nature-based Solutions but believed that a lot of those solutions should come in the form of restrictions to protect existing natural areas. He suggested, for example that: “we should now declare a moratorium on hillside development”

However, one interviewee pointed out that the idea of implementing Nature-based Solutions will need to gain political support if it is to ever gain traction in Trinidad and Tobago. He said:

“It has to have the political will...at the end of the day if we don't get buy-in from the powers that be, the decision-makers, then things would not really be implemented. I don't foresee any sort of pushback from the general public...you need to really convince the higher ups that it will be beneficial and that should be the focus...” - *Employee at the PURE Division of the MOWT*.

The PURE Division employee appeared to be correct that there would be minimal pushback from the public, as when survey respondents were asked to rate the perceived effectiveness of

different Nature-based Solutions using Likert scale questions, the results were very positive with most respondents find Nature-based Solutions to be effective (3.7/5.0) – ranking them as .1 more effective than conventional methods. When looking at the individual methods, water retention ponds were seen as being the most effective (4.0/5.0) method, followed by SUDS (3.9/5.0). In contrast, the ‘Grassed Swales’, ‘Green roofs’ and ‘Hard drainage pavements’ were tied as having the lowest rating of (3.6/5.0). It should be noted, that the lowest rating for any NBS method was still higher than the rating for the two least popular conventional methods. The detailed results are seen in the table below:

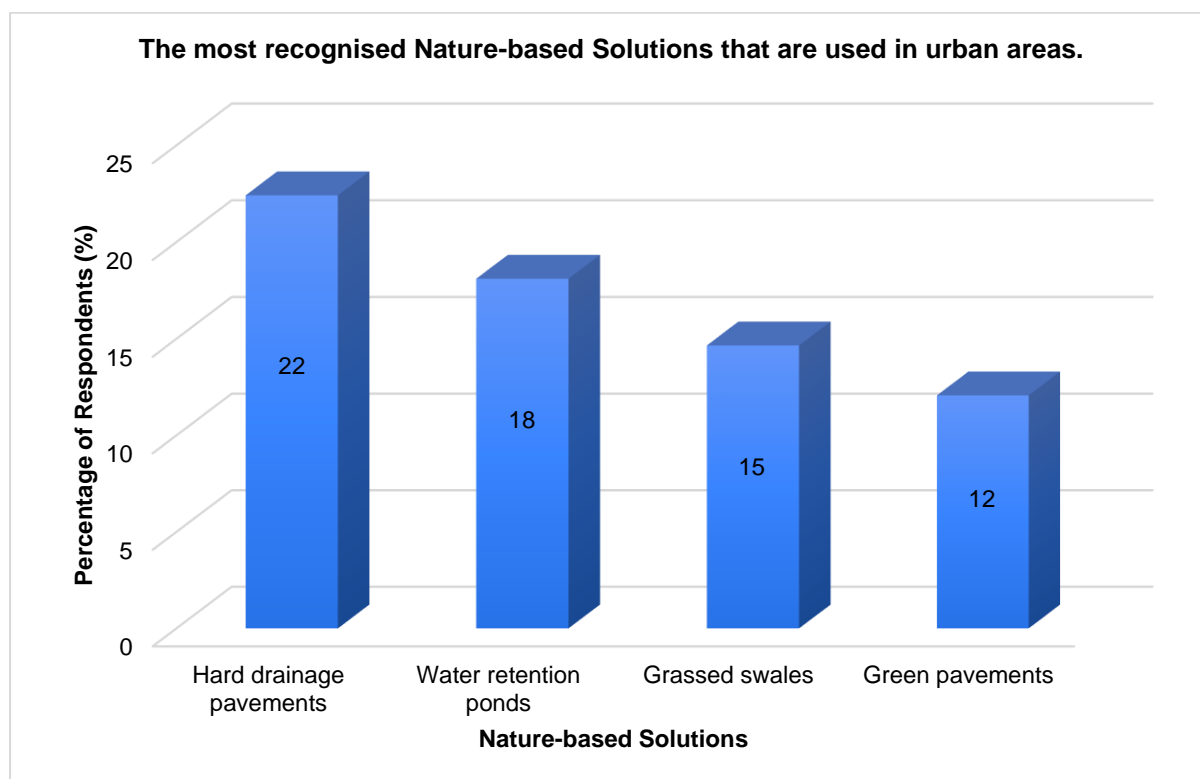
**Scale: 1 – Very ineffective, 2 – Ineffective, 3 – Unsure, 4 – Effective, 5 – Very effective**

