PLANNING AND RECORDATION OF HERITAGE CONSERVATION IN THE TROPICS: PILOTING DIGITAL PRESERVATION OF LA MINA RECREATION AREA, PUERTO RICO

RAYMOND FELICIANO[1] & JOHNNY LUGO-VEGA[2]
[1]United States Forest Service, El Yunque National Forest, Puerto Rico
[2]Museo de Arte de Puerto Rico, Puerto Rico

ABSTRACT

Managed by the US Forest Service, El Yunque National Forest is one of the oldest natural reserves in the world and the only tropical rain forest within the United States National Forest network. This internationally recognised cultural landmark is one of the most visited natural destinations in the Caribbean, and is increasingly sensitive to disturbances, enhanced by the effects of climate change. In 2017 major hurricanes ravaged the cultural resources within the forest's La Mina Recreation Area. This area was the first natural recreation location in the Caribbean and its historical infrastructure continues to serve as the main vector facilitating interaction between the public and the natural environment. Recognising the fragility and critical social value of those resources, the US Forest Service has planned and implemented sustainable initiatives, tempered to counterbalance the operational constraints of a tropical context plagued with limitations on resources. Our paper will focus on outlining an innovative collaboration that explored interagency partnerships for the digital preservation of two historically significant properties, using advanced technology, including 3D laser scanning and drone flight photogrammetry. The first property, the Stone House, was the first ranger station built by the USA in the Caribbean. The second site, called La Mina Trail Bridge, consists of a piece of handmade infrastructure that served as the only access to the most visited waterfall on the island. The recordation data served as a critical tool for documenting the properties and as a key planning tool for developing resilient and adaptive restoration of culturally significant heritage sites while ensuring sustainable public access to the land. We will discuss these efforts in more detail and outline the results as a case study for other professionals working with rural heritage conservation.
Keywords: heritage conservation, natural resources management, climate change.

1 INTRODUCTION

Cultural heritage has been identified as a key element of management concern by the United Nations [1] and other national and international institutions. Management of cultural assets helps guide actions that affect resources and the people who depend on them [2]. Governments, educational entities, non-governmental organisations, communities, and individuals share the responsibility of acknowledging, understanding, managing, and engaging with heritage resources. Governmental structures carry a special obligation in heritage stewardship, given their role in the establishment or approval of regulations that define and affect what is considered the hegemonical definition of patrimony. The execution of those responsibilities can be hindered by budget constraints, competing political agendas, conflicting definitions of heritage, etc. These issues are exacerbated in times of crisis, such as when faced with natural disasters. The building of collaborative relationships can prove highly beneficial for bridging these chasms. It could be argued that the higher the constraints, the more benefits could be derived from cooperation and collaboration in heritage management. Our case study explores one instance of collaborative management, which facilitated the use of recordation technology to document and restore damaged cultural resources at El Yunque National Forest in Puerto Rico.

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2 HERITAGE MANAGEMENT CONTEXT OF PUERTO RICO

Puerto Rico is composed by a group of small islands in the Caribbean located east from the Dominican Republic and northwest from the Lesser Antilles. Measuring 100 nautical miles in length by 35 nautical miles in width, the island is the smallest of the Greater Antilles (Fig. 1). I Its geographical location, size, sociopolitical history and exposure to hurricanes have all interacted to develop a complex and sometimes problematic context for the management and integration of its natural, cultural, economic and political spheres.

