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# MACRO-SIMULATION OF HUMAN EVACUATION IN CASE OF TSUNAMI

## FIRST RESULTS FOR A BETTER CRISIS MANAGEMENT (MARTINIQUE, FRANCE)

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### 1. CONTEXT AND OBJECTIVES

Within the "Natural hazards" component of the CARIBSAT Project, we propose to lead an evacuation simulation of coastal population in case of tsunami threatening the Martinique island. This approach is based on a GIS and Graph Theory modeling of pedestrian accessibility to safe areas (refuge points).

Among the 28 tsunami that reached Martinique since 1630, 20 would be generated by earthquakes. Tsunamigenic earthquakes meet some usual characteristics like an epicenter located in the sea, a shallow focal depth (10-40 km); a magnitude greater than 6.5.

Our research goals :

- ✓ to assess issues, challenge and feasibility of a population evacuation for known or simulated tsunami scenarios,
- ✓ to reveal human vulnerability to this underestimated risk.

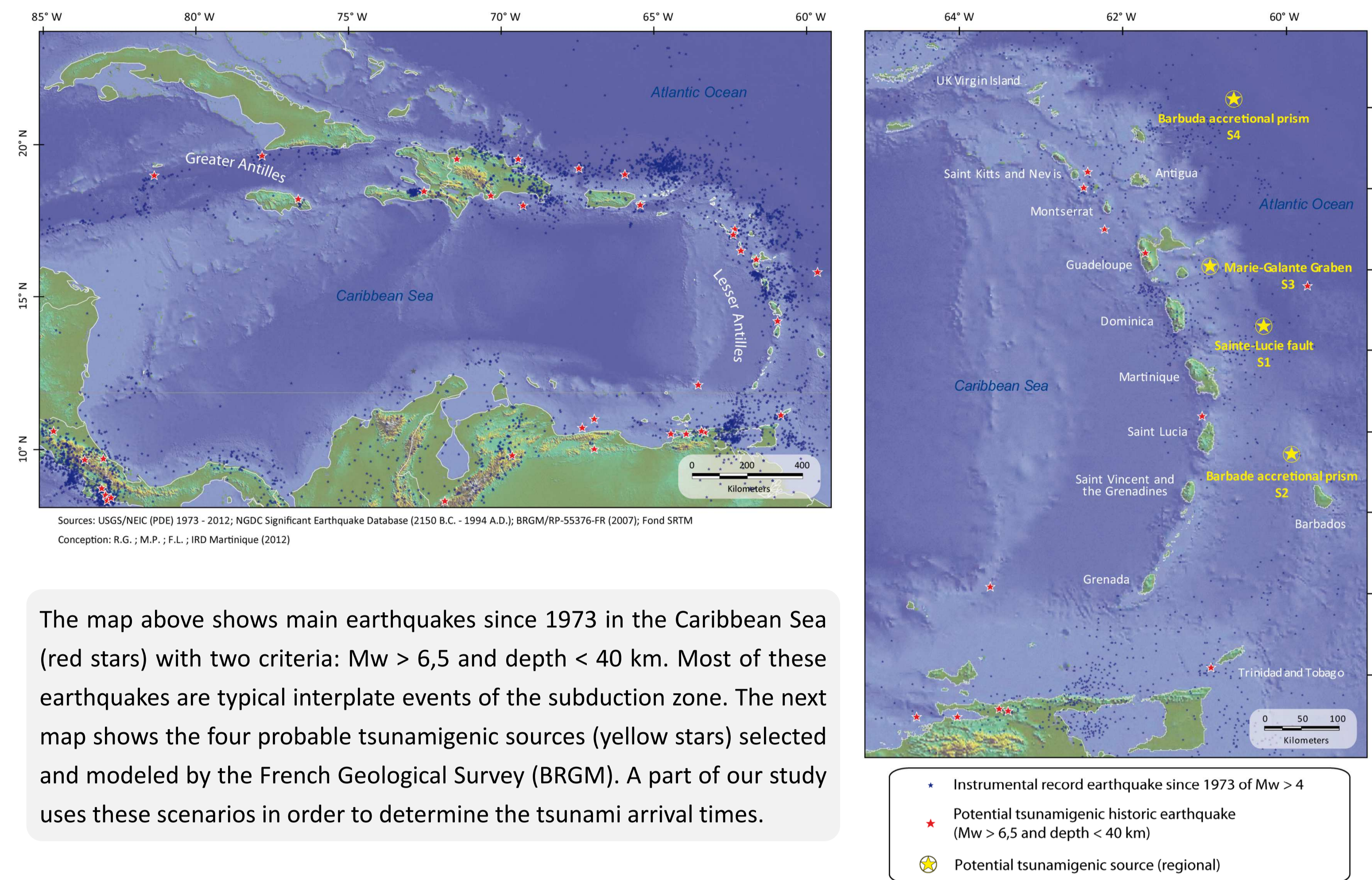
This study will provide an initial analysis for the implementation of crisis management tools, specific for tsunamis.