	Average	Mode
<b>Grassed Swales</b> – a shallow bioretention area placed along a road, with a soakaway underneath (Urban GreenUP 2021).	3.6	4
<b>Water retention ponds</b> - ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events (Urban GreenUP 2021).	4.0	4
<b>Green roofs</b> - The external upper covering of a building which the main aim is to favour the growth of vegetation (Urban GreenUP 2021).	3.6	4
<b>Rain gardens</b> - a bioretention shallow basin designed to collect, store, filter and treat water runoff (Urban GreenUP 2021).	3.8	4
<b>Channel re-naturing</b> - Removal of the existing concrete riverbanks of channel and replace it with a modular green system called Terramesh walls that stabilise earth embankment and create green slopes by requiring vegetation (Urban GreenUP 2021).	3.7	4
<b>Hard drainage pavements</b> - a combination of built and impervious surfaces and permeable material. They differ from (SUDs) or porous pavements, as they are not designed with a permeable membrane but a combination of hard (engineered) and an ecological (NBS) surface (Urban GreenUP 2021).	3.6	4
<b>Green pavements</b> - This kind of pavements has gaps, which will be filled with smart soil and with specific creeping grass species with a short growing and minimum maintenance (Urban GreenUP 2021).	3.7	4
<b>Sustainable Urban Drainage (SUDS)</b> – a combination of strategies designed to drain surface water efficiently and sustainably, while minimising pollution and	3.9	4

managing the impact on water quality of local water bodies (Urban GreenUP 2021).		
<b>Overall</b>	<b>3.7</b>	

**Table 6. Likert scale effectiveness ratings for Nature-based Solutions.**

Following this, respondents were asked to indicate any of the listed Nature-based Solutions that they recognised as being implemented within their area(s). The list of Nature-based Solutions was created based on information from the Urban GreenUP NBS Catalogue (2018). Essentially, the solutions that were seen as being able to contribute to water management were narrowed down to only include those that has a relatively low estimated budget and maintenance cost, and that appeared to be easy to implement. Based, on the data collected, the most popularly implemented Nature-based Solutions are ‘Hard drainage pavements’ and ‘Water retention ponds’, however, it is recognised that these percentages are still very low, indicating that they are still not commonly observed in urban areas in Trinidad and Tobago. It is also important to state that 59% of respondents had not seen any form of Nature-based Solutions implemented in their area(s).



**Figure 8. The common Nature-based Solutions used in urban areas, as recognised by survey respondents.**



In sum, the results showed us that most respondents found both the conventional adaptation methods and the implementation of Nature-based Solutions to be effective. In the case of conventional methods, the maintenance of existing drainage and irrigation systems was seen to be the most effective means of responding to the issue of flooding, while Nature-based Solutions that were perceived as more effective were water retention ponds and SUDS. It should be noted, though, that while most respondents saw Nature-based Solutions as an option that should be investigated and implemented, there were individuals who did not believe that NBS could make a significant difference, suggesting that we also investigate ways to decrease pollution or investigate the development of more drastic flood mitigation plans.

Now, this chapter aims to examine the data in the previous chapter in relation to the existing literature surrounding the subjects of vulnerability, and Nature-based Solutions. This will allow for the main research question to be answered through the identification of key trends and major findings. It will also help to show how this project helps to address existing research gaps and contributes to the fields of planning and environmental management.

