Journal of Sustainable Tourism

ISSN: 0966-9582 (Print) 1747-7646 (Online) Journal homepage: www.tandfonline.com/journals/rsus20

A dynamic vulnerability approach for tourism destinations

Jillian Student, Machiel Lamers & Bas Amelung

To cite this article: Jillian Student, Machiel Lamers & Bas Amelung (2020) A dynamic vulnerability approach for tourism destinations, Journal of Sustainable Tourism, 28:3, 475-496, DOI: 10.1080/09669582.2019.1682593

To link to this article: https://doi.org/10.1080/09669582.2019.1682593

Published online: 07 Nov 2019.

JOURNAL OF SUSTAINABLE TOURISM
2020, VOL. 28, NO. 3, 475–496
https://doi.org/10.1080/09669582.2019.1682593

A dynamic vulnerability approach for tourism destinations

Jillian Student[a,b], Machiel Lamers[a] and Bas Amelung[b]

[a]Environmental Policy Group, Wageningen University and Research, Wageningen, The Netherlands; [b]Environmental Systems Analysis Group, Wageningen University and Research, Wageningen, The Netherlands

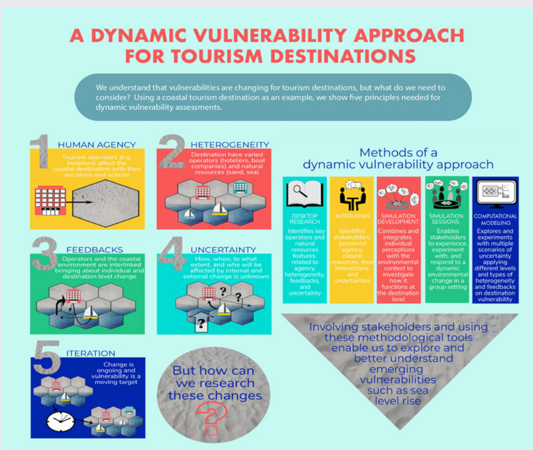
ABSTRACT

Tourism destinations are vulnerable to increasing environmental change. The available scientific knowledge, however, is of little practical use as it is too aggregate, too conceptual, or too static. Various authors have called for dynamic vulnerability assessments, but the principles for dynamic vulnerability assessments have not been specified nor is it clear *how* to operationalise these principles. This paper formulates five principles: human agency, heterogeneity, feedbacks, uncertainty, and iteration. To address these principles, it proposes a dynamic approach that involves stakeholders. The approach's proposed methodological tools enable system integration as well as the opportunity for both researchers and stakeholders to experience and experiment with dynamic vulnerabilities, which is key to moving beyond aggregate and static assessments. To demonstrate some of the approach's added value for tourism destinations, a short illustration is provided of the critical challenge of sea level rise for coastal tourism in the Caribbean islands of Barbados and Curaçao. Future application of the approach can extend well beyond Caribbean coastal destinations to any other tourism destination vulnerable to environmental change.

ARTICLE HISTORY
Received 14 June 2019
Accepted 6 October 2019

KEYWORDS
Vulnerability; dynamic approach; systems thinking; companion modelling; human-environmental dynamics; coastal tourism destination; sea level rise (SLR)

GRAPHICAL ABSTRACT



CONTACT Jillian Student jillian.student@wur.nl Environmental Policy and Environmental Systems Analysis Groups, Wageningen University and Research, Wageningen, The Netherlands
This article has been republished with minor changes. These changes do not impact the academic content of the article.

Introduction

Climate change has been identified as one of six mega trends affecting tourism (Buckley, Gretzel, Scott, Weaver, and Becken (2015). Some of the main segments of the tourism market, in particular alpine winter tourism and coastal tourism, rely heavily on environmental features that are vulnerable to climate change (Scott, Gössling, & Hall, 2012; UNWTO-UNEP-WMO., 2008). In recent years, tourism researchers have started to address tourism's vulnerability to climate change. Perch-Nielsen (2010) conducted a country-by-country analysis of vulnerability based on high-level indicators such as GDP, Moreno and Becken (2009) designed a destination-level vulnerability assessment based on hazard-activity pairs, Calgaro and Lloyd (2008) identified 13 key interlinking factors that contributed to vulnerabilities to external shocks, and Santos-Lacueva, Anton Clavé, and Saladié (2017) provide an overview of vulnerability assessments. While these studies represent significant advances in scientific knowledge, the practical applicability of this knowledge has so far been limited. As Cashman, Cumberbatch, and Moore (2012, p. 27) note: "one of the barriers facing the adaptation of the tourist industry is the lack of data generated by appropriate research and development". Given the prominence of tourism in many coastal areas and the potential magnitude of climate change impacts, the disconnect between research and practice is a critical problem.

Triggered by the lack of practical knowledge about vulnerability, Calgaro, Lloyd, and Dominey-Howes (2014, p. 347) were the first to systematically map out and categorise the "factors and processes that create and perpetuate destination vulnerability and resilience, along with the social actors and agenda that drive action and non-action". They created the Destination Sustainability Framework (DSF) and applied it in a follow-up publication (Calgaro, Dominey-Howes, & Lloyd, 2014). DSF has further been applied to other tourism vulnerability case studies by van der Veeken et al. (2016) and Pyke, Law, Jiang and de Lacy (Pyke, Law, Jiang, & de Lacy, 2018). The studies informed by Calgaro, Lloyd, et al. (2014) are examples of systems approaches in tourism research, which as Becken (2013b) and Amelung et al. (2016) note are rare. Espiner, Orchiston, and Higham's (2017) analysis of tourism sustainability and resilience concepts highlights the need to include complex socio-ecological systems thinking. Systems approaches can provide insights on the emergence of environmental and social vulnerabilities, resulting from the many interactions in socio-ecological systems, i.e., complex adaptive systems linking people and the environment (Levin et al., 2013). The impacts of climate change on destinations, for example, become manifest at very different moments in time (Gössling, Scott, Hall, Ceron, & Dubois, 2012), depending on the kind of impact and the destination's characteristics. As a result, vulnerability is a constantly moving target and must therefore be understood as a dynamic phenomenon (Adger, 2006; Rhiney, 2015). Accepting that vulnerability is dynamic changes the framing of destinations' vulnerability challenges and their set of appropriate responses. It also changes the kind of research that is needed to support destinations' decision-making processes and adapt destination management strategies. Without knowledge of vulnerability dynamics, decision-makers have limited scope when creating and applying measures to reduce vulnerabilities and improve resilience (Calgaro, Lloyd, et al., 2014; Duvat et al., 2017; Rhiney, 2015).

The dynamic nature of vulnerability is closely connected to the high prevalence of climate inaction in many sectors, including tourism (e.g., Bruno Soares, Alexander, & Dessai, 2018). Climate change's reality and disruptive potential is now beyond dispute, but the type, severity, and timing of its impacts on places is uncertain and often unpredictable. Climate change is oftentimes not experienced directly, which makes it an elusive phenomenon (Giddens, 2009) that is difficult to connect with everyday choices. This inspires inaction as it delays mitigation actions of governments, companies, and citizens. Santos-Lacueva, Ariza, Romagosa, and Saladié (2019) examined the influence and limitations of stakeholders' understanding of climate change risk on public action in coastal tourism destinations. Winn, Kirchgeorg, Griffi, and Linnenluecke (2011, p. 158) observe that companies' persistent belief that "current economic and social conditions will continue to flourish regardless of unfavourable biophysical conditions in Earth's natural and climate systems" inspires a risk management approach that is incompatible with the scope, scale, and systemic uncertainty that characterise climate change impacts. Moreover, a growing literature is devoted to understanding the psychological and sociological drivers of inaction in response to climate change (e.g., Amel, Manning, Scott, & Koger, 2017; Cohen, Higham, & Reis, 2013; Gifford, 2011). The recent 'climate services' literature builds on this work, attempting to overcome some of the barriers of inaction (Lemos, Kirchoff, & Ramprasad, 2012) by bridging the gap between producers and end-users of climate information. In a sense, climate services address the lack of personal sensory experience of climate change and the difficulty of identifying and evaluating the available courses of action: climate services make climate impacts more personal and 'tangible' and provide stakeholders with a scope of action to base their decisions on, so that learning can take place. Filimonau and De Coteau (2019) findings suggest that collaboration with stakeholders in tourism is key to breaking this gap between climate information and effective action. We argue that better addressing these same two elements (i.e., making impacts tangible and providing a scope of action) are key conditions for producing more meaningful and usable vulnerability assessments, and that we need different methods in order to do so (e.g., Lalicic & Weber-Sabil, 2019).

In its basic form, dynamic vulnerability involves people, environmental resources, space, and time, and most importantly, the interactions among these factors. These factors and interactions are all part of Calgaro, Lloyd, et al.'s (2014) seminal and hitherto unmatched work, which clearly advances our conceptual understanding of *what* to take into account when studying dynamic vulnerability. However, its guidance on *how* to do that is limited.

