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# Collaborative landscape research in Reunion Island: Using spatial modelling and simulation to support territorial foresight and urban planning

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ABSTRACT

This paper reflects on collaborative landscape research conducted in Reunion Island, an outermost region of the European Union. On this 2,500 km$^2$ tropical island also considered a major international biodiversity hotspot, land-use planners must address important challenges, especially growing population densities and urban sprawl that cause important pressure on agricultural land and natural ecosystems. While progress has been made towards land-use zoning and planning at the island scale, entrenched interests and a lack of communication between the agricultural, urban and environmental sectors continue to hinder the design and implementation of integrated land-use plans at the local level. This paper presents an approach to territorial foresight where urban development scenarios and spatial models were co-constructed with a collective of institutional actors in order to facilitate dialogue on future urbanization patterns and impacts on landscapes. It describes how spatially explicit models and simulations of urban development, first used as demonstrators, have raised individual interests and expectations and facilitated the structuring of a collaborative research network. Models and scenarios were then questioned, redesigned collectively and used as boundary objects to facilitate a shift away from statistical and sectorial readings towards more territorialized and integrated perspectives. Analysing inputs, reactions and feedback from the actors involved in the research, this paper discusses the role and potential value of landscape modelling and simulation in mediating debates among planning stakeholders and creating social learning situations.



## 1. Introduction

Despite substantial advances in scientific understanding of land-use dynamics at the interface of environmental and social disciplines, land-use planning in complex socioecological systems requires alternative approaches to conventional management (Berkes & Turner, 2006). Concerted reflection and cooperation (Folke, 2006; Frost, Campbell, Medina, & Usongo, 2006) along with the involvement of a large range of stakeholders in land management are highlighted as ways to improve the quality, legitimacy and sustainability of decision-making (Beierle, 2002; Bourgoin, Castella, Pullar, Lestrelin, & Bouahom, 2012; Lestrelin, Bourgoin, Bouahom, & Castella, 2011; Stringer & Reed, 2007). To address the governance of socioecological systems, recent literature also advocates for systemic perspectives (Lemos & Agrawal, 2006). Encompassing these concerns, the concept of adaptive co-management has been widely acknowledged in literature (Olsson, Folke, & Berkes, 2004; Plummer, Armitage, & de Loë, 2013). The paradigm is defined as the sharing of management power and responsibility within social networks through action and learning iterations (Berkes & Turner, 2006; Berkes, 2009). The term social network refers to a flexible set of relations between various stakeholders, including local users, policy makers and researchers (Leys & Vanclay, 2011). Within such

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networks, bridging organisations are designed to relate different levels of governance and provide arenas for knowledge sharing, collaboration, and learning (Berkes, 2009; Folke, Hahn, Olsson, & Norberg, 2005; Leys & Vanclay, 2011). Several authors argue that research organisations can play the role of bridging organisations by supporting networking, knowledge sharing and integration (Hahn, Olsson, Folke, & Johansson, 2006; Prager, 2010).

Much emphasis has been placed on social learning to support governance of socioecological systems. In this context, learning can be defined as "a process of social change" (Reed et al., 2010, p. 2) "where different actors can deliberate and negotiate rules, norms and power relations" (Rist, Chidambaranathan, Escobar, Wiesmann, & Zimmermann, 2007, p. 23). Whereas learning represents a normative goal in management agendas, the emergence of learning communities is also depicted as a way to enhance joint decision-making and proactive interaction about socioecological change within communities of practice (Armitage, Marschke, & Plummer, 2008; Fazey, Fazey, & Fazey, 2005; Folke, 2006; Wollenberg et al., 2007). Yet, although participatory processes can facilitate social learning (Cundill, 2010), they still represent a challenge for addressing landscape scale issues that require knowledge integration from a range of stakeholders (Albert, Zimmermann, Knieling, & von Haaren, 2012; Folke et al., 2005).