### ***5.1 Flooding and Public Perception: Contributing Factors, Vulnerability and Effects***

Using the questionnaire data, which was both quantitative and qualitative in nature, we can begin to answer the overall research question starting with the first objective: “to determine how the public has been affected by flooding, how they perceived their level of vulnerability and what they consider to be the key environmental and human factors that contribute to flooding”. Through the literature that was analysed, flooding has been clearly presented as a multi-dimensional issue with a variety of determining factors (Shrivastava, 2003) – which can be classed as either environmental or social. However, the questionnaire data showed that participants more commonly blamed human factors for the prevalence of flooding – with the six most popular factors selected by survey respondents all being human factors. In fact, with regards to the factors that contribute to local flooding, less than 50% of respondents recognised geology and soil texture as being a factor, less than 60% recognised the local climate as being a factor, and less than 70% of respondents recognised the contributions of topographical features (elevation and slope) and climate change. This shows that there may be some degree

of disconnect, preventing members of the public from recognising the contribution that environmental factors make to flooding.

With regards to vulnerability, it is noted that groups can perceive their degree of vulnerability in different ways. While there have been many studies worldwide which have assessed vulnerability - and its counterpart: risk - on various scales, there have not been many studies in Trinidad and Tobago which focus on exactly how citizens perceive their level of vulnerability to the issue of flooding. As such, the use of Likert scale questions to get Trinbagonian citizens to rank their level of vulnerability to flooding can be seen as a relatively new approach within the local context – with only one study by Thongs (2018) found to be employing a similar method. This means that the data collected can serve as a current baseline which can be built upon in further research. It can also contribute a qualitative data source towards the creation of future flood management decisions, which have previously been rooted in quantitative data (Thongs, 2018).

Lastly, the literature showed that there has been limited research on the health outcomes of flooding, and thus there is a lack of quantitative data (Few et al., 2004). While there have been some small-scale studies in the United Kingdom, the previous statement proves to be even more true in Trinidad and Tobago. This is the main reason why the method used was based on a study that took place in England and Wales (Tunstall et al., 2016), and not on a regional research paper. This method involved asking respondents to identify the emotional and physical ways in which they were affected (1) during or immediately after the flood and (2) in the weeks and months after flooding events was of the first datasets of this kind to be collected locally. The results of this analysis showed that respondents faced a large variety of effects in both scenarios and that the most common effects were emotional in nature.

## ***5.2 Opinions on conventional coping and adaptation strategies***

The literature showed that traditional engineering solutions are the main approaches currently being used to tackle flooding in Trinidad and Tobago (Shrivastava, 2003; Braithwaite, 2012), many of which were built to accommodate the rainfall patterns of the 1960s (Trinidad and Tobago Parliament, 2020). Many such strategies were recognised by several respondents as being used in their area(s). However, it is noted that 38% of respondents stated that they could not recognise any of the traditional strategies listed in their urban area - suggesting that there may be some areas which may not have any proper flood management features in place.

Moreover, while researchers have noted that conventional measures have proven to be largely unsuccessful (Shrivastava, 2003), the results show that respondents find them to be more effective than ineffective. This gives a solid indication that while there is an appreciation for the implementation of conventional methods in the public mindset, many persons also recognise that they are not always effective. Considering this, it is unreasonable to suggest that conventional methods should not be used for flood mitigation, instead what needs to be found are methods that can work in tandem with these conventional methods to lead to significant change.

### ***5.3 Opinions on the potential implementation of Nature-based Solutions***

In examining the results, we can see that despite the lack of their implementation, many respondents (59%) were aware of the notion of Nature-based Solutions and thought that they could help to moderate the issue of flooding and improve well-being (89%). While there are few studies which outline the type of Nature-based Solutions that would be most suitable for Caribbean SIDS, the survey respondents found Nature-based Solutions to be generally more effective, with the creation of water retention ponds and the implementation of SUDS being seen as the most effective measures. While this gives a clear idea of what the public would like to see take place, it is noted that further studies would need to take place to determine the Nature-based Solutions that would be most suitable from a technical and economic standpoint.

### ***5.4 Summary: Key Takeaways***

Using the results from this study it can be concluded that while flooding is a multi-dimensional issue, many locals perceive human factors as being larger contributors than environmental factors. This research also created one completely novel set of baseline data for Trinidad and Tobago on the emotional and physical health effects of flooding in urban areas - which can be built upon in further research. Lastly, the research has communicated that the public views the implementation of both conventional measures and Nature-based Solutions as effective and ranks them rather close in terms of effectiveness. From this result, it can be inferred that the public would be happy to see them used in tandem – a notion that, based on the conceptual framework used, should produce a positive outcome. Thus, the use of NbSs cannot be overlooked in the drive to reduce the impact of flooding and improve general well-being.