Calls for systemic and dynamic approaches to vulnerability assessments in tourism are not uncommon (Becken, 2013a; Cinner et al., 2018; Duvat et al., 2017), but attempts to formulate the principles of such assessments and provide practical guidelines to performing a dynamic approach are. This paper aims to address that knowledge gap by answering the question "How can we research vulnerability as a dynamic phenomenon in (coastal) tourism destinations?" It lays out a new approach for performing dynamic vulnerability assessments that emphasises interaction and change, and illustrates the merits of the approach by applying it to the two Caribbean case study areas of Barbados and Curaçao to assess their vulnerability to sea level rise (SLR), one of the better known consequences of climate change (e.g., Nurse et al., 2014; Rhiney, 2015; Scott, Simpson, & Sim, 2012). The dynamic vulnerability approach and tools presented in the paper can also be applied to other tourism destinations, while the underlying concepts can even be applied to vulnerability challenges in other sectors.

The paper has the following sections. The first section formulates a set of key principles pertaining to a dynamic vulnerability assessment, taking Calgaro, Lloyd, et al.'s (2014) Destination Sustainability Framework (DSF) as its point of departure. The second section describes a dynamic approach with concrete methods to achieve these principles. The third section illustrates the added value of the approach. Subsequently, the discussion explores the approach's merits and notes limitations. Lastly, the conclusion highlights the scientific and societal relevance of the approach for tourism destinations and indicates promising avenues for further research.

Principles for dynamic vulnerability assessments

A vulnerability assessment is a process of identifying, quantifying and prioritising the vulnerabilities in a system. Vulnerabilities in highly dynamic systems, such as the socio-ecological systems underlying coastal tourism, are in constant flux, so that static assessments are of limited use. Effective assessments take account of what vulnerabilities change, how that happens, and who is affecting and affected by change. They consider how the interactions among space, environment, people, and time emerge. To use a camera metaphor, we need our scientific lens to act like a video camera that captures emerging vulnerabilities rather than like a photo camera that takes a snapshot of vulnerabilities at a specific moment in time.

Sticking with the camera metaphor, this section aims to formulate some of the technical specifications that our video camera should possess in order to be effective, based on the current level of technology. It aims to formulate key features that dynamic vulnerability assessments should possess in order to be effective. Such assessment principles have not yet been described explicitly, but several of them strongly emerge from the literature. Calgaro, Lloyd, et al.'s paper (2014), which integrates much of that literature, clearly implies that vulnerability assessments for tourism systems should account for human agency, heterogeneity, feedbacks, and uncertainty, even though it does not explicitly state these principles. To this list of four principles inspired by Calgaro, Lloyd, et al. (2014), we propose to add iteration as a fifth, to acknowledge the necessity of accounting for ongoing interactions and the preference of repeated engagement with stakeholder communities. The five principles of human agency, heterogeneity, feedbacks, uncertainty, and iteration are described in the following section.

Principles

Human agency

Humans play an undeniable role in socio-ecological systems and need to be considered in dynamic vulnerability assessments. Humans create and perpetuate many feedbacks of these systems (Larsen, Calgaro, & Thomalla, 2011), and by doing so, shape future options for development (Folke, Biggs, Norström, Reyers, & Rockström, 2016). A pragmatic approach to complex socio-ecological issues therefore requires stakeholders' information and collaboration (Pahl-Wostl et al., 2007). It also requires stakeholders' perspectives. According to Pahl-Wostl et al. (2007), people use mental representations of their physical and social environments to attach meaning to these environments and to information about them. Adger (2006, p. 276) even suggests that vulnerability could be "measured directly through perceptions of those that are vulnerable". In a similar vein, Calgaro, Lloyd, et al. (2014) recognise that human agency influences differential vulnerability patterns.

Tribe and Liburd (2016) signal a lack of local and tacit knowledge in tourism research and highlight a mismatch between scientific knowledge on the one side and local knowledge and stakeholder perceptions on the other. The Barbadian coral reef use for tourism serves as an example. Oxenford et al. (2008) conclude that Barbados depends on coral reefs and needs a management plan. In contrast, Uyarra et al. (2005) find that tourists do not value the Barbadian coral reefs as highly as the reefs in Bonaire, a popular dive destination; sea turtles and water clarity are more important for enjoyment in Barbados. As tourism service providers (e.g., hoteliers, water-sports, beach activities) tend to respond to tourist demand, their actions may not align with what would appear logical from an expert perspective. Understanding this potential mismatch can help unveil emerging vulnerabilities, barriers to act, and potential opportunities to improve adaptive capacity.

Stakeholders face a variety of obstacles when responding to change. In Barbados, for example, high financial investment costs and low perceived returns were found to be barriers to improving water systems (Charara, Cashman, Bonnell, & Gehr, 2011). In the context of small island states, Becken, Mahon, Rennie, and Shakeela (2014, p. 955) conclude that the lack of investment in risk reduction "is interrelated with deficient planning processes, on-going demand for coastal products, lack of political will, and poor environmental conditions". Stakeholders can provide valuable input by identifying the obstacles and trade-offs they face, the resources they use, the opportunities they perceive, and the actors they interact with. Their participation in research is therefore critical to understanding human agency in the system.

Knowledge about stakeholder decision-making processes is crucial for devising effective governance arrangements for the (global) commons (Levin et al., 2013). Moreover, understanding agency is key for adaptation (Cinner et al., 2018). Most adaptation measures that address the local context not only affect stakeholders' livelihoods, but also need local support for implementation (Csete & Szécsi, 2015; Pahl-Wostl et al., 2007). Incorporating stakeholders' understanding of the system and environmental challenges in which they operate is therefore critical, as is knowing which actions local stakeholders are willing to take and which environmental resources stakeholders are willing to protect.

Heterogeneity

Stakeholders, environmental features, and system interactions in the tourism system are inherently diverse. Heterogeneity refers to the range of diversity present in the system; this includes diversity within and among individual components across varying spatial and temporal scales. This heterogeneity contributes to non-linear change and increases system complexity (Darbellay & Stock, 2012; Levin et al., 2013) as they combine in divergent ways. Since heterogeneities imply the need for context specific adaptation measures rather than general ones (Duvat et al., 2017; Rhiney, 2015), accounting for heterogeneities is a key principle of dynamic vulnerability assessments.

Destination actors differ from one another in many aspects, including resource use, coping capacities, decision-making, and power. This paper focuses on one particular type of actor: individuals working for (commercial) tourism businesses in coastal destinations. To refer to these actors, we use the term 'tourism operators', not to be confused with the distinct term 'tour operator', which refers to a company combining and packaging different tourism products and services. Tourism operators, then, vary with respect to the tourism services they provide, the parts of the coastal system they use (e.g., beach, nearshore waters, underwater areas), and their assets (e.g., permanent infrastructure or boats). Actors also have unique individual thresholds (Adger, 2006). Tourism operators differ in their capability and willingness to attract tourists, prevent local environmental problems, and respond to new environmental challenges. Moreover, tourism operators can decide to act individually or collectively. They also differ in their connections and power relationships with other operators as well as local community and global markets. These heterogeneities strongly affect who is vulnerable to what, in what ways, and under which circumstances.

Heterogeneity is also ubiquitous in the environment. In the coastal system, for example, environmental features range from sand to nearshore water and coral reefs. Moreover, environmental change occurs at diverse spatial and temporal scales (Calgaro, Lloyd, et al., 2014). The scope of impacts ranges from individuals (e.g., coral deterioration at a dive site) to the industry as a whole (e.g., coral bleaching throughout the region). As Adger and Brown (2009, p. 110) point out, "virtually all natural hazards and human causes of vulnerability impact differently on different groups in society". Heterogeneity in time and severity are characteristic of vulnerability dynamics: "what is vulnerable in one period is not necessarily vulnerable in the next period" (Adger, 2006, pp. 275–276). Environmental vulnerabilities themselves are heterogeneous as well, because the external threats that define them are. External threats can come in the form of shocks or stressors (Turner et al., 2003); shocks are quickly-developing events, whereas stressors are gradually developing phenomena that have increasingly serious consequences. To understand context specific dynamics of vulnerabilities as well as relevant adaptation measures, heterogeneity needs to be included.

Feedbacks

Another key feature of interactions is feedbacks. Humans and the environment interact in a system that has dynamic, interlinked components and processes (Turner et al., 2003). In the context of tourism, Perch-Nielsen (2010) observes that the interactions between environmental change and tourism are complex, including direct and indirect effects, and multiple possible responses. The possibility of response implies that relationships are not exclusively unidirectional, but also reciprocal, with the system feeding back into itself. Tribe and Liburd (2016) recognise that within a (tourism) system, feedbacks are key for linking inputs, outputs, and processes.