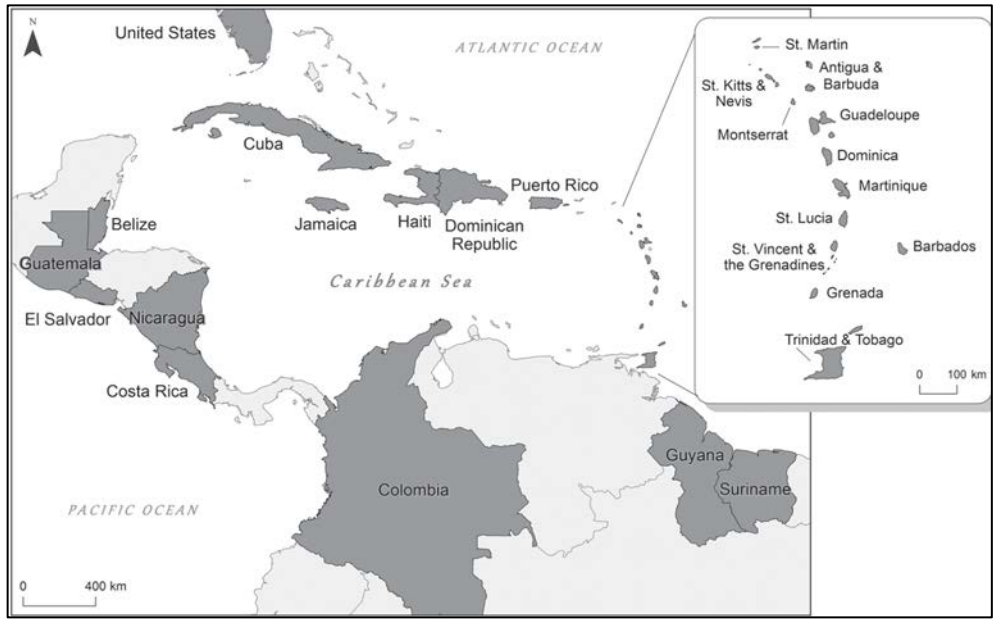

Figure 1: Puerto Rico's location in relation to the Caribbean [3].

2.1 Historical context of the area of study

Puerto Rico was first inhabited around six thousand years ago [4], by various migrations of Amerindian cultures that arrived from South America. During the last decade of the 15th century, the island was occupied by the Spanish and exploited for mercantile purposes until the late 18th century. Spanish Crown policies in the 19th century triggered agrarian and economic reforms, marked by the settling of the island's rural areas by migrants from Europe and other Spanish colonies. By the late 19th century Puerto Rico's economy had become one of a sugar mill, coffee, and tobacco colony [5].

In 1898 the former Spanish colony came under rule of the USA. Between the 1900s and the early 1940s [6] the economy pivoted towards the maximisation and exploitation of sugarcane production. Between 1928 and 1932 three mayor hurricanes struck the island, destroying the local economy and worsening the already poor conditions of the island caused by the Great Depression. These events represented a turning point in the relationship between the USA and the island, especially after the Franklin D. Roosevelt administration developed the New Deal programs designed to be implemented mainly in the US, but also extended to Puerto Rico [7]. The new policies instituted new approaches towards the economy, land

management and society. Following the Second World War the island's economy industrialised, and decolonisation took place. A Commonwealth political system was instituted with the governance of the island divided between a local state government, and a superseding non-elected federal structure. This federalised system operates on the island as it does on the mainland US, albeit without the same parity of funding for some agencies and programs. In the last 30 years the island has been plagued by economic problems caused by the displacement of manufacturing towards less expensive production markets, and overall mismanagement by the local government. To supplement economic development, tourism has been fomented as a fiscal driver, with cultural resources serving as a significant component of that industry [8]. Currently, cultural tourism accounts for over 5% of business revenues in Puerto Rico [9].

2.2 Management challenges of nature tourism mediate by historic sites

Located on the eastern part of Puerto Rico, El Yunque National Forest (Fig. 2) represents the second most visited destination for tourists on the island. The forest attracts visitors for being the only tropical rain forest in the National Forest System of the US. It is also one the most biodiverse in the nation, and one of the oldest officially designated natural reserves in the Americas [10]. The policies implemented by the US during the Great Depression are the ones responsible for the current importance of El Yunque as a tourism destination [11]. The infrastructure developed by programs such as, the Work Progress Administration (WPA) and the Civilian Conservation Corps (CCC), helped facilitate recreation in natural areas [12], [13]. In El Yunque this was manifested in 1934 with the construction of La Mina Recreation Area. This natured base recreation area was built relying on beautiful rustic infrastructure that enabled North American perspectives of recreation in the tropics [14]. The roads, hiking trails, pools, cabins and towers built by the men working for and trained by the federal government [15] continue to serve to this day as the sole mediators for public recreation in the forest. They also helped cement El Yunque in the folkloric imagination as a cultural identity landmark.