Considering Trinidad and Tobago's background with the issue of flooding, this study aimed to assess the potential for the use of Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago. This was done through: (1) determining how the public has been affected by flooding, how they perceive their level of vulnerability and what they consider to be the key environmental and human factors that contribute to flooding, (2) determining the degree to which the public and key decision-makers find conventional coping and adaptation strategies effective, and (3) determining the opinion of the public and key decision-makers with regards to the potential implementation of Nature-based Solutions.

The process of meeting these objectives began with a review of literature related to the key themes of the research project: urbanisation, climate change, vulnerability, flooding, wellbeing, and Nature-based Solutions. While this chapter outlined the key factors that affect vulnerability to flooding in Trinidad and Tobago, made note of the conventional measures that have been used to respond to the issue, and explained how the implementation of different Nature-based Solutions could reduce the issue, it also identified various gaps in the existing literature, highlighting the need for further research to be conducted. The information that was collected during this literature review was then used, to develop a conceptual framework, which was used as the basis for the methodology that was used to further this research project.

The methodology used included the collection and analysis of both primary and secondary data of a qualitative and quantitative nature. While the secondary data came from a mix of academic journals, policy documents, books and other sources, the primary data was obtained through: (1) the collection of 116 online questionnaire responses and (2) the completion of 3 semi-structured interviews with persons in the realm of environmental planning, disaster management and engineering. Of the 119 persons who were involved in the process of primary data collection, the majority were female and were between 18-44 years of age. Furthermore, most respondents had a 'Bachelor's degree or equivalent' and were either students or involved in some form of employment.

The key highlights from the results that were obtained using these methods were that most participants found both the conventional adaptation methods and the implementation of Nature-based Solutions to be effective - suggesting that the average person would be happy to see a

combination of these methods being put into play. This point was made clear as some participants emphasised that they did not believe that Nature-based Solutions could make a significant impact on their own. Overall, the flood management methods that were seen as being the most effective by survey respondents were: (1) the maintenance of existing drainage and irrigation systems, (2) the creation of water retention ponds, and (3) the implementation of SUDS. This information can now be used to as evidence for the development of sustainable flood management plans for urban areas, that are not only effective, but also acceptable in the public eye.

While the methodology was successfully completed and the results obtained proved to be very useful, it is important to note that the scope of the study was limited by the COVID-19 pandemic. On the other hand, it is important to recognise that this study could be extended through future research to allow for more detailed results. As such, my recommendations for further research are as follows:

- As this project focuses on sites in Trinidad, it is suggested that the more urbanised areas in Tobago can also be assessed in another study.
- Considering that this project did not attain a survey group that statistically represented the population, aiming for a larger survey group in further research would be beneficial – the likelihood of getting more responses could be increased by providing an incentive for survey completion.
- Case studies focusing on the major urban areas of Port of Spain, Saint Augustine/Curepe, Chaguanas, and San Fernando could be conducted to determine the most cost-effective and efficient means of incorporating Nature-based Solutions in these areas – providing key spatial data which can be shared with decision-makers.
- As this is one of the first studies of this kind for Trinidad and Tobago, there is still a lot to learn about exactly how cost effective the implementation of Nature-based Solutions would be in comparison to conventional methods. This could be explored in further research.

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## APPENDIX 1: QUESTIONNAIRE

### ABOUT THE STUDY AND CONSENT

Dear Respondent,

My name is Jamala Alexander, and I am a student in the Department of Geography and Planning at the University of Liverpool. Currently, I am pursuing a MSc. Environmental Assessment and Management and as a requirement for this, I am working on a dissertation entitled 'Assessing the potential for the use of Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago'.