In socio-ecological systems, such as tourism systems, feedbacks are often nonlinear (Folke et al., 2016; Levin et al., 2013). Feedbacks bring about changes at the individual and at system level. The collective effects of individual actions manifest at the system level, and in turn affect the options available to individuals (Levin et al., 2013; Scott, Gössling et al., 2012). Adaptation is a form of feedback-driven co-evolution. Duvat et al. (2017) reveal path dependencies in adaptation, and Csete and Szécsi (2015) note that adaptation is not an isolated event but an ongoing process requiring actions at various spatial, institutional, and temporal scales. Thus, feedbacks help us consider nonlinearities of change effects on vulnerability, resilience, and adaptation and are necessary in a dynamic vulnerability assessment.

Uncertainty

Tourism is recognised as a complex system (e.g., Amelung et al., 2016; Baggio, 2008), characterised by uncertainty. Important contributors to uncertainty are the timing, scale/size, type and frequency differential of shocks and stressors (Calgaro, Lloyd, et al., 2014), of which climate change, accelerating socioeconomic development, globalisation (Pahl-Wostl et al., 2007), and tourism flow trends are of particular relevance. Uncertainty is also part and parcel of future-oriented approaches. For example, we do not and cannot know when climate change impacts will become relevant for tourism destinations (Gössling et al., 2012), how changes of sea level rise can combine with other events such as droughts and shifts in the seasonal pattern of tourist demand, nor how external shocks and stressors interact with local dynamics (Folke et al., 2016). Since uncertainty in future-looking approaches cannot be avoided, it must be embraced when assessing vulnerability and forming adaptive strategies (Larsen et al., 2011). As such, dynamic vulnerability assessments necessitate considering how uncertainty affects and is related to human agency, heterogeneity, and feedbacks.

Iteration

Continuous change is an undeniable reality we face. Outcomes of feedbacks create cycles of procedural and structural change (Pahl-Wostl et al., 2007), which is something a dynamic approach must account for. Iterative processes enable learning, adaption, and flexibility. Several authors see iterative processes as a key strategy in dealing with changes and uncertainty. In this context, Folke et al. (2016) highlight the need to accumulate knowledge, apply systems thinking, encourage learning, and increase participation. Duvat et al. (2017) argue for a dynamic understanding of vulnerability, including continuous reconceptualisation of problems and processes in order to better inform the design of adaptive measures. Pahl-Wostl et al. (2007) propose participatory approaches and adaptive management to speed up the learning cycle. A faster learning cycle would enable more rapid assessment and the incorporation of new insights into policies and research agendas (Adger, 2006). Thus, iterative processes are not only essential for dynamic vulnerability assessments but also for adaptation.

From principles to the dynamic vulnerability approach

This section outlines how the principles can be operationalised in a dynamic approach for tourism. The approach consists of three complementary phases. The first phase 'scoping' aims at investigating the space, environment, people, time, and interactions, and identifying key components of human agency, heterogeneity, feedbacks, and uncertainties. The second phase 'system integration' centres on bringing these components and interactions together, and raising awareness among stakeholders about their position in the system they are operating in. The third phase 'experiencing and experimenting' provides stakeholders and researchers with a virtual setting in which they can experience and experiment with changes to the system, including stakeholder interactions. In particular, the second and third phases set the dynamic vulnerability approach apart from traditional assessments.

The dynamic approach offers a set of tools that can be tailored to suit the requirements of the case at hand and be applied in different phases. For the purpose of this article, the approach is described in a linear format. However, future case studies do not necessarily need to follow this particular order nor use all of the methods presented. The process is iterative and each stage offers the opportunity for reflection and adjustments in approach, tools, and system representation. The insights required, rather than the order, should be prioritised when planning future research.

The dynamic vulnerability approach presented below consists of five main methods: desktop research, interviews, simulation development, simulation sessions, and computational modelling. The methods can be flexibly used in multiple assessment phases, but desktop research and interviews were used in the scoping phase, interviews and simulation development in the system integration phase, and simulation session and computational modelling in the experiencing and experimenting phase. This mix of methods is complementary; the information gained through one method (e.g., interviews) is used as an information source for another (e.g., simulation development). The methods provide multiple means to improve understanding of each of the principles.

The essential role of humans in tourism systems favours a participatory approach. Participation can be achieved through interviews, simulation development, and simulation sessions. All methods can indicate missing or contested information that hinders understanding of the system and its vulnerabilities, and these knowledge gaps can be targeted in subsequent iterations. Table 1 explains the connections between principles and recommended tools.

The methods

Desktop research, based on secondary data, can be used to ascertain which regions most urgently require dynamic vulnerability assessments and what previous assessments have already accomplished. Insights of environmental feedbacks are often derived from available scientific literature. System mapping helps set up initial parameters of the research in terms of space, environment, people, and time. Local experts can indicate context specific issues as well as documents to review and stakeholders to contact.

Interviews aim to fill in knowledge gaps on human agency. They shed light on stakeholder heterogeneity, resource use, and perceptions of (environmental) trends, risks, and threats. Interviews can also reveal stakeholders' coping capacities, willingness to act, trade-offs, and perceived obstacles. The knowledge representation method ARDI (which stands for actors, resources, dynamics, and interactions) is a way for structuring interview questions to help stakeholders co-create system representation (Étienne, Du Toit, & Pollard, 2011). Moreover, ARDI enables the transfer of interview data into simulations or computational modelling such as agent-based modelling. Semi-structured interviews are a common interview format for collecting data. Simulation-guided interviews are an innovative way to generate more specific information on how and where stakeholders act in the systems and how they respond to changes. Simulation-guided interviews use parts of the physical simulation, such as the spatial setting, the environmental features, actors, and scenarios (see Figure 1). This enables stakeholders to position themselves and describe and co-construct the resources they use in the context of the larger (coastal) system.

Table 1. Dynamic vulnerability approach insights- matrix of the five principles of dynamic assessments with methods.

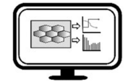
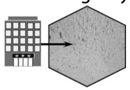
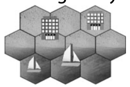
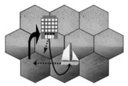
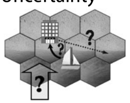
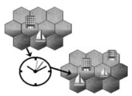
		Methods				
		 Desktop research	 Interviews	 Simulation development	 Simulation sessions	 Computational modelling
Principles	Human Agency 	- Inventorise potential actors and actions	- Note stated perceptions	- Integrate actions with environmental context	- Apply perceptions in a dynamic group setting - State perceptions of actions of different participants - Observe actions and responses	- Apply and test of behaviour rules in scenarios
	Heterogeneity 	- Identify key potential human and environmental differences	- Identify key stated and perceived differences	- Explore different roles and scenarios - Include human, environmental, spatial and temporal differences	- Experience changing heterogeneities - Explore participants' responses - Test the implications of different heterogeneities	- Apply human and environmental heterogeneities to virtual version of coastal setting - Experiment with different types and levels of heterogeneities
	Feedbacks 	- Identify existing observations	- Note perceived feedbacks	- Check implications of individual feedbacks on wider system	- Experience change - Observe participants' responses	- Test implications of feedback mechanisms on virtual world
	Uncertainty 	- Identify future potential scenarios and knowledge gaps	- Identify perceived uncertainties	- Incorporate uncertainties	- Stakeholders reactions to uncertainties	- Introduce uncertainties (e.g. added randomness) - Explore and experiment with different levels of uncertainties
	Iteration 	- Initial process set-up	- Combine interviews with system information (simulation-guided interviews)	- Companion modelling process - Revisit islands - Improve process - Adapt approach to new context	- Show stakeholders - Improve process - Update simulation to include insights from previous sessions	- Specify human and ecological mechanisms

Figure 1. Simulation-guided interview with parts of the simulation represented.

Simulation development is the process of combining the various pieces of system information together with stakeholders. This process helps involve stakeholders and makes individual inputs to system change more tangible. Simulation development can result in a simulation (or serious game) or a model, but it can also simply be a tool to include stakeholders in understanding the system and problem. Stakeholders, researchers, and technical experts can participate in simulation development. A particularly useful form is Companion Modelling (ComMod), an iterative approach to stakeholder engagement and simulation/model co-development (Étienne, 2014). ComMod has been applied to a number of complex natural resource and land management problems, including forestry management (Simon & Étienne, 2010) and watershed management (Souchère et al., 2010). The simulation-guided interviews help check how the current system representation aligns with stakeholders' perceptions and help make improvements. Alternatively, focus group sessions can be organised.