Club Med Resort, Martinique, Sainte-Anne



Fort de France, capital city, Martinique



The map above shows main earthquakes since 1973 in the Caribbean Sea (red stars) with two criteria: Mw > 6,5 and depth < 40 km. Most of these earthquakes are typical interplate events of the subduction zone. The next map shows the four probable tsunamigenic sources (yellow stars) selected and modeled by the French Geological Survey (BRGM). A part of our study uses these scenarios in order to determine the tsunami arrival times.

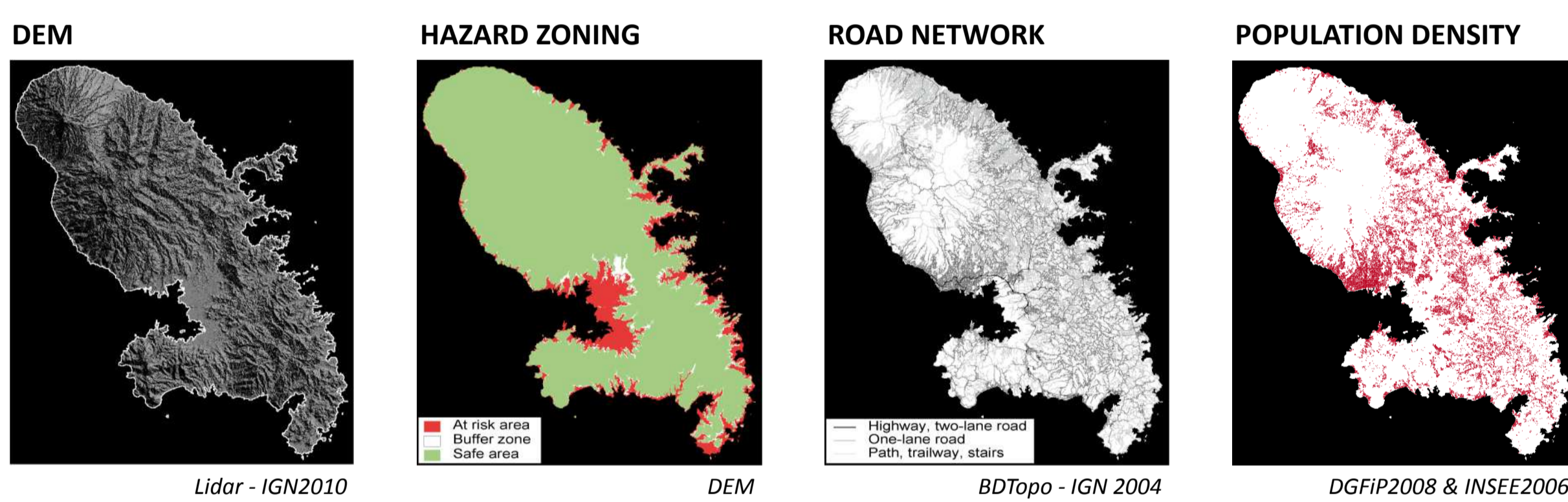
### 2. METHODOLOGY

#### 2.1. Graph theory for measuring accessibility

Evacuation's modeling problem can be solved by a mathematical model based on Graph Theory. We used Routefinder®, a network analysis application for the GIS software Mapinfo®, which allows to generate routes from a starting point to destinations (or vice versa), according to two methods: the shortest or the fastest distance. This application uses the Dijkstra's algorithm (1959).