To facilitate this project, this questionnaire serves as a main function of data collection and will be used to gather diverse perspectives for persons who reside, work or study in urban areas. Specifically, the questionnaire will aim to collect data about the impacts of flooding, the degree of vulnerability, the effectiveness of existing coping and adaptation strategies, and the perceived usefulness of Nature-based Solutions which can then be shared with relevant bodies and considered when making future planning decisions.

Therefore, I would be extremely grateful if you could complete this survey as accurately as possible, which will take no more than 10 minutes. It should be noted that your participation in this data collection process is completely voluntary and that all responses provided are anonymous. You can also exit the survey at any time before clicking the final submission button, but once you have submitted your responses your responses cannot be retracted.

By participating in this data collection process, you will be contributing to research on the potential for Nature-based Solutions to address various urban issues.

If you have any questions or if there is a problem, please contact the principal student investigator at [j.t.alexander@liverpool.ac.uk](mailto:j.t.alexander@liverpool.ac.uk). If you have a complaint and you feel like you cannot contact the student investigator directly, please contact the Research and Ethics Integrity Office at [ethics@liv.ac.uk](mailto:ethics@liv.ac.uk).

Thank you for your time.

Kind regards,

**STATUS AND LOCATION SELECTION**

1. An urban area may be defined as a human settlement with a relatively high population density and dense built environment.

Do you work, live or study in an urban area? (Select all that apply)

- Work
- Live
- Study

**If you do not work/live/study in an urban area, please do not continue with this survey.**

**Thank you!**

2. In which urban area(s) do you currently work/live/study? (Select up to two options)

- Arima
- Arouca / D'Abadie
- Tunapuna / El Dorado
- Curepe / St. Augustine
- Barataria / San Juan / Laventille
- Port of Spain
- Chaguaramas
- Chaguanas
- San Fernando
- Point Fortin
- Other: \_\_\_\_\_

**FLOODING IMPACT**

3. Have you been affected by flooding in the last five years?

- Yes – 2021
- Yes – 2020
- Yes – 2019
- Yes – 2018
- Yes - 2017
- No

4. If yes, how were you affected during or immediately after the flood(s)? (Please state all that apply)

- Cold, coughs, flu, sore throats, or throat infections
- Headaches
- Injuries due to exertion or being knocked over e.g., cuts/bruises/sprains/strains
- Skin irritations e.g., rashes
- Exposure to chemicals and contaminants in flood waters
- Insect or animal bites
- Electric shock
- Shock (emotional)
- Abandonment of house and/or relocation
- Loss of agricultural crops
- None of the above
- Other: \_\_\_\_\_

5. If yes, how were you affected during the weeks and months after the flood(s)? (Please state all that apply)

- Diarrhoea, vomiting and upset stomachs
- Worsening arthritis
- Respiratory/chest illness e.g., asthma, infections
- Stiffness in joints
- Skin irritations e.g., rashes, dermatitis
- Anxiety when it rains

- Increased stress levels
- Sleeping problems
- Flashbacks to the flood
- Increased tension in relationships e.g., more arguing
- Moderate depression
- Severe depression
- Anger/tantrums
- Difficulty in concentrating on tasks
- Mood swings/bad moods
- Lethargy/lack of energy
- Panic attacks
- Nightmares
- Increased use of alcohol/drugs
- Abandonment of house/workplace
- None of the above

Other: \_\_\_\_\_

6. Vulnerability is defined as ‘the extent to which a natural or social system is susceptible to sustaining damage...’ (IPCC 2001).

How vulnerable do you believe your community/workplace/educational facility is to flood?

- Very High Vulnerability
- High Vulnerability
- Medium Vulnerability
- Low Vulnerability
- Very Low Vulnerability

7. What environmental and human factors do you think contribute to flooding vulnerability?  
(Please state all that apply)

- Local climate: tropical, wet climate
- Climate change
- Topographical factors e.g., elevation and slope

- Geology and soil texture
- Population growth
- Increased urbanisation and infrastructural development
- Poor urban planning e.g., planned development along floodplains
- Increased informal and improper development practices
- Increased deforestation
- The persistence of inappropriate agricultural practices
- Inadequate manmade drainage systems
- Poor maintenance of natural and manmade drainage systems
- Improper disposal of solid waste and derelict objects in drains and other waterways
- The need for improved flood risk data
- The need for improved research in the fields of meteorology and land use planning
- Other: \_\_\_\_\_

### **CONVENTIONAL COPING AND ADAPTATION STRATEGIES – FLOODING**

Proposed solutions for this flooding in Trinidad and Tobago have been centred on traditional engineering-based approaches. These measures which have been implemented and their effectiveness will be assessed below.