Simulations sessions, also referred to as serious games or interactive sessions, are meetings where people are given different roles and go through different rounds and scenarios in a particular spatial and temporal setting. The people invited to the simulation sessions can be selected experts as well as stakeholders. The roles they take may reflect their real-life roles or those of other stakeholders. During simulation sessions, participants are exposed to a sequence of events that stakeholders (need to) act on. Participants interact with their environment and other participants. Depending on the simulation's design, they may decide to respond individually or choose to collaborate or compete with others. Their actions may then change their capacities, their environment, actions available to them in the future, as well as how other participants (can) respond. Some simulations are reminiscent of board games, such as Catan® or other table top games (e.g., Souchère et al., 2010), while others use virtual platforms (e.g., Simon & Étienne, 2010) or free-form role playing (e.g., Brown, Eernstman, Huke, & Reding, 2017). Simulation sessions are new for many stakeholders, who are more accustomed to surveys and interviews. As a result, some may feel hesitant to participate. The use of simulation-guided interviews in the earlier stages can help stakeholders feel more comfortable to participate in simulation sessions. Moreover, pre-testing the simulation with simulation specialists, context experts, and stakeholders helps ensure the playability of the game and how well it is suited for studying the system of interest. Lalicic and Weber-Sabil (2019) provide an overview of serious game design for tourism.

Simulation sessions enable researchers to test the information about human agency, heterogeneities, and feedbacks provided by individual interviews, in a dynamic group setting. Researchers can observe how stakeholders respond to changes in their system, and how stakeholders change their behaviour and strategies. Also, researchers can explore the role of uncertainty, by introducing new events, actors, resources, or randomness in the simulation sessions. In the sessions, stakeholders experience change resulting from combinations of environmental processes, external pressures, and other stakeholders' decisions. Simulation sessions enable participants to perform their unique strategies within the system. Thus, they are a means of understanding and enabling human agency and social learning.

Computational modelling helps bring together knowledge about different parts of the system and test the effects of heterogeneity, feedbacks, and uncertainties under different conditions. Agent-based modelling (ABM) is a particularly useful approach for expressing complex human-environment systems in a model as it can represent individual entities (such as tourism operators) and their environment (e.g., a coastal destination with beach and sea) and enable interactions to occur over space and time. ABM can function as a platform for integration, helping to better understand the complex interactions in the tourism system (Nicholls, Amelung, & Student, 2017). ABM allows for heterogeneity by accommodating a variety of actors, environmental features, and resources (Levin et al., 2013) instead of requiring an aggregate to represent all tourism operators' (e.g., capacities and resource use) and environmental characteristics.

ABM permits testing of feedbacks under different time frames and multiple scenarios. ABM can thereby help assess how these interactions results in different levels and types of vulnerability in different parts of the systems (e.g., loss of beach area), individual entities (e.g., number or type of operators that go bankrupt), or overall results (e.g., environmental degradation). With known factors and processes (e.g., of resource use, behaviours) as inputs, ABM facilitates the exploration of emerging patterns, such as what types of vulnerabilities emerge when the system is exposed to external shocks and stressors, ranging from environmental changes to changes in tourism demand. ABM can address uncertainty by enabling the user to explore multiple combinations of start-up values, actor and environmental actions, and scenarios, many more than can be addressed in a single simulation session. In addition, ABM can introduce different degrees of randomness, for example, in decision-making, and the occurrence, order, and intensity of events. However, application of ABM to tourism is limited. ABM requires time and technical skills to develop the conceptual framework and write code. Johnson et al. (2016) propose ways to improve the accessibility.

Illustrating the dynamic vulnerability approach: lessons from Barbados and Curaçao on sea level rise

This section intends to give a flavour of the potential of the dynamic vulnerability approach by using it to assess the effects of sea level rise (SLR) in Barbados and Curaçao, two coastal tourism destinations in the Caribbean (see Figure 2) where the approach for dynamic vulnerability assessment was developed. Among the many climate-related challenges that coastal destinations face, SLR is a particularly critical issue for small islands, including those in the Caribbean (Nurse et al., 2014; Rhiney, 2015). For example, Scott, Simpson, et al. (2012) demonstrate that approximately 29% of Caribbean coastal tourism resort properties would be affected by 1 m SLR and between 49-60% by the combination of SLR and coastal erosion. However, the differential effects of SLR to coastal tourism destinations require more attention (Rhiney, 2015). What follows is a description of how the dynamic vulnerability approach was applied in Barbados and Curaçao, and a presentation of key findings that were gained about the tourism sector's vulnerability to SLR.

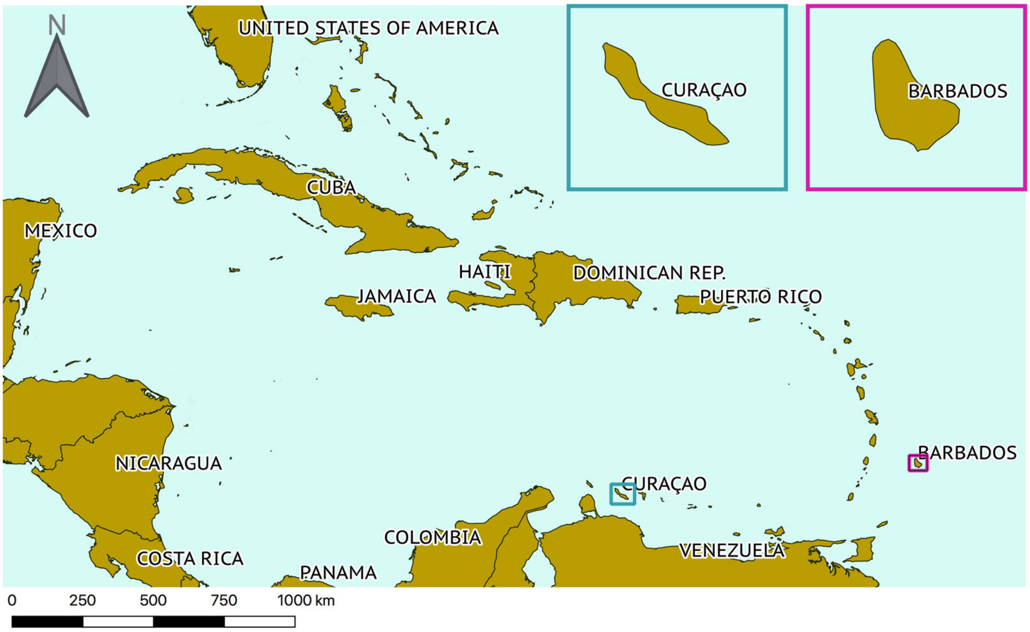


Figure 2. Map of the Caribbean case studies (QGis- Natural earth pkg).

Overview of application of the approach

The Caribbean archipelago counts 13 sovereign island nations and 12 dependent territories. This abundance of potential cases allowed us to select based on a mix of substantive and pragmatic grounds. Access to local stakeholders and data availability through Barbados's extended history of coastal tourism and research made Barbados an attractive first case study to develop the approach. To test the generalisability of the approach to (Caribbean) coastal tourism destinations, Curaçao was selected as a second case. Curaçao faces similar climate challenges as Barbados, but the relative lack of research on climate change and coastal tourism is a critical knowledge gap. The case study on Barbados (with study visits in 2015 and 2016) was completed before starting research on Curaçao (with visits in 2016 and 2017). The phases of scoping, system integration, and experiencing and experimenting were completed on both islands, but with different levels of emphasis.

For this illustration, Barbados therefore provides the context for the first steps (literature review, interviews, simulation development), whereas Curaçao provides the backdrop for simulation sessions and computational modelling. The case studies focus on the relatively understudied supply side of tourism, and more specifically on tourism operators. Tourism operators have a critical impact on the coastal system and are characterised by high vulnerability and limited adaptive capacity (e.g., Kaján & Saarinen, 2013; Moreno & Becken, 2009). The studies focus on the present and the next 20 years until approximately 2040. This timeframe bridges the shorter time scales of island tourism policies (5-10 years) and the longer ones of different environmental change processes such as SLR.

Scoping

Scoping of initial parameters of space, environment, people, and time started with desktop research. Desktop research took multiple forms including literature review, contact with location experts, as well as initial system mapping of the key stakeholders, environmental resources, and likely environmental changes (e.g., SLR). Barbados, like many Caribbean islands, has been identified as being vulnerable to losing beach areas and infrastructure to SLR (e.g., Fish et al., 2008; Scott, Simpson, et al., 2012). Location experts helped identify key government institutions and

Table 2. Example interview questions for understanding emerging vulnerabilities using ARDI.

Focus	Questions
ARDI	
Actors	What is your role in tourism services?
	What do you need (information, other resources) in order to enable decision-making?
Resources	What resources do you need and how often do you use them?
Dynamics	What environmental conditions do you need to provide your tourism services?
	What changes to environmental resources/tourism have you observed?
Interactions	What types of tourists do you depend on?
	What type of (other) tourism operators do you rely on?
	How do you use environmental resources?
Tourism operators' perceptions	
Vulnerabilities	What vulnerabilities do you perceive?
	What changes or challenges do you anticipate for environment and tourism?
	In what ways can changes affect you?
Uncertainties	What are the most important uncertainties for you related to tourism?
	What are the most important uncertainties for you related to tourism?
	In what ways can uncertainties affect you?
Adaptation	What actions can be taken to lower vulnerability? By whom?

tourism-related stakeholders, pinpoint local studies, and some gave historical context of environmental challenges and climate policy. For both islands, tourism is an important economic activity; in Barbados tourism contributed approximately 40% of GDP in 2016 (WTTC, 2017) and, according to the Curaçao Tourism Board (CTB, 2015), tourism's share in Curaçao's GDP was approximately 18% in 2015. In addition to desktop research, 62 semi-structured interviews were conducted during the first fieldwork trip to Barbados to expand the knowledge-base. As the goal was to better understand emerging vulnerabilities in coastal tourism, most interviewees were tourism operators (39), but other individuals with coastal tourism expertise, such as local (research) experts (5), government officials (13), and NGO representatives and tourism-related parties (5), also participated. Table 2 details examples of the semi-guided interview questions.