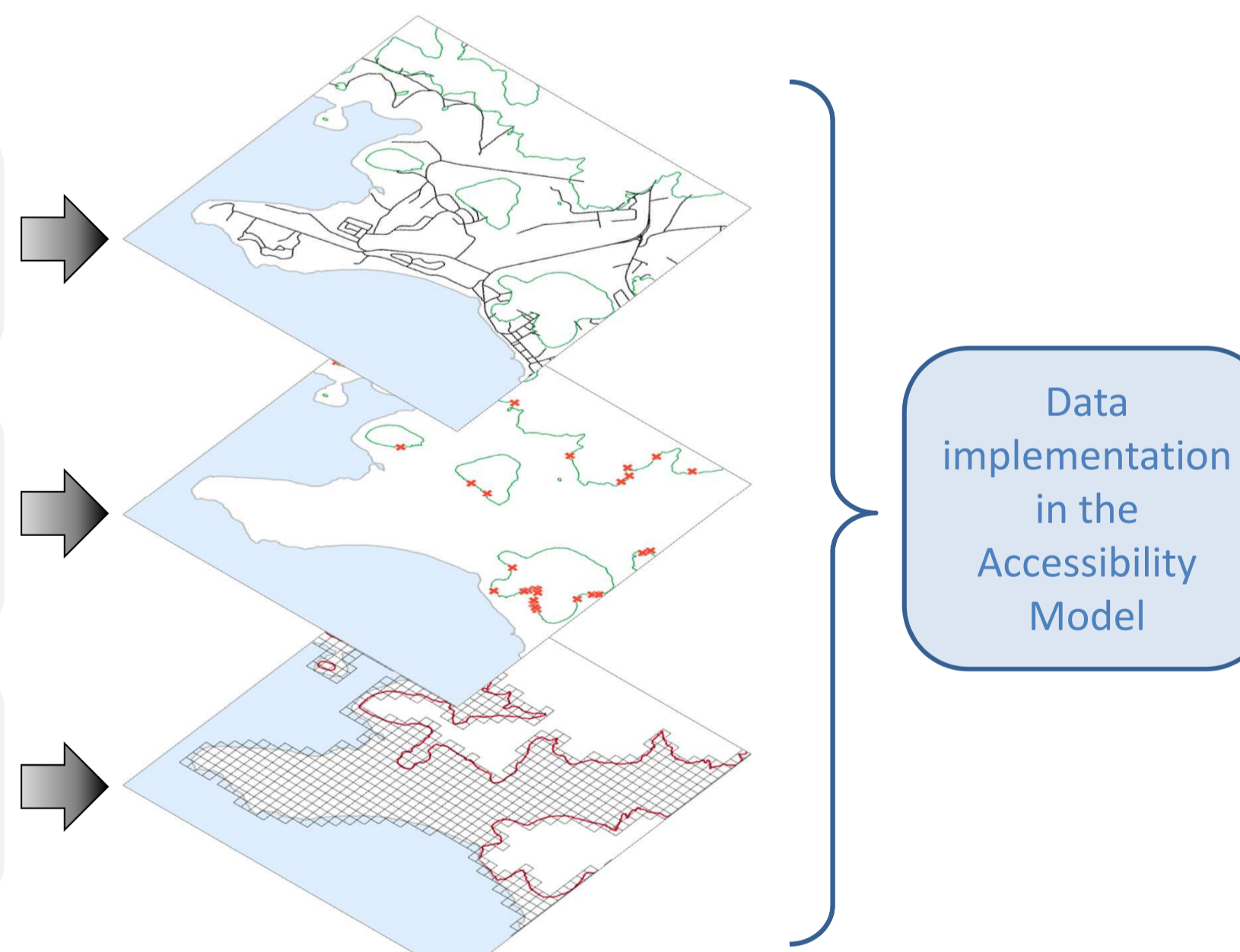
Our graph is an undirected communication network, where the refuge points and the areas to be evacuated are nodes and where roads are edges. In order to optimize the model, we adjust the network settings according to two parameters: the topographic slope value and the road specific typology. These two parameters allowed to define the suitable pedestrian velocity in case of evacuation.