8. Do you recognise any of the following methods as being used in your area?

- Dredging, paving, straightening, and widening of natural waterways
- Construction of conventional (grey) drainage and irrigation systems
- Maintenance of drainage and irrigation systems
- Restricting development along flood plains
- Restricting the removal of vegetation cover such as trees
- Creation of flood levees, floodwalls, and flood embankments
- Creation of concrete reservoirs
- None of the above
- Other: \_\_\_\_\_

9. Of the methods listed, please indicate how you perceive their effectiveness using the scale below.

	Very ineffective	Ineffective	Unsure	Effective	Very Effective
Dredging, paving, straightening, and widening of natural waterways	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Construction of conventional (grey) drainage and irrigation systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Maintenance of drainage and irrigation systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Restricting development along flood plains	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Restricting the removal of vegetation cover such as trees	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Creation of flood levees, floodwalls, and flood embankments	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Creation of concrete reservoirs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dredging, paving, straightening, and widening of natural waterways	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Construction of conventional (grey) drainage and irrigation systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### **PUBLIC OPINION ON NATURE-BASED SOLUTIONS**

Nature-based Solutions (NbS) put nature at the forefront when aiming to tackle environmental and societal challenges. It is defined by the European Commission (2020) as “solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience...”.

10. Have you ever heard of Nature-based Solutions?

Yes



No

11. Based on the definition provided above, do you think that Nature-based Solutions can help to moderate the issue of flooding and improve wellbeing in Trinidad and Tobago? Please explain your answer.

Yes

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No

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12. How effective do you think the following Nature-based Solutions can be with regards to flooding? Please indicate using the scale below.



	Very ineffective	Ineffective	Unsure	Effective	Very Effective
<b>Grassed Swales</b> – a shallow bioretention area placed along a road, with a soakaway underneath (Urban GreenUP 2021).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Water retention ponds</b> - ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events (Urban GreenUP 2021).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Green roofs</b> - The external upper covering of a building which the main aim is to favour the growth of vegetation (Urban GreenUP 2021).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Rain gardens</b> - a bioretention shallow basin designed to collect, store, filter and treat water runoff (Urban GreenUP 2021).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Channel re-naturing</b> - Removal of the existing concrete riverbanks of channel and replace it with a modular green system called Terramesh walls that stabilise earth embankment and create green slopes by requiring vegetation (Urban GreenUP 2021).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Hard drainage pavements</b> - a combination of built and impervious surfaces and permeable material. They differ from (SUDs) or porous pavements, as they are not designed with a permeable membrane but a combination of hard (engineered) and an ecological (NBS) surface (Urban GreenUP 2021).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Green pavements</b> - This kind of pavements has gaps, which will be filled with smart soil and with specific creeping grass species with	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

a short growing and minimum maintenance  
(Urban GreenUP 2021).

**Sustainable Urban Drainage (SUDS)** – a combination of strategies designed to drain surface water efficiently and sustainably, while minimising pollution and managing the impact on water quality of local water bodies (Urban GreenUP 2021).

- 

13. Do you recognise any of the listed Nature-based Solutions as being used in your area?  
(Please select all that apply)

- Grassed Swales
- Water retention ponds
- Green roofs
- Rain gardens
- Channel re-naturing
- Hard drainage pavements
- Green pavements
- SUDS
- Other: \_\_\_\_\_

### **DEMOGRAPHIC QUESTIONS**

14. AGE:

- 18 – 24
- 25 - 34
- 35 - 44
- 45 - 54
- 55 – 64
- 65+

15. Please state your gender:

- Male: He/Him
- Female: She/Her
- Non-binary: They/Them
- Prefer not to disclose

