Environmental Science and Policy 89 (2018) 393–400

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Unavoidable solutions for coastal adaptation in Reunion Island (Indian Ocean)

Alexandre K. Magnan[a,b,*], Virginie K.E. Duvat[b,*]

[a] Institute for Sustainable Development and International Relations, Sciences Po, 27 rue Saint Guillaume, 75007, Paris, France
[b] UMR LIENSs 7266, University of la Rochelle-CNRS, 2 rue Olympe de Gouges, 17000, La Rochelle, France

ARTICLE INFO

Keywords:
Vulnerability
Adaptation
Climate change
Coastal areas
Small islands

ABSTRACT

The study of recent past trajectories of vulnerability to climate-related hazards allows for highlighting the prevailing environmental and anthropogenic drivers that operated over the last fifty to sixty years and given latency phenomena in social systems, therefore have the potential to continue driving a system's vulnerability in the coming decades. Stop or even reverse these trends represents as much unavoidable solutions for enhancing concrete long-term adaptation to climate change, whatever the end-century warming scenario.

Using the case study of Reunion Island (Indian Ocean), we emphasize four major drivers of the recent coastal trajectory of vulnerability, i.e. changes in human-built assets, shoreline position, natural buffers' characteristics, and the extent of coastal protection structures. Together, these drivers highlight the need for controlling the urbanisation process to reduce the anthropogenic pressures exerted on morphological-ecological systems, restoring the buffering function of the latter, and moving towards a less hard structure-dependent coastal defence strategy. Such a shift in coastal management however supposes some radical changes in the way coastal development strategies consider environmental issues (hazards, resources and services). Here we bring empirical material showing that neither Reunion Island decision-makers are keen to drive such radical changes, nor the population is ready to accept potentially constraining policies that will have benefits only in the future. We conclude on the need for further advancing the design of adaptation pathways that build on the implementation of context-specific unavoidable solutions, and thus that seriously consider limiting the risk of maladaptation as a baseline strategy.

1. Introduction

The identification of climate change adaptation solutions that can be implemented now and allow bypassing the problem of uncertainty on future global warming and induced local impacts, is a growing concern worldwide. Prior to the 21st Conference of the Parties of the United Framework Convention on Climate Change (COP21) in 2015, the international community shifted from the design of the problem to the "era of solutions" (UNFCCC, 2014). Similarly, the scientific community gets more and more involved in practice-oriented analyses, notably with growing efforts into understanding the maladaptation and adaptation pathways issues. Maladaptation refers to adaptation-labelled initiatives that can actually turn out to be harmful, and so to the risk that efforts aiming at fostering adaptation in the short-term in fact affect territories', sectors', and people's long-term capacity and opportunities to cope with the impacts of climate change (Juhola et al., 2016; Magnan et al., 2016). A critical underlying question deals here with the identification of tangible ways to prevent the risk of maladaptation. The adaptation pathways literature advocates that any long-term adaptation strategy of a particular decision-maker must be based upon decision cycles that sequence a set of possible actions based on alternative external, uncertain developments (Haasnoot et al., 2013; Barnett et al., 2014; Wise et al., 2014; Fazey et al., 2016). However, a critical underlying question refers to the identification of both the first solutions to be put in place and the sequencing of initiatives on the long run. A third contextual element pushes for advancing the "era of solutions" further. There is indeed a risk that the IPCC Special Report on the impacts of a + 1.5 °C world does not intentionally allow for the uncertainty problem to get back on stage. In the substance, this report questions the feasibility for the global society to effectively decarbonize its development patterns (Fawcett et al., 2015; Anderson and Peters, 2016), and for the scientific community to bring new evidence on the differential local-scale impacts induced by only few tenths of a degree in global temperature on a multi-decadal scale (Mitchell et al., 2016;

* Corresponding authors.
E-mail addresses: alexandre.magnan@iddri.org (A.K. Magnan), virginie.duvat@univ-lr.fr (V.K.E. Duvat).

https://doi.org/10.1016/j.envsci.2018.09.002
Received 11 January 2018; Received in revised form 6 September 2018; Accepted 7 September 2018
1462-9011/

Peters, 2016; Schleussner et al., 2016). These two aspects encompass considerable sources of uncertainty. Regarding impacts, scientists legitimately deliver results in terms of probability and ranges of uncertainty, such as illustrated in recent studies on long-term sea-level rise (Schaeffer et al., 2012), on the future of Mediterranean ecosystems (Guiot and Cramer, 2016) and on global marine fisheries (Cheung et al., 2016). While science is clear on the fact that uncertainty cannot prevent decision and action (Stafford-Smith et al., 2011; Hallegatte et al., 2016; Oppenheimer and Alley, 2016), there is still a risk that the decision-making arena uses uncertainty as an alibi to postpone difficult decisions (e.g., relocation of economic activities or settlements). This would however have exponential detrimental effects worldwide, and so there is a crucial need for science to reaffirm that taking now long-term adaptation-compatible action is possible.