System integration

Simulation development brought the individual fragments of information together in a largely participative way. It was used to co-create the Coasting game, a simulation aimed at exploring emerging environmental vulnerabilities to a coastal tourism destination. Participation in simulation development took several forms: interviews (parameter identification through ARDI questions) (in Barbados and Curaçao), focus group sessions (two in Barbados), simulation-guided interviews (in Barbados and Curaçao), and game testing. The interviews provided the information to start developing the operators' profiles (e.g., decisions, trade-offs, interdependencies). During the focus group sessions, the participants collaboratively mapped and discussed their coastal system using the ARDI format. The simulation-guided interviews gave actors a visualisation of the system as a context to discuss their role in the system. Simulation-guided interviews further enabled stakeholders to describe and to physically co-construct the resources they use, their location, and inputs in terms of the larger coastal system context. This improved the set-up of the system representation and verified tourism operators' profiles and resource use. Moreover, they helped address the challenge of bringing people together for simulation sessions. In Barbados, stakeholders were approached with simulation-guided interviews so that data could be collected without requiring small groups. In Curaçao, simulation-guided interviews were used to familiarise stakeholders with the concept of simulations and adapt the game to Curaçao's context. Combined, these activities determined the set-up of the Coasting simulation, the input categories of the operators, and the flow of interactions. Tests of a beta-version of the Coasting game improved the game's flow, exposed inconsistencies, and identified questions stakeholders had.

Figure 3. Coasting simulation.

Experiencing and experimenting

The information brought together was explored and tested in simulation sessions of the Coasting game and were used to observe tourism operators' behaviour and interactions in a dynamic setting. The sessions explored questions such as what (environmental) changes participants noticed; which environmental changes they were willing to respond to and how; when and how they changed their strategies; and if and when they decided to collaborate. The sessions involved three to eight stakeholders, each playing at least one of the four main types of tourism operator roles in the coastal system: hoteliers, beach vendors, nearshore operators (e.g., surfing, jet skis, stand-up paddling), and dive or boat operators. The physical features of the coastal system were represented by the Coasting game board, which consists of a flexible set of tiles (see Figure 3). The board embodies a simplification of the following environmental features: nearshore waters, deep sea, beach area, inland, coral reef, fish, sea turtles, and mangroves and is put together to reflects the general context of the tourism destination.

The Coasting game was played for three to five rounds, mimicking the passage of time. Each round, all players allocated their operational input categories in order to keep in business and the mobile operators decided individually about the location of their operations. Players were subsequently exposed to one of six different challenges with varying levels of severity: increased tourism inputs required, coral bleaching, coastal erosion, storms (varying from storm surge from a passing storm to a hurricane), drought, or a new unknown event. Coastal erosion was the proxy for SLR given the short playing time of the simulation. In the game, when coastal erosion occurred, the coastal tiles were replaced with randomly selected new tiles, many of which represented beach loss. Players then decided whether to respond to the challenges and how, either individually or collaboratively. Depending on the action taken, the challenge affected the next round of the game, either through changes in the environment or operational budgets.

During the simulations, behaviours and decisions were observed in multiple ways. Players filled in their operational input decisions on a form at the beginning of each round. If new challenges affected their operations, they recorded these changes in their input sheets. In addition, an observation protocol was used to code extra information about the players' behaviours. The simulation sessions ended with a debriefing, in which players could discuss what happened, what moments were important, and what influenced their decisions. In addition, they could reflect on the similarities and differences between the game and their real-life experiences.

The agent-based model, developed in NetLogo 6.0.4., mimics the Coasting simulation: it simulates tourism operators and the coastal setting has similar environmental features (e.g., beach, coastline, nearshore waters). The model's operator decision rules were based on behaviours observed during the simulation sessions: simulated operators have individual preferences for their input budgets, and can act alone, collaborate, or do nothing. To explore the emergence of vulnerabilities for tourism operators and the environment in relation to SLR, different levels of SLR were introduced into the system. The outputs of SLR scenarios show how many and which types of operators are affected by insufficient resources for operational budget and insolvency, and what the environmental effects are of loss of environmental resources and biodiversity, pollution levels, and environmental degradation.

Key findings

The application yielded a wealth of insights on SLR-induced vulnerability and vulnerability change. Table 3 shows some of those insights, ordered by assessment principle and method. The mixed methods approach resulted in consistent, complementary insights on some issues, but inconsistent and contradictory insights on other issues. This section describes three illustrative findings in further detail: the mismatch between scientific and local understanding of SLR, differences in human agency, and unintended feedback effects of traditional adaptation mechanisms.

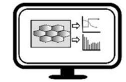
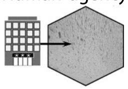
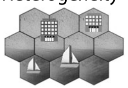
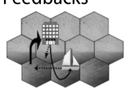
Mismatch

The application illustrates the mismatch between the level of urgency attached to SLR in the scientific literature on the one hand and in the interviews with local stakeholders on the other. Few stakeholders who were interviewed considered environmental change an urgent issue, which contrasts sharply with the concerns the scientific community has. However, when stakeholders actually experienced the proxy of coastal erosion for SLR in the simulations, they expressed immediate concern. Stakeholders who played a land-based operator role (hotelier or beach cafe/vendor) and had available resources, would often opt for beach nourishment to replenish the beach. They would even act individually to regain beach instead of relying on collaboration to put together enough funds. Those who could not expend resources, expressed concern about the potential implications on income. The results imply that, although the greater issue of SLR may be missed by many stakeholders, participants quickly show understanding when confronted with losing beach during simulations. This illustrates that for stakeholders, experiencing environmental effects may be key to their understanding.

Differences in human agency

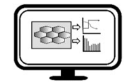
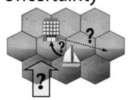
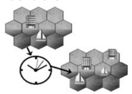
Heterogeneity in location and mobility contributed to the variation in participants' responses to coastal erosion in the simulation. Those directly affected were more willing to act than those situated elsewhere. Moreover, land-based operators (e.g., hoteliers) are fixed to their location while water-based operators can relocate when faced with a threat. The consequence of the difference in mobility was reflected in the simulation: water-based operators were less willing to collaborate when they could opt to move away. The iterations of the simulation sessions showed ongoing change, as participants had to deal with the consequences of previous rounds and changing available resources. Limited operational budgets, trade-offs, and uncertainties (whether events will occur and actions will

Table 3. Dynamic vulnerability approach insights for SLR.

		Methods				
		 Desktop research	 Interviews	 Simulation development	 Simulation sessions	 Computational modelling
Principles	Human agency 	- Hotel and beachfront infrastructure affected (inundated)	- Unsure how they would be affected by 1m SLR - Not a clear plan on how to deal with SLR, unsure whether anything should be done - Concern about losing beach - Use beach nourishment to deal with erosion - SLR considered for height sea wall	- Initial set-up, choosing of location near to beach important although they are more exposed - Some mentioned the payment for more sand (beach nourishment); added as a potential action	- Option to use resources to increase beach size (input costs) - Some individuals consider beach nourishment - Recognise that beach loss is not good for tourism - People tend to build too close to the water even though it's not allowed and/or risky	- Tendency to place hotel or beach infrastructure as close as possible to the beach
	Heterogeneity 	- SLR affects land-based coastal tourism amenities more (directly)	- Some beach areas are currently growing while others are disappearing - Local researchers recognise more studies on SLR than other environmental threats	- Mangroves in some areas protect the coast to some extent from erosion (Curaçao)	- Coastal erosion used as a proxy for SLR; some areas of beach are gained, others are lost - Some individuals specifically chose not to be close to the beach - Some operators not directly affected - Location of lost and gained beach was different within and among simulations	- Use of different time scales and rates of SLR - Opportunity to act alone or collaborate - Some operators not directly affected (e.g. water-based operators)
	Feedbacks 	- Global climate change effects on Caribbean islands	- Need to preserve beach area to keep tourists	- Closer to the beach is easier to get more tourists, thus many motivated to be close to the beach - Sand covers coral/ causes damage - Less resources available for other inputs or actions	- Adding sand causes "pollution", in water area to mimic sand covering the reef - Lack of funds, unable to deal with coastal erosion - Beachfront properties most affected (e.g. revenues)	- Test how SLR relates to other internal island changes

(*continued*)

Table 3. Continued.