16. ETHNICITY:

- African
- East Indian
- Mixed Race (African/East Indian)
- Mixed Race (Other)
- Indigenous
- White
- Other: \_\_\_\_\_

17. EMPLOYMENT STATUS:

- Temporary Employment
- Permanent Employment
- Self-employed
- Unemployed
- Student
- Retired
- Unable to work

**Thank you for your participation, I hope that you have a wonderful day. If you have any inquiries about this study, please contact: [j.t.alexander@liverpool.ac.uk](mailto:j.t.alexander@liverpool.ac.uk).**

## APPENDIX 2

### Official Information Sheet

You are being invited to participate in a research study. Before you decide whether to participate, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully, and feel free to ask questions if you would like more information or there is anything you do not understand. You are free to decline this invitation or withdraw at any time.

#### **What is the purpose of this study?**

This research assesses the potential for *Nature-based Solutions* to reduce the issue of flooding and improve well-being in urban areas in Trinidad and Tobago. *Nature-based solutions* are, simply put, interventions inspired by or using nature to combat societal issues such as climate change and to lead to a variety of benefits including, but not limited to improving community health and well-being. Generally, *Nature-based solutions* refer to improvement of existing green space, adding new green space or greening existing surfaces (e.g., trees, green roofs, green walls) or water features (e.g., rain gardens, wetlands, natural drainage systems). We will be aiming to assess the potential effect that these interventions can have on flooding and well-being in urban areas in Trinidad and Tobago.

The aspect of the research you will be participating in focuses on gathering professional opinions on (1) the effectiveness of the conventional grey infrastructure methods which have been implemented to tackle the issue of flooding, (2) the extent to which members of the public should have a say in planning decisions and (3) if/how you believe that *Nature-based Solutions* can be effectively implemented. Other aspects of this research will gather the opinions of other persons who live, work or study in urban areas that are affected by flooding.

#### **Why have I been chosen?**

You have been chosen because of your professional background in planning, environmental management, disaster management, drainage, engineering, or a related field.

#### **What will happen?**

You will be asked to participate an online interview which will be recorded and transcribed for

data analysis purposes.

### **What are the benefits?**

Your participation will assist with recording and integrating professional opinions into project recommendations. Even though this research is not being undertaken on behalf of the relevant authorities, its findings could potentially support improvements in the approaches which are used to manage the issue of urban flooding in Trinidad and Tobago.

### **What will happen to the results of the study?**

The results of the study will be submitted to the University of Liverpool, and to the Caribbean Catastrophe Risk Insurance Facility (CCRIF SPC), who has provided the principal student researcher with a scholarship. The results may also be published in one or more academic journals and shared with key decision makers in Trinidad and Tobago.

### **What are the costs and risks? Will my participation be kept confidential?**

There is no cost for taking part, and there are minimal risks involved. No personal identifiers are being stored, although we are collecting some demographic details to assist with the analysis. All data from the workshop will be aggregated in a spreadsheet and stored securely. Your identifying information will never be published.

You are also free to withdraw from the study at any time, without explanation.

### **How will my data be used?**

The University processes personal data as part of its research and teaching activities in accordance with the lawful basis of ‘public task’, and in accordance with the University’s purpose of “advancing education, learning and research for the public benefit”.

Under UK data protection legislation, the University acts as the Data Controller for personal data collected as part of the University’s research. Jamala Alexander acts as the Data Processor for this study, and any queries relating to the handling of your personal data can be sent to the Principal Investigator, Jamala Alexander, whose information is at the bottom of this sheet. Further information on how your data will be used can be found in the table below.

How will my data be collected?	Your interview will be recorded and then a transcription will be made without any personal identifiers except demographic details. The recordings will be deleted as soon as they are no longer needed.
How will my data be stored and what measures are in place to protect the confidentiality of my data?	Your data will be securely stored on a password protected computer, without any personal identifiers.
How long will my data be stored for?	All data (except interview recordings) will be stored until 1 year after the project is completed.
Will my data be anonymised?	Your data will be anonymised and analysed alongside other responses, and you will never be personally identified in any publications.
How will my data be used?	Please refer to “what will happen to the results of this study?” - above.
Who will have access to my data?	Only the principal student researcher and her supervisor will have access to your data before it is anonymised. After it is anonymised, transcripts will be stored and made publicly available.
Will my data be archived for use in other research projects in the future?	No, the data will be deleted one year after the project has been completed.
How will my data be destroyed?	Any personally identifiable data will be deleted as soon as it is no longer needed, other data will be deleted no later than 1 year after the project terminates.

