THE RESILIENCE PERFORMANCE ASSESSMENT (RPA), AN INNOVATIVE SOLUTION TO MEASURE THE BALANCE BETWEEN ADAPTATION AND MITIGATION INVESTMENTS FOR INFRASTRUCTURES, BUILDINGS AND TERRITORIES

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Abstract

The Resilience Performance Assessment (RPA) is an innovative solution allowing efficiency and balance between climate change mitigation and adaptation about the full infrastructure's life cycle, buildings and territories. It provides a holistic approach combining visualization of both current and future climate change impacts. It also brings vulnerability scoring of future and existing assets. This decision-making tool also allows the formulation of detailed recommendations and a costs-benefits assessment to estimate the resilience performance of each project or policy aiming at improving resilience and avoiding GHG emissions.

Keywords: resilience, decision-making tool, infrastructures, exposure, vulnerability, costs-benefits

Introduction

Climate change is currently increasing the frequency, the intensity and the duration of natural hazards (IPCC, 2021). The magnitude of damages caused by recent disasters led the decision-makers to the conclusion that our infrastructures and territories are not or no longer adapted to the climate-induced risks. If the cost of investing in resilient infrastructures is still an obstacle to the implementation of adaptation strategies (Casello and Towns, 2017), the cost of the inaction is higher than the cost of the prevention and represents more than 20% of the global GDP[1]. In the "business as usual scenario", the climate-induced economic disasters will reach 1450 billions EUR per year by 2025 and 25 000 billion EUR by 2075[2]. Prioritizing the adaptation of our infrastructures, buildings, territories and projects is urgently required as well as drastically reducing Green House Gases (GHG) emissions.

Infrastructures, particularly critical infrastructures ensuring water and energy supply, sanitation, transport and telecommunications, are strongly interconnected. The slightest failure or dysfunction of a component of a critical infrastructure can generate major cascade effects on the territories that they supply (La Porte, 2006; Robert and Morabito, 2009). Specific indicators exist to evaluate infrastructure physical and socio-economic vulnerability (Lhomme et al., 2010; Koks et al., 2015; UNDP, 2017;

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[1] The cost of inaction in https://www.territoires-climat.ademe.fr/ressource/174-56

[2] The climate inaction costs more than strong measures in https://www.letemps.ch/economie/linaction-climatique-coute-plus-cher-prise-mesures-fortes

CEREMA, 2019, among others) as well as their role in amplifying climate change economical or financial impacts (Alogoskoufis et al., 2021). But there is no existing tool intended for decision-makers to both consider the costs/benefits of required measures/policies/investments dedicated to infrastructure and territories resilience improvement and avoid GHG emissions. Moreover, interviews previously made by our team with international stakeholders (public authorities and infrastructure managers) reveal their needs to be equipped with digital services to manage their assets and anticipate climate risks.

This article explains how the Resilience Performance Assessment (RPA) could tackle this issue. The RPA is an innovation developed by RESALLIENCE by SIXENSE. In a first part, we describe the main tool functionalities and in a second part how this tool is already applied to support adaptation strategies at different scales.

1. The Resilience Performance Assessment (RPA), a tool to support adaptation and mitigation strategies

The Resilience Performance Assessment (RPA) is composed of two operational tools: the first one is a Geographical Information System (GIS), allowing a clear and comprehensive visualization of climate change impacts ; the second one is an analytical table to help stakeholders prioritizing adaptation and mitigation strategies (fig.1).