	Methods				
	 Desktop research	 Interviews	 Simulation development	 Simulation sessions	 Computational modelling
Uncertainty 	- Degree of SLR - How it will combine with coastal erosion	- Unsure if/how 1m SLR would affect them	- Beach erosion is one of the events that can occur in the simulation, the timing uncertain - Uncertainty whether beach will naturally change back or persist - Tiles that change the coastline are randomly selected	- How much beach loss will affect their incomes - Will it go away - Location of lost and gained beach - Consequences of actions to the system - How much resources are needed for future challenges	- Multiple scenarios of rate to proxy explore uncertainty in rate of SLR on system
Iteration 	- SLR is one of the known key challenges for SIDS	- Interviews indicate that not much is known - Building plans do not significantly indicate a concern for SLR - Ongoing erosion problems, losing of beaches - Erosion which has some similar consequences is a concern	- Verifying how components are brought together with different stakeholders (e.g. location selection and reasoning therefore) - Applying different means to get participation in developing simulation (e.g. simulation-guided interviews instead of focus group sessions)	- May have less resources to deal with erosion due to previous challenges; thus unwilling or unable to pay themselves - May or may not be willing to collaborate based on previous events that participants faced, may be affected by other events that worsen effects	- Simplified behaviour choices of beach nourishment based on personal interest (i.e. owning a hotel) combined with limitations of personal resources and scenarios of SLR (timing and scale) to explore SLR vulnerability patterns

be effective) were cited by many stakeholders as reasons for not acting when faced with coastal erosion as well as other challenges. The agent-based model explored the longer-term implications of differences in mobility, capacities, and operational input preferences in the context of SLR.

Unintended feedbacks

Traditional methods of dealing with SLR and erosion include building sea walls, setting back beach amenities, and beach nourishment, or nature-based solutions, such as having mangroves. However, these are not simple solutions. Sea walls in combination with groynes (that prevent the transport of sand along the coast) create beaches in one area while keeping away sand from another. According to several interviewees, most sea wall have been placed without considering the impacts on other parts of the coastal system. This category of sea wall has the unintended effect of aggravating erosion on leeward beaches. During one of the simulations, damage to existing marine resources (including coral reefs) by building sea walls and groynes was discussed. During interviews, stakeholders noted that these structures also have an impact on tourism activities, as sea walls disrupt the wave patterns and make activities such as surfing difficult. Boat operators expressed concern about uncertain accessibility of harbours due to sand build-up, attributed to the placement of sea walls, since uninhibited harbour access is important for a smooth exchange of passengers.

Setting back amenities is difficult as many coastlines are already developed. Furthermore, when given the choice, both during the simulation-guided simulations and simulation sessions, most participants chose the closer beach areas for their business location instead of the safer areas farther in-land, which are potentially less attractive to tourists. Thus, even in areas that are not yet developed, the desire to place infrastructure as close to the sea as possible is prevalent. The unintended consequences of this location choice preference is further explored in the agent-based model under varying rates of SLR.

Desktop research and interviews indicated that reclaiming beach through beach nourishment is not only costly, but can negatively affect other aspects of the environment. Sea turtles that rely on the beaches are an important and endangered environmental resource that attracts tourists. Losing beach limits the options for sea turtles to successfully nest. At the same time, compacting of sand through beach nourishment can bury sea turtle nests, also resulting in lower hatching success. In the simulation, participants could choose beach nourishment to regain beach. However, this choice caused a negative feedback effect in the form of pollution, which mimics sand covering the reef.

Mangroves are a nature-based adaptation that can serve to protect the beach from erosion. During interviews, few people detected the potential benefits of maintaining or adding mangroves. This was consistent with simulation sessions: although mangroves were present and prevented erosion, few participants decided to plant mangroves and those who did had heated discussions about where and how many to plant, in order to avoid altering the beach aesthetics.

Through participating in simulation sessions, stakeholders could witness actual behaviours and feedbacks rather than hypothetical ones. Through reflection, stakeholders could increase their awareness of some of the consequences of location selection, erosion, and potential adaptation strategies.

Discussion

Practical information about climate change vulnerability constitutes vital input for effective climate change adaptation strategies in the Caribbean and other coastal destinations. This paper presents five principles of dynamic vulnerability assessments, introduces an approach to translate these principles into workable research action, and illustrates the approach's added value by applying it to SLR in a coastal tourism context. The approach shifts the focus of analysis away from external forces and destinations' aggregate features towards the internal structure of tourism destination systems and the features of and interactions among individual stakeholders and their environment. It shows how changes at the individual level play out together over time and affect system level vulnerabilities. Metaphorically speaking, it produces vulnerability motion pictures, showing the emergence of vulnerabilities over time, rather than static vulnerability snapshots. Although not all methods need to be applied nor in the order presented in the illustration, to really perform a dynamic assessment, experiencing and experimenting are essential. Thus, integrating system components and using some form of simulation session and/or computational model is required.

Our approach to studying vulnerability is similar to the four process steps of the tourism knowledge system proposed by Tribe and Liburd (2016): scoping, comparison, reflection, and abstraction. Desk research and interviews typically provide scope. Comparison of system features and processes can be done within as well as between case study areas. Reflection is achieved through the iterative process of interviews, simulation development, simulations, and computational modelling, leading to continuous co-creation of knowledge about system features and problems, and abstraction is achieved during debriefings and modelling. However, it takes it a step farther by integrating systems components as well as enabling researchers and stakeholders to experience and test complementary and contradictory insights of vulnerabilities.

The illustrative application of the approach to Barbados and Curaçao suggests that the approach has most to offer when its methods yield conflicting or contradictory insights that would have been missed by more aggregate top-down approaches. For example, the application clearly highlighted the contrasts between the alarmism about SLR among experts, the indifference about the issue expressed by local stakeholders in interviews, and the considerable willingness to act among these same stakeholders when experiencing the effects of SLR during simulations. The responses to SLR seem more straightforward than other climate change effects and yet the illustration highlighted trade-offs and unintended consequences when the ongoing interactions between tourism operators and environmental are considered.

The approach is rooted in transdisciplinary research. It combines and integrates knowledge from a variety of scientific and stakeholder sources and as such necessitates stakeholder participation. Stakeholders bring their beliefs, interests and (tacit) knowledge to the table, but they also benefit from participation (e.g., in the form of changed beliefs or new knowledge). The simulations in particular offer an important opportunity to learn from others, comment on previous knowledge assumptions, and experience the changing system, which was co-created with other stakeholders. Our approach supports Tribe and Liburd (2016) suggestion for co-creating knowledge, and it resonates with appeals for more transdisciplinary research that promotes systems thinking, looks at interactions and various feedbacks, and encourages learning (see e.g., Amelung et al., 2016; Folke et al., 2016). Social learning is "considered to be more appropriate for integrated and adaptive management regimes needed to cope with the complexity of social-ecological systems" (Pahl-Wostl et al., 2007, p. 5). Insights remain not only in the hands of researchers; they develop in the minds of the very stakeholders that can take the actual action needed to build resilience and reduce vulnerabilities. Learning, facilitating agency, creating supportive collaborations, and enabling the flexibility to change strategies are important for building adaptive capacity (Cinner et al., 2018).

Advocating stakeholder participation is one thing, achieving it is another. Stakeholder involvement requires time, resources, presence in the case study areas, and, preferably, support from key local actors (see e.g., Étienne et al., 2011). Adger (2006, p. 268) recognises the challenges of incorporating "diverse methods that include perceptions of risk and vulnerability" in vulnerability research. In addition, bringing stakeholders together at one time and place is especially challenging. A flexible research design is therefore crucial to consider participant availability and realistic participant numbers for group sessions. Alternatively, researchers can use simulation-guided interviews to collect data one-on-one or consider virtual sessions. The combination of methods facilitates acquiring heterogeneous perspectives and learning from others without requiring everyone to participate simultaneously.

This dynamic vulnerability approach addresses some of the weaknesses of previous approaches. It goes beyond identifying high-level vulnerability indicators, as in Perch-Nielsen (2010) work on the relative vulnerabilities of countries, by analysing who and what is vulnerable and how these vulnerabilities can emerge. The approach acknowledges the interconnectedness of problems and solutions in a complex system, which implies that one solution can produce a problem in another part of the system. Despite the advances, the approach can neither erase nor solve uncertainty and complexity. Nor does it strive to. It accepts uncertainty as an integral part of complex systems and creates a platform, through iteration, simulations, and modelling, that helps stakeholders deal with the unknown.