In this aim, scientists suggest to explore the consequences of different choices under various end-century warming scenarios (Hallegatte et al., 2016), based for example on the assessment of the risks of impact of such contrasting futures on social-ecological systems (Gattuso et al., 2015; O'Neill et al., 2017). Here, we argue for a complementary way that aims at drawing lessons from the recent past rather than only looking forward to the long-term future, in order to demonstrate that critical solutions for the future already exist. This refers to the "Trajectory of Vulnerability" approach (ToV), which consists in designing part of the adaptation solutions based on the lessons learnt from storylines highlighting the prevailing drivers of a given coastal system's vulnerability to climate variability and change over the last five to six decades (Duvat et al., 2017). Because of path-dependency effects inherent to both social systems inertia (e.g.,Fehr-Duda, 2016) and lock-in phenomena (e.g. in urban processes; Reyna and Chester, 2014), and in the context of sea-level rise, the observed multi-decadal drivers have the potential to continue driving the system's vulnerability in the coming decades (Duvat et al., 2017). Accordingly, actions to overcome past-to-present trends represent an area of "unavoidable" solutions and constitute together a first pragmatic step to both limit maladaptation and enhance long-term adaptation pathways.

Here, we use the case study of Reunion Island to demonstrate the relevance of studying the past-to-present drivers of vulnerability in order to highlight the unavoidable solutions for coastal adaptation. Looking backward however raises a major question for the Present, namely about the ability of a given society to effectively implement well-known solutions to well-known problems. Using empirical material on Reunion Island decision-makers' visions of the future and on coastal residents' perceptions of current to future climate-related coastal risks, we discuss how neither the formers are ready to drive radical change towards more climate-proof coastal development strategies, nor the latter are keen to accept potentially constraining policies that will mainly have delayed benefits. We also analyse and discuss the need for further advancing the design of adaptation pathways that build on the implementation of context-specific unavoidable solutions, and thus that seriously consider limiting the risk of maladaptation as a baseline strategy.

2. Study area

Reunion Island is a French overseas territory located in the south-western Indian Ocean (21°10′S, 55°30′E). It has a land area of 2512 km^2, with its highest point at 3070 m above sea level (Piton des Neiges inactive volcano). Its 240 km-long coastline is made of a variety of morphological features, including three main river deltas, high and low rocky coasts, as well as volcanic and coral beach-dune systems, most of which are bordered with fringing coral reefs (Cazes-Duvat and Paskoff, 2004). Its 850,727 inhabitants[1] are mostly located in the coastal zone. With an economy based on services, tourism and agriculture, and a Gross National Income per capita higher than $23,000, this case is representative of a High-income economy according to the World Bank Income Groups[2] (GNI > $12,476 per capita), and its coastal development patterns follow the worldwide trend, i.e. densification and urbanisation (Wong et al., 2014).

The study area covers 39.7 km of coastline from north to south along the western side of the island, where most of the population and economic activities concentrate. It is composed of four municipalities that this paper uses as case studies, including the island's two main urban centres (Saint-Denis in the north, 146,985 inhabitants; and Saint-Pierre in the south, 84,063 inhab.), its industrial harbour (Le Port, 35,280 inhab.) and its first municipality for coastal tourism (Saint-Paul, 105,967 inhab.). In addition to urbanised seafronts, the area exhibits alluvial features made of volcanic material, such as sand and pebble beaches bordered with sand dunes, coral coasts made of beach-dune systems fringed with embryonic to fringing coral reefs, and rocky volcanic coasts including low-lying areas and cliffs (Cazes-Duvat and Paskoff, 2004). The whole area is prone to tropical cyclones and distant-source swells, both of which frequently generating impacts on coastal morphology (i.e., erosion and accretion, and marine inundation), vegetation and human assets (Duvat et al., 2016a).

3. Material and methods

This study involves three datasets that have thus far only been published in French and analysed separately (Duvat and Salmon, 2015; Magnan et al., 2015; Duvat et al., 2016b; Magnan and Charpentier, 2016). The added-value of this paper relies in the combination of their main results into an integrative analysis going from the drivers of vulnerability to adaptation-related issues.

The first dataset refers to the characterization of the changes that have occurred between 1950 and 2011 in human-built assets (number and location of buildings and key infrastructures), shoreline position (calculation of shoreline change rates and analysis of human-driven disruption of natural processes), terrestrial natural buffer zones (extent, nature and buffering functions of beach-dune systems and alluvial features such as coastal deltas) and coastal protection structures (extent, nature, condition and dimensions). This dataset covers the four studied municipalities, i.e. Saint-Denis, Le Port, Saint-Paul and Saint-Pierre. For each of the above-mentioned items, data were generated based on multi-date aerial image analysis, i.e. on the comparison of historical aerial photographs provided by the Institut Géographique National (IGN) for 1950 and 1978, with the 2011 ortho-photography provided by the IGN. Each historic aerial photograph was georeferenced and integrated into a Geographic Information System (GIS) using ArcGis 10.2 software. This allowed conducting a comparative analysis of the three data series (1950, 1978 and 2011), and emphasizing specific changes, for example in terms of *(i)* buildings' distance to the shoreline (using the "near" tool of the ArcGis software, which allows for calculating the minimal distance between two entities, here a building and the shoreline), *(ii)* terrestrial natural buffer zones contraction, or *(iii)* shoreline change (using the Digital Shoreline Analysis System software, DSAS). The buildings' elevation values were extracted using Lidar elevation data (2012-issued Litto3D®IGN, data collected between September 2008 and October 2010, precision in elevation of 20 cm) applied to the centroid of each building. To document coastal protection structures (location, nature, condition and dimensions, see Duvat (2013) for details on the methodology) and their contribution to the disruption of natural processes (Duvat and Salmon, 2015), we used multi-date aerial image analysis and fieldwork, which was conducted between 2012 and 2016. Two limitations must be mentioned here that

[1] https://www.insee.fr/fr/information/2018985.

[2] Data for 2015. Source: INSEE Reunion, https://www.insee.fr/fr/statistiques?debut=0&idprec=3290942&theme=0&collection=32+113+86.