#### 2.2. Spatial data sources for human evacuation simulation



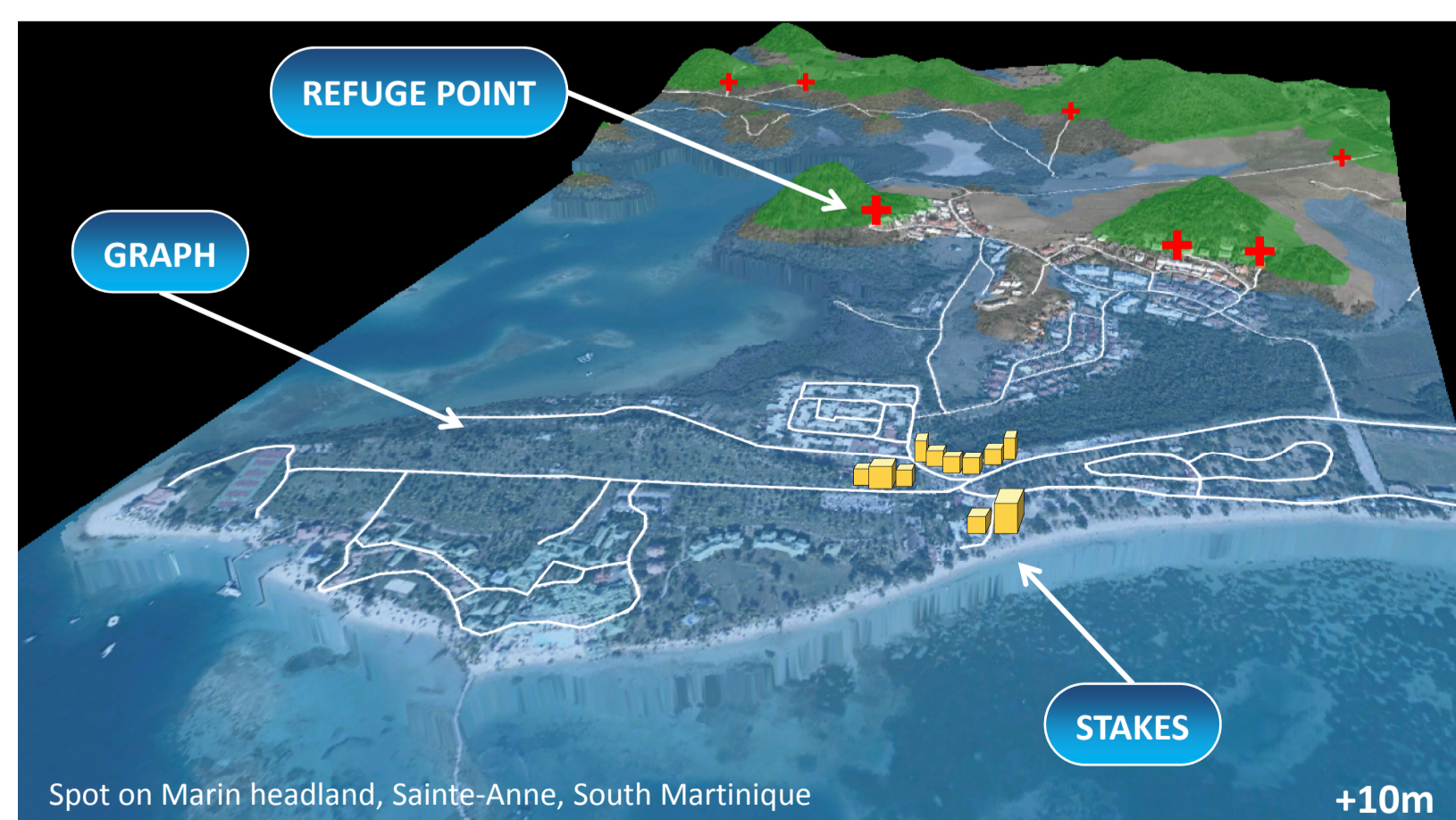
#### 2.3. Model input GIS Datasets

- ROAD GRAPH** (63 821 segments)
  - Road sections located below 20 meters alt.
  - 30 classes of pedestrian velocity
- ENTRANCE POINTS TO REFUGE ZONE** (3 854 ZR)
  - Access to safe areas: crossing points between roads and relevant isohypse
- HUMAN STAKES** (66 188 residents)
  - Grid (50m) on risk areas (marine flooding)
  - Night and diurnal population density