Conclusion

Many tourism destinations are vulnerable to environmental change. However, they are vulnerable in different ways. Vulnerabilities differ widely between local stakeholders, and change over time. This has direct consequences on how to manage tourism destinations. Therefore traditional assessments based on snapshots of high-level indicators do not provide the kind of information that destinations need to inform their vulnerability policies. Systematic approaches that capture the principles of dynamic vulnerability assessments, while providing the flexibility to account for local specificities are urgently needed. This paper formulated five principles that tourism-related dynamic vulnerability assessments should possess in order to be effective: human agency, heterogeneities, feedback, uncertainty, and iteration. More importantly, it has laid out a flexible methodological approach to put these principles into practice for scoping, system integration, and experiencing and experimenting: desktop research, interviews, simulation development, simulation sessions, and computational modelling. Experiencing and experimenting is perhaps the most characteristic phase of the dynamic vulnerability approach, and is also a potential tool against climate inaction. For example, the simulation sessions provided clearer insights on how actions affect their coastal system, exposed barriers to act, as well as offered the chance to discuss opportunities for action.

The approach and tools presented in this paper can be easily adjusted to other Caribbean and international coastal tourism destinations. Each coastal destination or island is different but shares many types of environmental resources and tourism actors with other destinations. Insights, materials, and processes developed for Barbados and Curaçao can be reused and widened to apply to other coastal tourism destinations, especially in the Caribbean. For example, the Coasting simulation could either be used in its current form on other islands to see what similarities and differences participants experience or be adapted to reflect different coastal environments and/or composition of tourism operators. Similarly, the set-up of the coastal environment and tourism operators in the agent-based model could be changed to reflect a different coastal destination. The transfer of information and adaptation of the process from the Barbados context to Curaçao provide an example of how iteration and further application can be achieved. The approach's scope of application is, however, by no means limited to Caribbean or coastal destinations. The approach's generic set of principles and the flexible methodological tools make it applicable to any kind of tourism destination that faces environmental challenges.

The explicit formulation of the principles and approach is an invitation to others to replicate and further develop the approach in other spatial and temporal settings. This approach provides a flexible starting point to conceptualise and operationalise vulnerability as a dynamic phenomenon. Future applications to tourism destinations could assess the effect of the new information that stakeholders obtain during simulations or during the debriefing. By restarting the simulation again after debriefing or by adding another round, changes in behaviour can be observed, as well as stakeholders' ability to prevent or address some of the challenges and threats. More elaborate agent-based models can broaden the type of scenarios to be explored and address a new range of questions. Improving and accelerating the cycle of knowledge coproduction is desperately needed to derive practical recommendations for the tourism industry and policy makers.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The PhD research was supported by the Dutch NWO-MAGW Research Talent grant Project Number: 406.14.068. Part of the research was developed in the Young Scientists Summer Program at the International Institute for Applied Systems Analysis, Laxenburg (Austria) with financial support from the Dutch National Member Organisation, NWO YSSP 2017 grant Project number: 0539.600.102. Thank you Dr Wei Liu and Dr Asjad Naqvi for comments on early versions of this manuscript and Grace Besharah for editing work.

Notes on contributors

Jillian Student, PhD candidate, Environmental Policy & Environmental Systems Analysis Groups, Wageningen UR, Hollandseweg 1, 6706 KN Wageningen, The Netherlands, jillian.student@wur.nl

Dr. Machiel Lamers, Associate Professor, Environmental Policy Group, Wageningen UR, Hollandseweg 1, 6706 KN Wageningen, The Netherlands.

Dr. Bas Amelung, Assistant Professor, Environmental Systems Analysis Group, Wageningen UR, Lumen building, Building number 100, Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands.

Jillian Student's research pursuits include human-environmental dynamics, interactive (companion) modelling, tourism, environmental change, and participatory research.

Dr. Machiel Lamers' main research interests are in new modes of governance in sustainable tourism and conservation tourism across the world.

Dr. Bas Amelung's research focuses on tourism in relation to climate change, water use, and ecosystem services.

ORCID

Jillian Student http://orcid.org/0000-0002-2859-3691
Machiel Lamers https://orcid.org/0000-0002-4189-3066
Bas Amelung https://orcid.org/0000-0001-8501-9787

References

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268–281. doi:10.1016/j.gloenvcha.2006.02.006

Adger, W. N., & Brown, K. (2009). Chapter 8 Vulnerability and resilience to environmental change: Ecological and social perspectives. In N. Castree, D. Demeritt, D. Liverman, & B. Rhoads (Eds.), *A Companion to Environmental Geography* (pp. 109–122). Oxford, UK: Wiley-Blackwell. doi:10.1002/9781444305722

Amel, E., Manning, C., Scott, B., & Koger, S. (2017). Beyond the roots of human inaction: Fostering collective effort toward ecosystem conservation. *Science*, *356*(6335), 275–279. doi:10.1016/b978-012091560-6/50013-5

Amelung, B., Student, J., Nicholls, S., Lamers, M., Baggio, R., Boavida-Portugal, I., … Balbi, S. (2016). The value of agent-based modelling for assessing tourism–environment interactions in the Anthropocene. *Current Opinion in Environmental Sustainability*, *23*, 46–53. doi:10.1016/j.cosust.2016.11.015

Baggio, R. (2008). Symptoms of complexity in a tourism system. *Tourism Analysis*, *13*(1), 1–20. doi:10.3727/108354208784548797

Becken, S. (2013a). A review of tourism and climate change as an evolving knowledge domain. *Tourism Management Perspectives*, *6*, 53–62. doi:10.1016/j.tmp.2012.11.006

Becken, S. (2013b). Developing a framework for assessing resilience of tourism sub-systems to climatic factors. *Annals of Tourism Research*, *43*, 506–528. doi:10.1016/j.annals.2013.06.002

Becken, S., Mahon, R., Rennie, H. G., & Shakeela, A. (2014). The tourism disaster vulnerability framework: An application to tourism in small island destinations. *Natural Hazards*, *71*(1), 955. doi:10.1007/s11069-013-0946-x

Brown, K., Eernstman, N., Huke, A. R., & Reding, N. (2017). The drama of resilience: Learning, doing, and sharing for sustainability. *Ecology and Society*, *22*(2), 8. doi:10.5751/ES-09145-220208

Bruno Soares, M., Alexander, M., & Dessai, S. (2018). Sectoral use of climate information in Europe: A synoptic overview. *Climate Services*, *9*, 5–20. doi:10.1016/j.cliser.2017.06.001

Buckley, R., Gretzel, U., Scott, D., Weaver, D., & Becken, S. (2015). Tourism megatrends. *Tourism Recreation Research*, *40*(1), 59–70. doi:10.1080/02508281.2015.1005942

Calgaro, E., Dominey-Howes, D., & Lloyd, K. (2014). Application of the destination sustainability framework to explore the drivers of vulnerability and resilience in Thailand following the 2004 Indian Ocean Tsunami. *Journal of Sustainable Tourism*, *22*(3), 361–383. doi:10.1080/09669582.2013.826231

Calgaro, E., & Lloyd, K. (2008). Sun, sea, sand and tsunami: Examining disaster vulnerability in the tourism community of Khao Lak, Thailand. *Singapore Journal of Tropical Geography*, *29*(3), 288–306. doi:10.1111/j.1467-9493.2008.00335.x

Calgaro, E., Lloyd, K., & Dominey-Howes, D. (2014). From vulnerability to transformation: A framework for assessing the vulnerability and resilience of tourism destinations. *Journal of Sustainable Tourism*, *22*(3), 341–360. doi:10.1080/09669582.2013.826229

Cashman, A., Cumberbatch, J., & Moore, W. (2012). The effects of climate change on tourism in small states: Evidence from the Barbados case. *Tourism Review*, *67*(3), 17–29. doi:10.1108/16605371211259803

Charara, N., Cashman, A., Bonnell, R., & Gehr, R. (2011). Water use efficiency in the hotel sector of barbados. *Journal of Sustainable Tourism*, *19*(2), 231–245. doi:10.1080/09669582.2010.502577

Cinner, J. E., Adger, W. N., Allison, E. H., Barnes, M. L., Brown, K., Cohen, P. J., … Morrison, T. H. (2018). Building adaptive capacity to climate change in tropical coastal communities. *Nature Climate Change*, *8*(2), 117–123. doi:10.1038/s41558-017-0065-x

Cohen, S. A., Higham, J. E. S., & Reis, A. C. (2013). Sociological barriers to developing sustainable discretionary air travel behaviour. *Journal of Sustainable Tourism*, *21*(7), 982–998. doi:10.1080/09669582.2013.809092

Csete, M., & Szécsi, N. (2015). The role of tourism management in adaptation to climate change – a study of a European inland area with a diversified tourism supply. *Journal of Sustainable Tourism*, *23*(3), 477–496. doi:10.1080/09669582.2014.969735

Curaçao Tourist Board (CTB). (2015). *Tourism master plan 2015–2020*. Retrieved from https://www.curacao.com/media/uploads/2015/10/07/CUR_TMP_Oct-05-15_Final.pdf

Darbellay, F., & Stock, M. (2012). Tourism as complex interdisciplinary research object. *Annals of Tourism Research*, *39*(1), 441–458. doi:10.1016/j.annals.2011.07.002