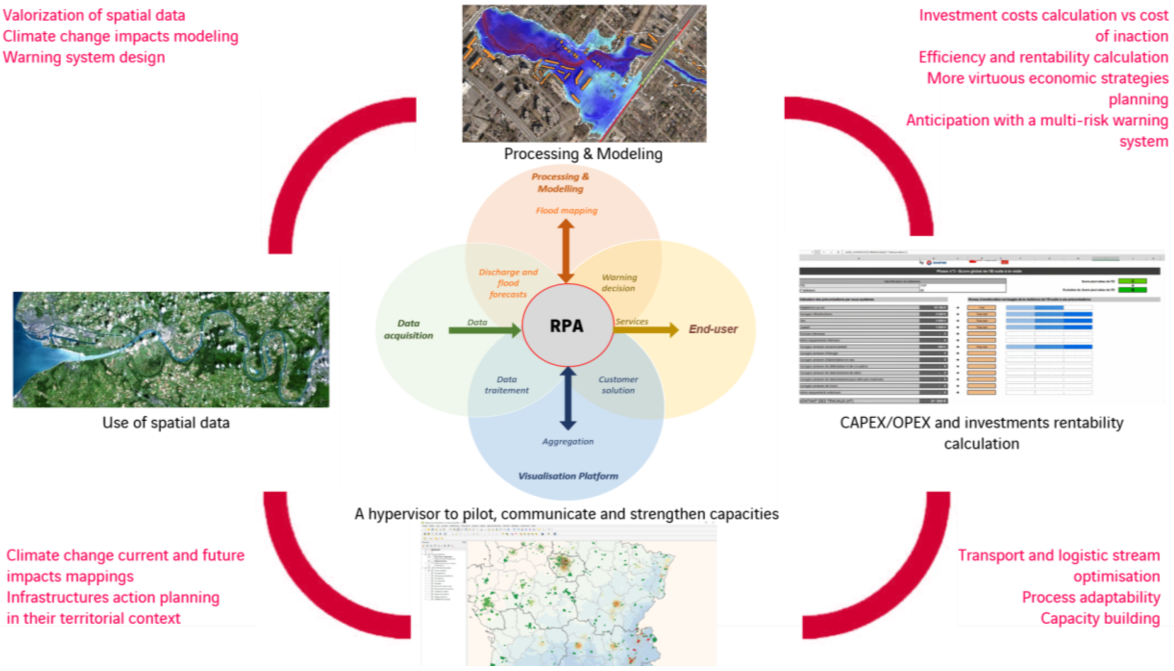

Figure 1: The RPA methodological approach

1.1. A Geographical Information System to visualize climate change impacts

Climate change is not actually creating new hazards but is contributing to extend their spatial impacts, reinforce their intensities and worsen the territorial vulnerabilities (Gilbert, 2009; Metzger and D'Ercole, 2009, among others). What is relevant for a decision-maker is to visualize the exposure of their assets during their entire lifecycle or infrastructure concession period, and to identify the critical and vulnerable components and how this vulnerability will be intensified by one or several hazards.

A Geographical Information System (GIS) is the appropriate tool to meet these expectations as it provides viewing and computational possibilities to both process climate and infrastructure data with a 2D/3D/4D mapping option. With a GIS, it is possible to create the following maps:

- Exposure, which defines the spatial extent of a hazard impact. Exposure can be inferred from spatial data and climatic models and requires downscaling and correction methods to adapt the output results to topographical constraints and land-use (Solecki and Oliveri, 2004; Themeßl et al., 2011; fig.2).