#### Contributions of Graph Theory applied to crisis management :

- ✓ To define the closest refuge points from risk areas
- ✓ To measure accessibility to these refuge zones (routes, time, distance)
- ✓ To design evacuation routes
- ✓ To assess sheltered population in each refuge zone
- ✓ To select the best refuge zones

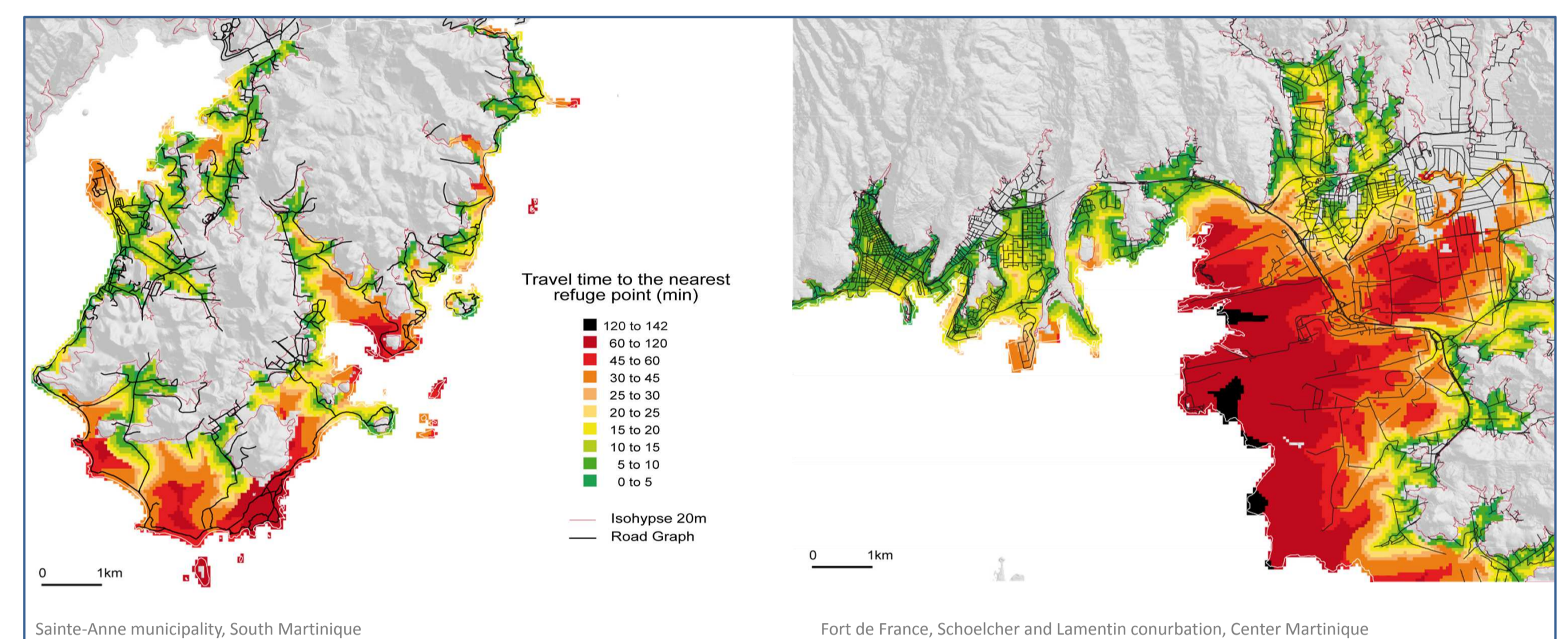


### 4. PERSPECTIVES & DISCUSSION

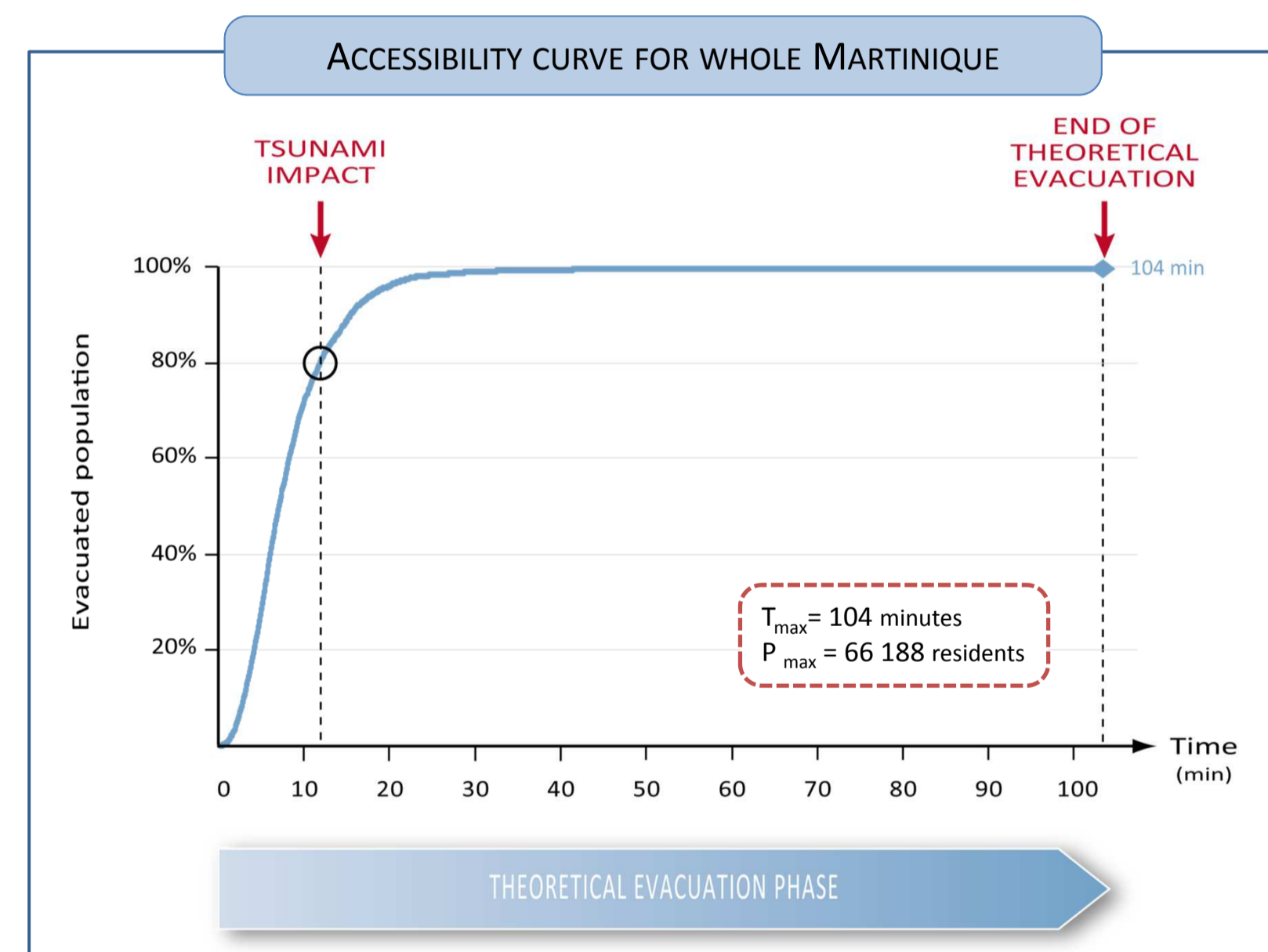
This preliminary work gives some useful results to plan an evacuation in case of tsunami early warning: amount of exposed population, selection of safer areas, time to reach these areas, and design of best evacuation routes to protect the population before a tsunami impact. But our working hypothesis concerns only resident population and we suppose a prepared evacuation with road signs indicating evacuation routes, and unlimited capacities of refuge areas. This first approach should be optimized with a multi agent simulation in order to detect possible critical points like bottlenecks and population behaviors.