Duvat, V. K. E., Magnan, A. K., Wise, R. M., Hay, J. E., Fazey, I., Hinkel, J., … Ballu, V. (2017). Trajectories of exposure and vulnerability of small islands to climate change. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(6), e478. doi:10.1002/wcc.478

Espiner, S., Orchiston, C., & Higham, J. (2017). Resilience and sustainability: A complementary relationship? Towards a practical conceptual model for the sustainability–resilience nexus in tourism. *Journal of Sustainable Tourism*, *25*(10), 1385–1400. doi:10.1080/09669582.2017.1281929

Étienne, M. (Ed.). (2014). *Companion modelling- a participatory approach to support sustainable development*. Versailles: Springer Netherlands- Éditions Quae. doi:10.1007/978-94-017-8557-0

Étienne, M., Du Toit, D. R., & Pollard, S. (2011). ARDI: A co-construction method for participatory modeling in natural resources management. *Ecology and Society*, *16*(1), 44. doi:10.5751/ES-03748-160144

Filimonau, V., & De Coteau, D. (2019). Tourism resilience in the context of integrated destination and disaster management (DM^2). *International Journal of Tourism Research*, 1–21. doi:10.1002/jtr.2329

Fish, M. R., Côté, I. M., Horrocks, J. A., Mulligan, B., Watkinson, A. R., & Jones, A. P. (2008). Construction setback regulations and sea-level rise: Mitigating sea turtle nesting beach loss. *Ocean & Coastal Management*, *51*(4), 330–341. doi:10.1016/j.ocecoaman.2007.09.002

Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society*, *21*(3), 41. doi:10.5751/ES-08748-210341

Giddens, A. (2009). *The politics of climate change*. Cambridge, UK: Polity Press.

Gifford, R. (2011). The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. *American Psychologist*, *66*(4), 290–302. doi:10.1037/a0023566

Gössling, S., Scott, D., Hall, C. M., Ceron, J. P., & Dubois, G. (2012). Consumer behaviour and demand response of tourists to climate change. *Annals of Tourism Research*, *39*(1), 36–58. doi:10.1016/j.annals.2011.11.002

Johnson, P., Nicholls, S., Student, J., Amelung, B., Baggio, R., Balbi, S., … Steiger, R. (2016). Easing the adoption of agent-based modelling (ABM) in tourism research. *Current Issues in Tourism*, *20*(8), 801–808. doi:10.1080/13683500.2016.1209165

Kaján, E., & Saarinen, J. (2013). Tourism, climate change and adaptation: A review. *Current Issues in Tourism*, *16*(2), 167–195. doi:10.1080/13683500.2013.774323

Lalicic, L., & Weber-Sabil, J. (2019). Stakeholder engagement in sustainable tourism planning through serious gaming. *Tourism Geographies*, 1–19. doi:10.1080/14616688.2019.1648543

Larsen, R. K., Calgaro, E., & Thomalla, F. (2011). Governing resilience building in Thailand's tourism-dependent coastal communities: Conceptualising stakeholder agency in social-ecological systems. *Global Environmental Change*, *21*(2), 481–491. doi:10.1016/j.gloenvcha.2010.12.009

Lemos, M. C., Kirchhoff, C. J., & Ramprasad, V. (2012). Narrowing the climate information usability gap. *Nature Climate Change*, *2*(11), 789–794. doi:10.1038/nclimate1614

Levin, S., Xepapadeas, T., Crépin, A.-S., Norberg, J., de Zeeuw, A., Folke, C., … Walker, B. (2013). Social-ecological systems as complex adaptive systems: Modeling and policy implications. *Environment and Development Economics*, *18*(2), 111–132. doi:10.1017/S1355770X12000460

Moreno, A., & Becken, S. (2009). A climate change vulnerability assessment methodology for coastal tourism. *Journal of Sustainable Tourism*, *17*(4), 473–488. doi:10.1080/09669580802651681

Nicholls, S., Amelung, B., & Student, J. (2017). Agent-based modeling: A powerful tool for tourism researchers. *Journal of Travel Research*, *56*(1), 3–15. doi:10.1177/0047287515620490

Nurse, L. A., McLean, R. F., Agard, J., Briguglio, L. P., Duvat-Magnan, V., Pelesikoti, N., … Webb, A. (2014). Small islands. In *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change* (pp. 1613–1654). Cambridge, UK and New York, NY: Cambridge University Press. doi:10.2134/jeq2008.0015br

Oxenford, H. A., Roach, R., Brathwaite, A., Nurse, L., Goodridge, R., Hinds, F., … Finney, C. (2008). Quantitative observations of a major coral bleaching event in Barbados, Southeastern Caribbean. *Climatic Change*, *87*(3–4), 435–449. doi:10.1007/s10584-007-9311-y

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., & Taillieu, T. (2007). Social learning in water resources management social learning and water resources management. *Ecology and Society*, *12*(2), 5. Retrieved from https://www.ecologyandsociety.org/vol12/iss2/art5/ doi:10.5751/ES-02037-120205

Perch-Nielsen, S. L. (2010). The vulnerability of beach tourism to climate change-an index approach. *Climatic Change*, *100*(3–4), 579–606. doi:10.1007/s10584-009-9692-1

Pyke, J., Law, A., Jiang, M., & de Lacy, T. (2018). Learning from the locals: The role of stakeholder engagement in building tourism and community resilience. *Journal of Ecotourism*, *17*(3), 206–219. doi:10.1080/14724049.2018.1505586

Rhiney, K. (2015). Geographies of Caribbean vulnerability in a changing climate: Issues and trends. *Geography Compass*, *9*(3), 97–114. doi:10.1111/gec3.12199

Santos-Lacueva, R., Anton Clavé, S., & Saladié, Ò. (2017). The vulnerability of coastal tourism destinations to climate change: The usefulness of policy analysis. *Sustainability*, *9*(11), 1–19. doi:10.3390/su9112062

Santos-Lacueva, R., Ariza, E., Romagosa, F., & Saladié, Ò. (2019). The vulnerability of destinations to climate change: A comparative analysis of contextual socio-political factors. *Journal of Sustainable Tourism*, *27*(8), 1217–1238. doi:10.1080/09669582.2019.1607865

Scott, D., Gössling, S., & Hall, C. M. (2012). International tourism and climate change. *Wiley Interdisciplinary Reviews: Climate Change*, *3*(3), 213–232. doi:10.1002/wcc.165

Scott, D., Simpson, M. C., & Sim, R. (2012). The vulnerability of Caribbean coastal tourism to scenarios of climate change related sea level rise. *Journal of Sustainable Tourism*, *20*(6), 883–898. doi:10.1080/09669582.2012.699063

Simon, C., & Étienne, M. (2010). A companion modelling approach applied to forest management planning. *Environmental Modelling & Software*, *25*(11), 1371–1384. doi:10.1016/j.envsoft.2009.09.004

Souchère, V., Millair, L., Echeverria, J., Bousquet, F., Le Page, C., & Étienne, M. (2010). Co-constructing with stakeholders a role-playing game to initiate collective management of erosive runoff risks at the watershed scale. *Environmental Modelling & Software*, *25*(11), 1359–1370. doi:10.1016/j.envsoft.2009.03.002

Tribe, J., & Liburd, J. J. (2016). The tourism knowledge system. *Annals of Tourism Research*, *57*, 44–61. doi:10.1016/j.annals.2015.11.011

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., … Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences*, *100*(14), 8074–8079. doi:10.1073/pnas.1231335100

UNWTO-UNEP-WMO. (2008). *Climate change and tourism: Responding to global challenges climate change and tourism responding to global challenges*. Madrid. Retrieved from http://sdt.unwto.org/sites/all/files/docpdf/climate2008.pdf

Uyarra, M. C., Côté, I. M., Gill, J. A., Tinch, R. R. T., Viner, D., & Watkinson, A. R. (2005). Island-specific preferences of tourists for environmental features: Implications of climate change for tourism-dependent states. *Environmental Conservation*, *32*(1), 11–19. doi:10.1017/S0376892904001808

van der Veeken, S., Calgaro, E., Munk Klint, L., Law, A., Jiang, M., de Lacy, T., & Dominey-Howes, D. (2016). Tourism destinations' vulnerability to climate change: Nature-based tourism in Vava'u, the Kingdom of Tonga. *Tourism and Hospitality Research*, *16*(1), 50–71. doi:10.1177/1467358415611068

Winn, M. I., Kirchgeorg, M., Griffi, A., & Linnenluecke, M. K. (2011). Impacts from climate change on organizations: A conceptual foundation. *Business Strategy and the Environment*, *20*(3), 157–173. doi:10.1002/bse.679

World Travel & Tourism Council (WTTC). (2017). *Travel & tourism economic impact 2017 Barbados*. Retrieved from https://www.wttc.org/-/media/files/reports/economic-impact-research/countries-2017/barbados2017.pdf