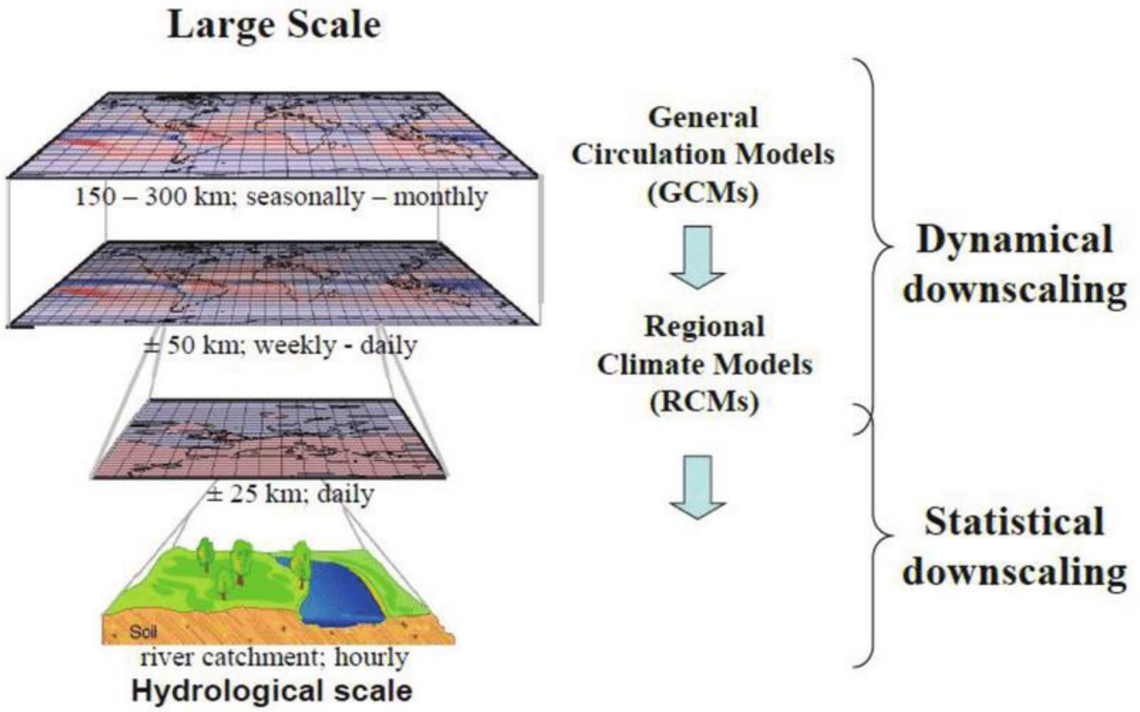

Figure 2: Downscaling principle to adapt climatic models' outputs to the land-use (Adapted from Willems, 2011 in Siwila et al., 2013)

- Vulnerability of buildings, infrastructures and territories. Vulnerability can be defined as "*the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes*." (IPCC, 2014, fig.3). Methodologies to assess and map vulnerability are numerous (Romero-Lankao et al., 2012; Armenakis and Nirupama, 2012; UNDP, 2017, Alonso, 2021) and need to evaluate the sensitivity and the adaptive capacity[3].

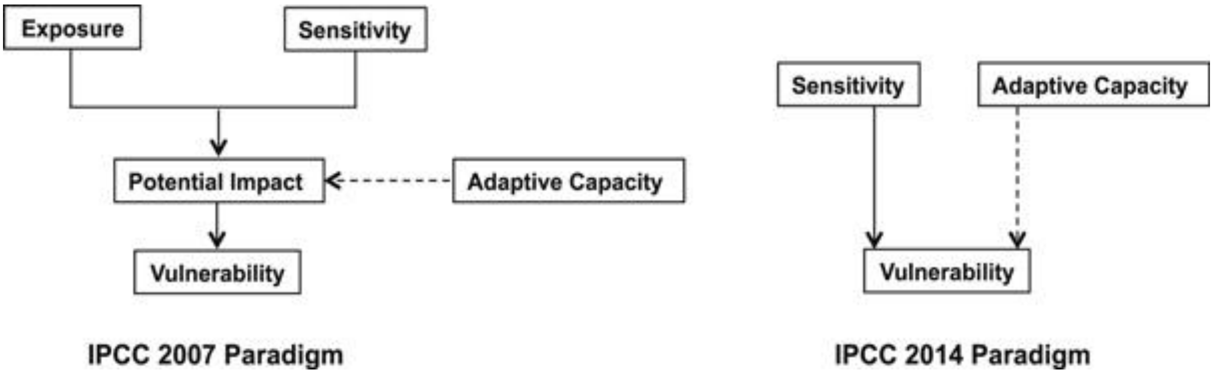

Figure 3: Conceptual mapping of vulnerability (Sharma and Ravindranath, 2019)

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[3] The sensitivity of a system designs its likelihood to experience particular conditions and the occupancy and livelihood of its characteristics to a given exposure. The adaptive capacity is more focused on adaptability, coping ability, management capacity, stability, robustness, flexibility and resilience (Smit and Wandel, 2006).

- Cumulative impacts of current and future climate change to determine the major risks according to IPCC scenarios. Indeed, climate change risks do not happen solely, but imply complex interactions between hazards, for example during a tropical cyclone. Several exposure perimeters (wind, riverine floods, flash floods and storm surges) must be combined and reinterpreted through preferential combinations requiring statistical treatments (fig.4).