### 3. RESULTS

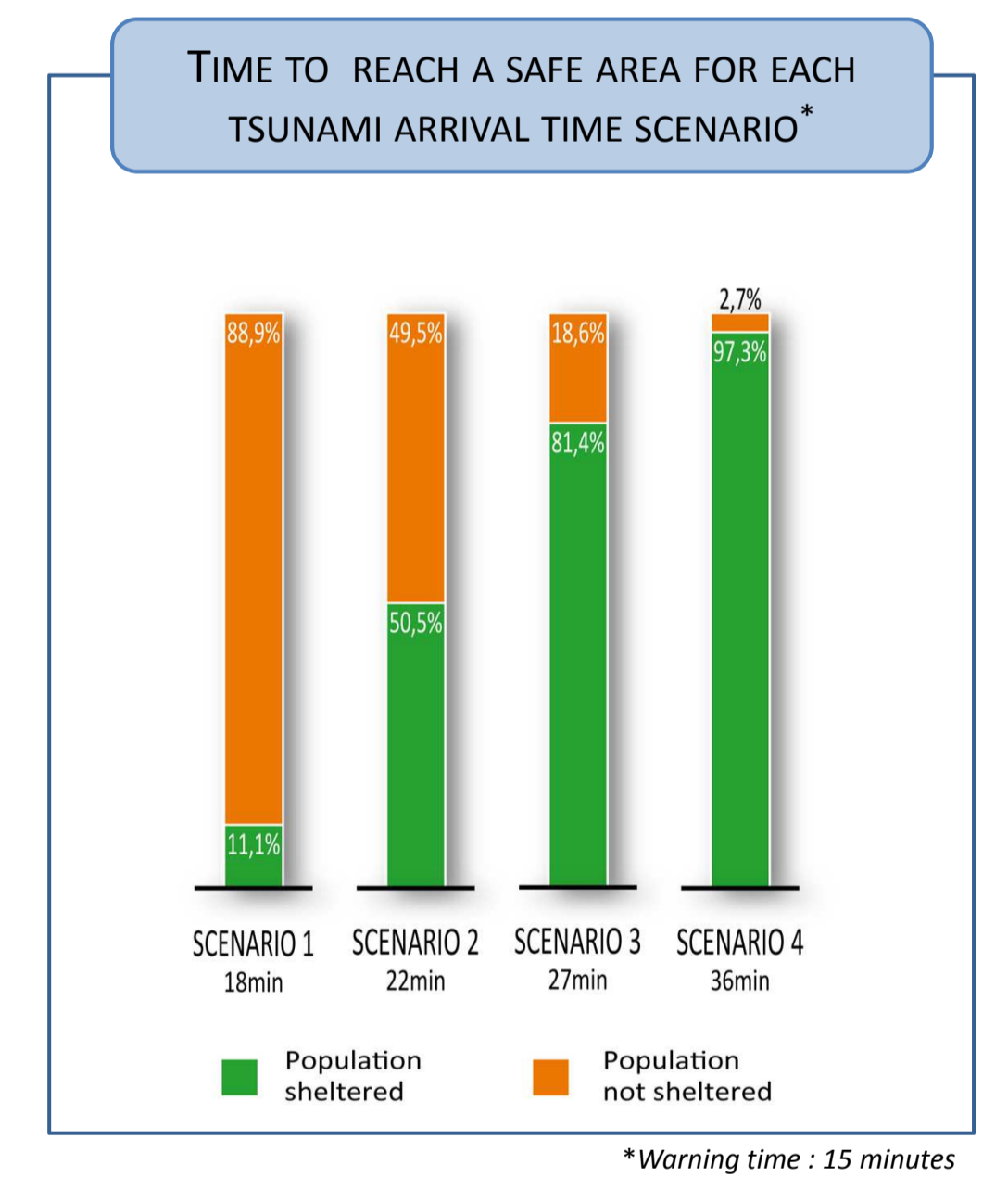
#### 3.1. Spatial heterogeneity of evacuation times (pedestrian)