**What if I am unhappy or if there is a problem?**

If you are unhappy, or if there is a problem, please contact myself or my supervisor, Dr. Sarah

Clement (Sarah.Clement@liverpool.ac.uk). If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the Research Ethics and Integrity Office at [ethics@liv.ac.uk](mailto:ethics@liv.ac.uk). When contacting the Research Ethics and Integrity Office, please provide details of the name or description of the study (so that it can be identified), the researcher(s) involved, and the details of the complaint you wish to make.

The University strives to maintain the highest standards of rigour in the processing of your data. However, if you have any concerns about the way in which the University processes your personal data, it is important that you are aware of your right to lodge a complaint with the Information Commissioner's Office by calling 0303 123 1113.

### **Who can I contact if I have further questions?**

#### **The principal student investigator:**

Jamala Alexander  
University of Liverpool  
J.T.Alexander@liverpool.ac.uk

#### **Project Supervisor:**

Dr. Sarah Clement  
School of Environmental Sciences  
University of Liverpool  
Roxby Building  
Liverpool, United Kingdom  
Sarah.Clement@liverpool.ac.uk



## APPENDIX 3

### Participant Consent Form - Interview

**Version date:** 27<sup>th</sup> June 2021

**Research ethics approval number:** 2582

**Title of the research project:** Assessing the potential for the use of Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago.

**Principal student investigator:** Jamala Alexander (J.T.Alexander@liverpool.ac.uk)

**Project supervisor:** Dr. Sarah Clement (Sarah.Clement@liverpool.ac.uk)

#### Confirming Consent

*Please initial*

*box*

1. I confirm that I have read and have understood the information sheet dated 27 June 2021 for the study. I have had the opportunity to consider the information, ask any questions and have had these answered satisfactorily.
  
2. I understand that taking part in the study involves participating in an interview.
  
3. I understand that this research is approved by the research ethics board at the University of Liverpool and that the researcher must safeguard all participants.
  
4. I understand that my participation is voluntary and that I am free to withdraw permission to use data from my interview at any point before the information is aggregated and analysed. In addition, I understand that I am free to decline to answer any question or questions.
  
5. I understand that the information I provide will be held securely and in line with data protection requirements at the University of Liverpool.

- 6. I understand that confidentiality will be maintained.
- 7. I understand that signed consent forms, demographic data forms and interview transcripts will be retained by Jamala Alexander for up to one year after project completion.
- 8. I understand that disguised extracts from my interview may be directly quoted.
- 9. I agree to take part in the above study.
- 10. I agree to my interview being recorded.
- 11. I agree for my demographic data to be used in this study.

\_\_\_\_\_

Participant name

\_\_\_\_\_

Date

\_\_\_\_\_

Signature

\_\_\_\_\_

Name of person taking consent

\_\_\_\_\_

Date

\_\_\_\_\_

Signature

## APPENDIX 4

### Participant Demographic Data Form - Interview

**Version date:** 27<sup>th</sup> June 2021

**Research ethics approval number:** 2582

**Title of the research project:** Assessing the potential for the use of Nature-based Solutions to reduce vulnerability to flooding and improve well-being in urban areas in Trinidad and Tobago.

**Principal student investigator:** Jamala Alexander (J.T.Alexander@liverpool.ac.uk)

**Project supervisor:** Dr. Sarah Clement (Sarah.Clement@liverpool.ac.uk)

#### Demographic Questions

1. **NAME:**

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2. **JOB TITLE:**

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3. **AGE:**

18 – 24

25 - 34

35 - 44

45 - 54

55 – 64

65+

Refused

4. **GENDER:**

Male: He/Him

Female: She/Her

Non-binary: They/Them

Prefer not to disclose