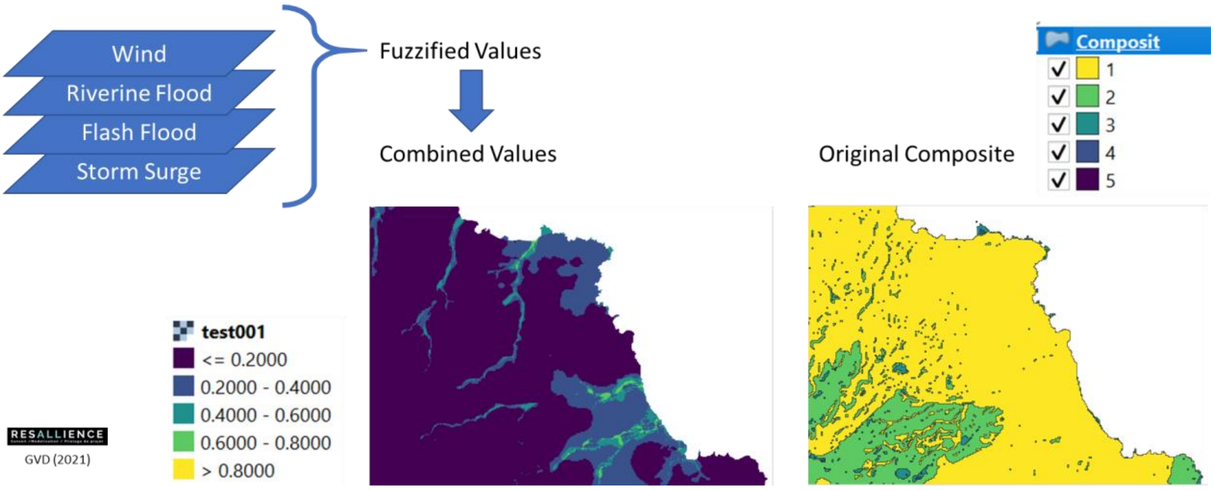
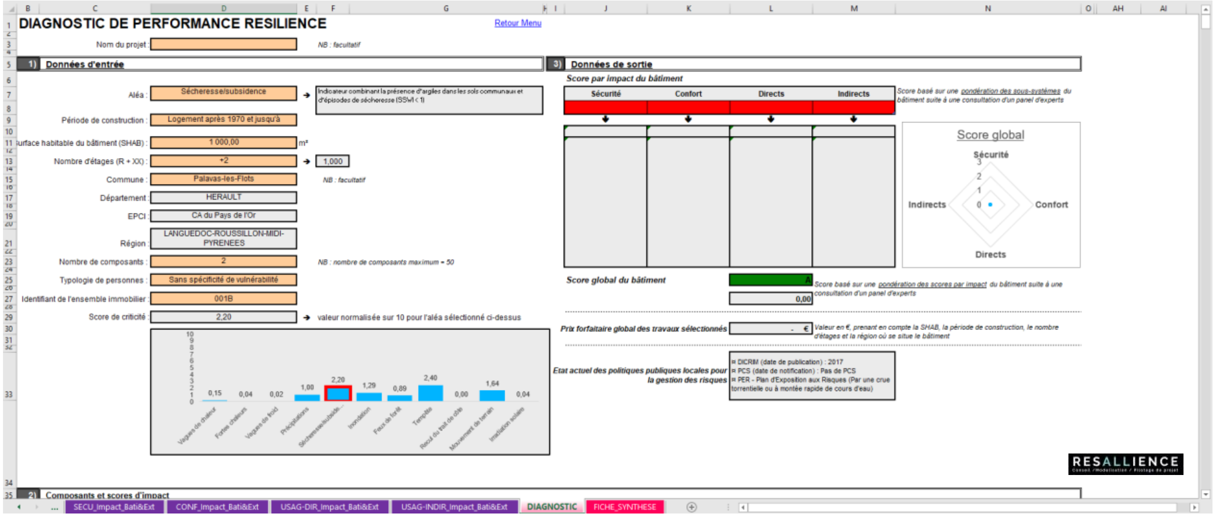


Figure 4: A multi-hazard approach to spatialize complex risks, such as tropical cyclones

1.2. An analytical table to help decision-makers prioritizing adaptation and mitigation solutions

The second tool composing the Resilience Performance Assessment is an analytical table (fig.5). Several menus are available to assess the resilience performance. First, a hierarchical breakdown is made according to the nature of the infrastructure: building, road, railway, water and sanitation equipment, bridge, *etc*.