Participatory processes can benefit from various forms of spatial representations. Spatial representations, modelling and simulations can facilitate connectivity between actors and their different worldviews (Couclelis, 2005; Van Vliet, Kok, & Veldkamp, 2010; Pahl-Wostl & Hare, 2004; Voinov & Bousquet, 2010). Given the evident reliance of landscape studies on spatial and temporal information, spatially explicit modelling and simulation are being increasingly employed when landscape changes are at stake (Bourgoin, Castella, Hett, Lestrelin, & Heinimann, 2013; Sandker et al., 2010). They constitute powerful tools for engaging with landscape-related issues and result from a particularly active research field organized around modelling formalisms that include top-down (e.g. systems dynamics) and bottom-up or individual based (e.g. cellular automata, agent-based) approaches coupled with geographic information systems (GIS) (Degenne et al., 2009; Maurel et al., 2007; Veldkamp & Verburg, 2004). These tools allow integrating spatial and non-spatial information from multiple sources in order to describe landscape patterns and processes across scales. From a social constructivist perspective, spatial models and simulations can also serve as boundary objects (Van Egmond & Zeiss, 2010). They are technological artefacts constructed through social interactions and they can be plastic enough to allow for different interpretations while conserving sufficient integrity to act as a means of translation between different worldviews (Star & Griesemer, 1989). In turn, by mediating between different social groups and facilitating communication among individuals, they may foster social learning (Fominykh, Prasolova-Førland, Divitini, & Abbas Petersen, 2016).

In this paper, we present a case study of collaborative landscape research in Reunion Island, a 2,500 km$^2$ French island located in the Western Indian Ocean. In the *Territoire de la Côte Ouest* (TCO) inter-municipality, we tested state-of-the-art spatial modelling and simulation tools within a broad participatory scenario planning framework. One of our central objectives was to identify efficient strategies for engaging stakeholders into collaborative landscape research and, especially, to assess the value of participatory scenario planning and modelling for fostering dialogue and creating enabling conditions for social learning. In the next sections, we present the study area, the experimental framework and tools employed. We then describe how this framework and tools have shaped the emergence of a science-policy bridging organization, constituted by a flexible network of diverse institutional actors and a pivotal relation between researchers and urban planning experts. Finally, analyzing stakeholders' reactions and feedback observed and collected throughout the research process, we discuss the potential contribution of participatory landscape modelling and simulation to addressing key land-use planning challenges in Reunion Island and beyond.

## 2. Challenges and history of land-use planning in the study area

Reunion Island is characterized by a steeply sloping volcanic relief with a maximum elevation of 3,070 m. A third of its area is covered by native vegetation, ranging from lowland rainforest to subalpine grassland (Strasberg et al., 2005). Since the creation of a National Park in 2007, 43% of the island (1,000 km$^2$) has become protected area. The island is recognized as a UNESCO World Heritage Site and is a global priority for conservation owing to high concentrations of endemic taxa. At present, more than 80% of the 840,000 inhabitants live on the coastal fringe where most of the economic activities are concentrated, leading to population densities up to 800 per km$^2$. The population has been increasing at a rate of 1.5% per year since 2000 and is expected to reach 1 million in 2030. Since the 1990s, development funds from the European Union have boosted the economy of the island. Concomitantly, urban areas have expanded rapidly and the remaining land has become a coveted resource. Below 1000 m elevation, landscapes are now expected to fulfil multiple functions including housing, commercial, industrial and leisure activities, agricultural production and ecosystem conservation. In a context of growing population densities, low employment and high poverty rates, future challenges for land-use planning in Reunion Island include the control of urban sprawl and the protection of agricultural land and natural ecosystems from conversion by urbanization (Lagabrielle et al., 2010; Martignac, Metzger, Thinon, & Cheylan, 2011). With very high population densities in littoral areas, strong demand for housing and urban development, uncontrolled urban sprawl on the slopes and landscapes of high agricultural and/or conservation value, the TCO inter-municipality concentrates these challenges on a 536 km$^2$ territory (Fig. 1).

Various sectorial and integrated planning schemes are being used to address these challenges. At the island scale for instance, alongside the establishment of the National Park, a regional water management scheme and a regional planning scheme have been developed in 2009 and 2011 respectively. At the inter-municipal level, these legal instruments are framing more detailed planning schemes, especially a 10-year Territorial Coherence Scheme (SCoT) that attempts to integrate urban planning with wider issues of territorial armature, interactions with agriculture and environmental preservation. Other, guidance and planning schemes have been developed by the TCO inter-municipality, especially a landscape charter adopted in 2007 that puts forward a series of provisions to ensure the preservation of agricultural and natural lands, the improvement of urban and built environments, and the development of the transportation network. The landscape charter was later expanded in two specific directions with the production of inter-municipal plans for the development of peri-urban fringes (*lisières urbaines*) in 2009 and the protection of ravines in 2010.

Notwithstanding these various regulations and plans, the TCO inter-municipality is facing substantial difficulties when it comes to actual integration and implementation on the ground. The landscape charter and the plans for peri-urban fringes and ravines have had impacts and translations in legal documents, especially in local urbanization plans (PLU). A number of landscape-related regulations have thus been made compulsory for urban land managers and project developers. With public debates organized in relation