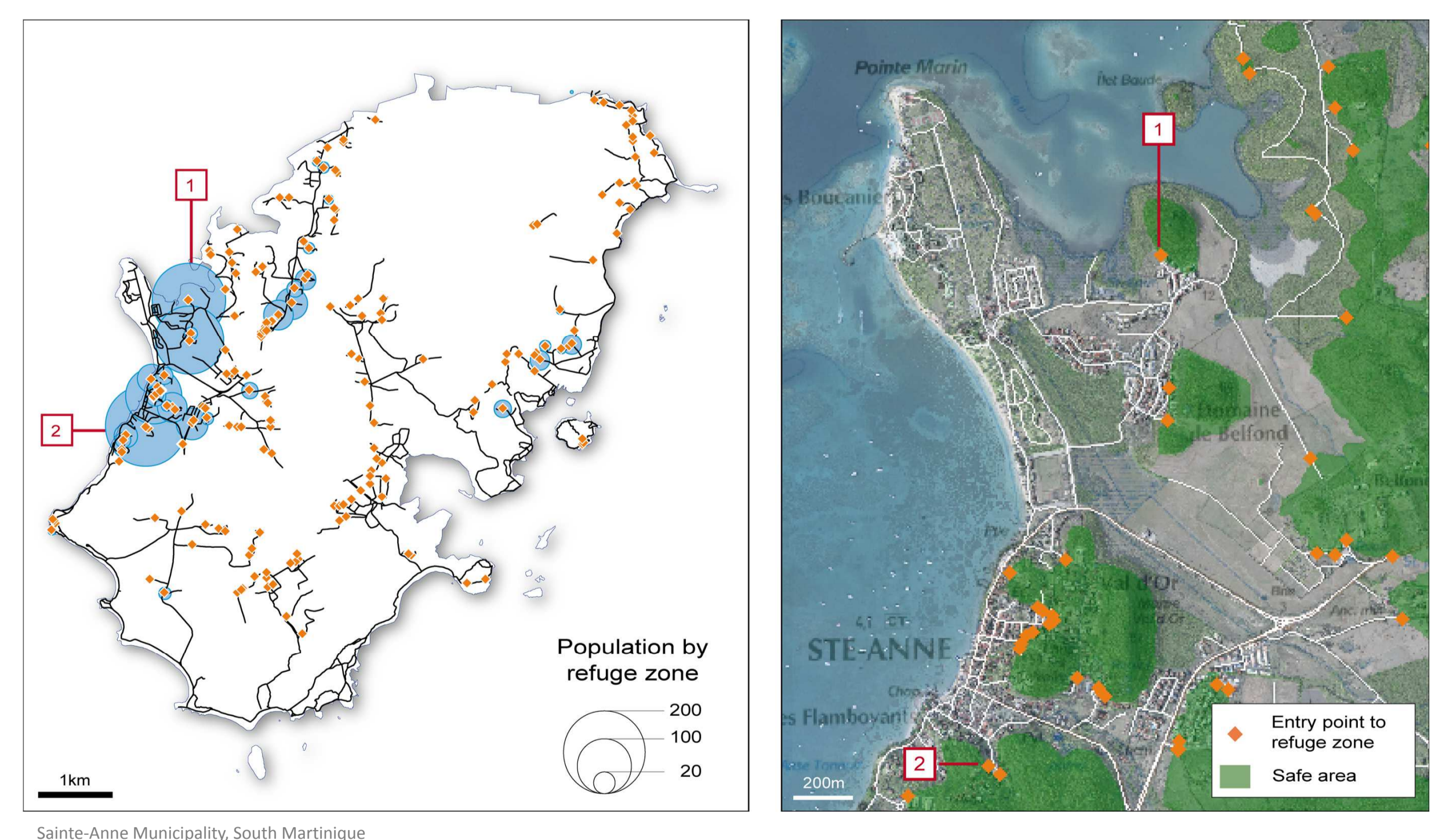
#### 3.2. Evacuation vs tsunami arrival times



#### 3.3. Potential victims assessment



#### 3.4. Decision help for selection of refuge zones and evacuation routes



Related to local tsunami sources, the time for issuing an alert is very limited. This fact confirms the need to set up an early-warning system to shorten the bottom-up and top-down alerts delays. The theoretical time to evacuate have to be cumulated with this warning time but also with the population reaction time. These last point can be reduced by an educational program in order to make easier a massive evacuation in Martinique. The management of a future tsunami crisis have to be planned also at a local level by integrating our scientific outputs in the emergency plans named PCS in France (Plans Communaux de Sauvegarde).