DIAGNOSTIC DE PERFORMANCE RESILIENCE

Retour Menu

Nom du projet : NB : facultatif

1) Données d'entrée

Aléa : Sécheresse/subsidence → Indicateur combinant la présence d'argiles dans les sols communaux et d'épisodes de sécheresse (SSWI < 1)

Période de construction : Logement après 1970 et jusqu'à

Surface habitable du bâtiment (SHAB) : 1 000,00 m²

Nombre d'étages (R + XX) : +2 → 1,000

Commune : Palavas-les-Flots NB : facultatif

Département : HERAULT

EPCI : CA du Pays de l'Or

Région : LANGUEDOC-ROUSSILLON-MIDI-PYRENEES

Nombre de composants : 2 NB : nombre de composants maximum = 50

Typologie de personnes : Sans spécificité de vulnérabilité

Identifiant de l'ensemble immobilier : 001B

Score de criticité : 2,20 → valeur normalisée sur 10 pour l'aléa sélectionné ci-dessus

2) Composants et scores d'impact

3) Données de sortie

Score par impact du bâtiment

Sécurité	Confort	Directs	Indirects

Score basé sur une pondération des sous-systèmes du bâtiment suite à une consultation d'un panel d'experts

Score global du bâtiment: A 0,00

Score basé sur une pondération des scores par impact du bâtiment suite à une consultation d'un panel d'experts

Prix forfaitaire global des travaux sélectionnés: - €

Valeur en €, prenant en compte la SHAB, la période de construction, le nombre d'étages et la région où se situe le bâtiment

Etat actuel des politiques publiques locales pour la gestion des risques:
¤ DICRIM (date de publication) : 2017
¤ PCS (date de notification) : Pas de PCS
¤ PER - Plan d'Exposition aux Risques (Par une crue torrentielle ou à montée rapide de cours d'eau)

Figure 5: The Resilience Performance Assessment analytical table allowing the evaluation of climate change impacts and preventive and corrective measures costs

A study impact is made for each system and component with a ranking from 1 to 3 for one or multiple hazards. A first score is provided based on a theoretical assessment, meaning without a detailed audit of the infrastructure. Secondly, an analytical framework must be filled based on an on-site visit, to characterize the potential current and future failures, in terms of safety, users' comfort and uses, affecting the infrastructure, its equipment and surrounding territory. It provides a second score to be compared with the first one. Finally, a cost-benefit matrix is completed following this visit to determine the needs in terms of CAPEX/OPEX and related schedule (short/medium/long term), as well as benefits and co-benefits in terms of resilience improvement, GHG emissions reduction and biodiversity protection.

The tools can be applied to infrastructures at each stage of their lifecycle but also investment projects dedicated to climate change adaptation and mitigation, urban planning policies, sustainable transport plans at a national, regional or local scale. For each application, an investment plan is generated considering specific targets: spatial coverage, duration, ability to make revenue streams or conformity with international commitments (Paris Agreement, Sustainable Development Goals).

2. An operational and customizable tool

The RPA was developed to be in line with the work of the Global Alliance for Building and Construction (Global ABC), the Coalition for Climate Resilient Investment (CCRI) and the Coalition for Disaster Resilient Infrastructure (CDRI), which RESALLIENCE is a member, and is currently used by several customers of RESALLIENCE.

This article details RPA application to a Caribbean small island. This territory is strongly dependent of its critical infrastructures for importing essential supplies and exporting goods. With a population and critical infrastructures located along the coastline, this state has been hardly affected by two hurricanes, Erika in 2015 and Maria in 2017. This last disaster has led to the entire destruction of 20% of the buildings and damages to the 80% left. A Resilience Performance Assessment was developed to support the national resilience strategy and optimize future investments.

This one is available through a secured web page, giving access to a hypervisor of current and future impacts of climate change. Multi-hazards maps have been realized to assess the impacts of complex hazards, such as hurricanes. A multicriteria analysis has allowed to identify the most extreme risk scenarios for each hazard. They are then combined in a correlation matrix to evaluate the different combinations of event occurrence e.g. the simultaneous occurrence of both high wind and floods, both high wind and storm surge, or both floods and storm surge (fig.6).

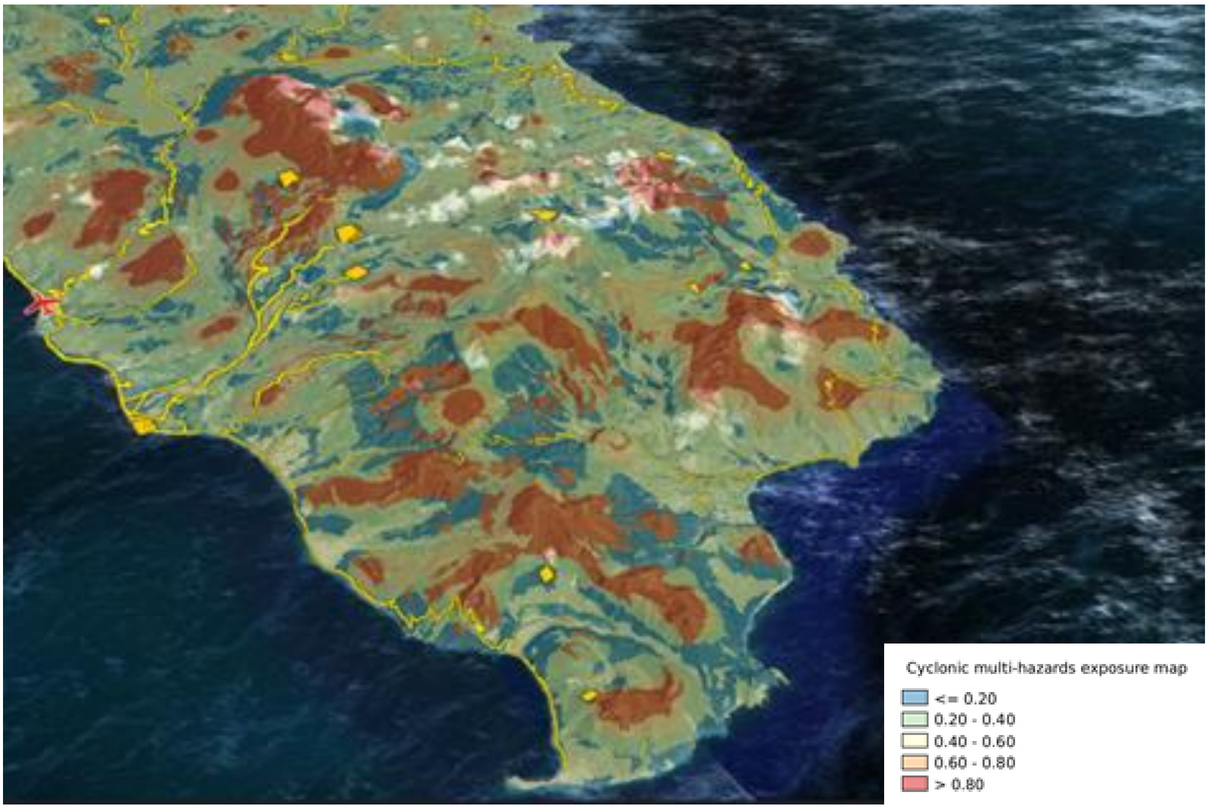


Figure 6: Exposure mapping to multiple hazards to identify most exposed parts of the island to complex risks such as hurricanes[4]

Vulnerability maps have been calculated for a 350 square meters mesh. The density of human and environmental assets as well as critical infrastructures assets has been considered into the GIS, with an analyse of their statistical variance through a Principal Component Analysis (fig.7).

Figure 7: Vulnerability mapping to multiple hazards to identify most vulnerable sectors of the island

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[4] The hypervisor content cannot be shown in its entirety due to a confidentiality agreement.

In this case study, the resilience performance of current and future investment projects has been assessed. More than 300 projects have been analysed through dedicated surveys with institutional stakeholders and private decision-makers. Each project has been scored considering its ability to make revenue streams, its spatial coverage, its duration, its capacity to reduce risk and mitigate GHG emissions and its compliance with international and national commitments (SDGs).

A specific flag for each project is set on the platform to cross the investment scoring with the vulnerability of the critical infrastructures. The combination between these two layers of information allows an identification of the sectors where projects are missing or needed to enhance infrastructures resilience (fig.8).

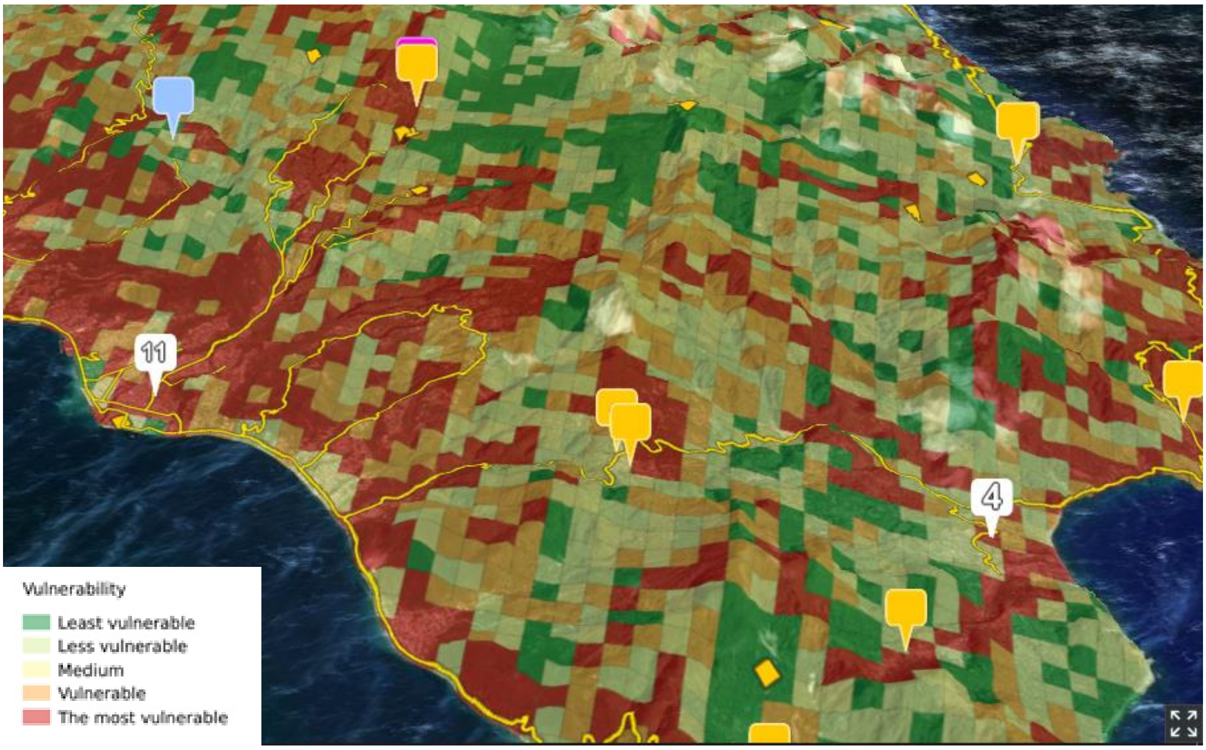

Figure 8: Localisation of current and future investment projects facing island territorial vulnerability

Conclusion

The Resilience Performance Assessment (RPA) is an innovative solution allowing efficiency and balance between climate change mitigation and adaptation on full infrastructure life cycle, buildings and territories. It is composed of two operational tools: a Geographical Information System, allowing a clear and comprehensive visualization of climate change impacts and an analytical table to support stakeholders in prioritizing adaptation and mitigation strategies.

The RPA addresses climate change adaptation and mitigation issues in investment policy statements. It provides dedicated tools metrics and analyses to assess the capabilities of internal and external investment managers to incorporate adaptation and mitigation issues, to ask investment service providers (financial analysts, consultants, brokers, research firms, rating companies) and to advocate training for investment professionals.

The RPA is currently applied to several use cases. One concerns small islands states in the Caribbean area to support national adaptation policy. The application of the tool has allowed a clear visualization of current and future climate change impacts and a cost/benefit analysis of applying specific recommendations to avoid destruction or damage to infrastructures due to future hurricanes. The first results of this analysis indicate that the inaction will have a higher cost than the annual GDP of the island in case of a new hurricane. Moreover, applying the recommendations resulting from the RPA could help reducing by 30% the cost of the impacts of a new disaster.

Acknowledgment

The authors express their gratitude to their partners and to Mrs. Chloe Vuillaume for the reviewing.

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