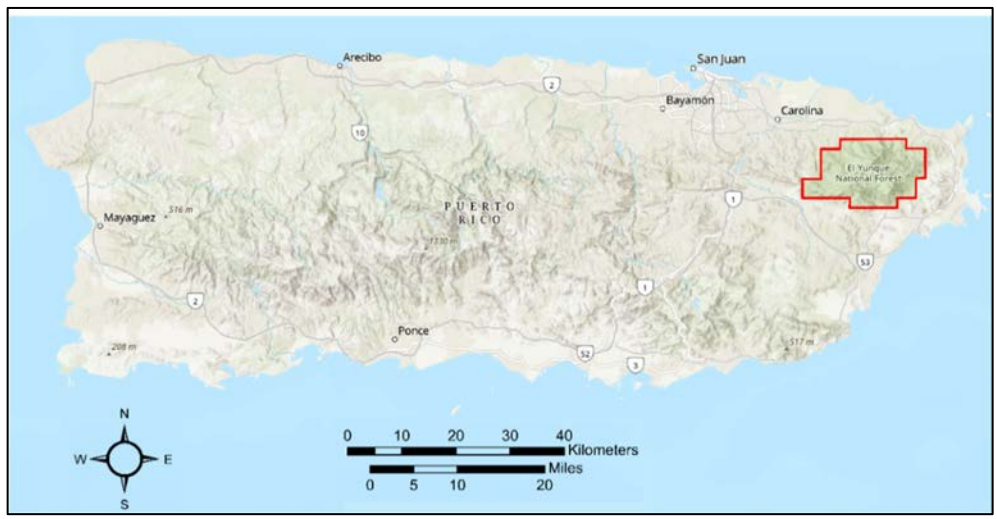

Figure 2: Location of El Yunque National Forest (red outlined area).

Management of these historically significant resources is mandated by federal regulation [16] and implemented through a Heritage Management Program [2]. The program itself operates within the framework of broader management strategies defined in a Land Management Plan [17].Research performed by the agency and the program outlined that the historic recreation infrastructure in the forest is highly vulnerable to damages caused by severe weather events [18]. Projections of climate data predict that the intensity of hurricanes in the Caribbean basin, where the forest is located, could increase due to global warming [19], [20], potentially augmenting their destructiveness up to 60% [21]. Although for the most part the recreation infrastructure built by the CCC has withstood the ravages of hurricanes and time [22], the data suggested that these resources could be highly susceptible to future damages. Similar cultural heritage risk models have been explored for the coastal areas on the island [23]. These studies have highlighted that coastal cultural resources are beginning to be threatened by inundation of sites due to projected sea level rise and erosion exacerbated by severe weather events. Pre-emptive documentation of cultural resources has been suggested as a key mitigation action to prevent the overall and complete loss of those resources [8], [23].

The vulnerabilities faced by the cultural resources in Puerto Rico were manifested in 2017 when two high intensity hurricanes wreaked havoc on the island. The hurricanes severely damaged the historic recreation infrastructure at El Yunque. Compounding this problem was the lack of preexisting historic and structural data on the properties that could guide and inform their restauration after the natural disasters. The collaboration between Lugo-Vega and Feliciano was born at this historic juncture. The partnership intended to enable the acquisition and employment of vanguard technology that could facilitate the recordation and later restoration of the damaged historic assets. It also served as a case study for the implementation of Lugo-Vega's 'Positive Virus' model.

2.3 'Positive Virus' model for reaching sustainable heritage conservation in the tropics

Hurricane María hinted that as the models have been suggesting, tropical cyclones can indeed potentially become more severe because of climate change. In 2017 Puerto Rico was ill prepared to deal with the effects of the storms, and much less prepared to attend to its heritage resources during the recovery phase. This can be attributed to compounding dependencies, including lack of funding towards maintenance and preservation, insufficient amounts of experienced and proficient preservation professionals on island, lack of planning, as well as generalised institutional and governmental neglect. Moreover, conceptualisation of cultural heritage management in Puerto Rico was and continues to be an area lacking in development aside from marginal work on the creative economy sphere. All these factors compounded the difficulties for prompt and effective preservation of cultural resources in the aftermath of the 2017 hurricanes. Although the last five years saw advances for the development of historical resources recovery plans [8], the island still lacks global adoption, and implementation of these plans.

Within this scenario Lugo-Vega proposed a sustainable heritage conservation model aligned with the UNESCO's Sustainable Development Goals (SDGs). The model aimed at bridging the gaps previously outlined to improve cultural resources governance and protection through interconnections and collaborations. The model's structure was founded around a 'positive virus' core, and a mainframe based on designing a sustainable planning platform called the 'Sustainable Heritage Community Complex' (SHCC) (Fig. 3) [24]. The theoretical inspiration of the model is based on an adaptation of the strengths, weaknesses, opportunities and threats cost benefit analysis (SWOT) model. Lugo-Vega's model replaces

the SWOT values with four alternative pillars (research and development, sustainable planning and education, community outreach, and creative economy), and cross-references them through a sustainability core. The model relies on the establishment of interdependencies between the four pillars to set 'viral' interconnections. These connections aim at strengthening and stabilising the symbiotic relationships between the parts, thus creating a more stable and resilient system. The model intends to support the development and maintenance of cultural and creative economies reliant on the sustainable use of heritage and cultural assets, such as the tourism sector of Puerto Rico. In line with the significance of the interconnectedness of the parts, it recognises and integrates the creation of collaborative cooperative enterprises to execute and develop the core pillars, including direct participation in cultural heritage sustainable planning and preservation.

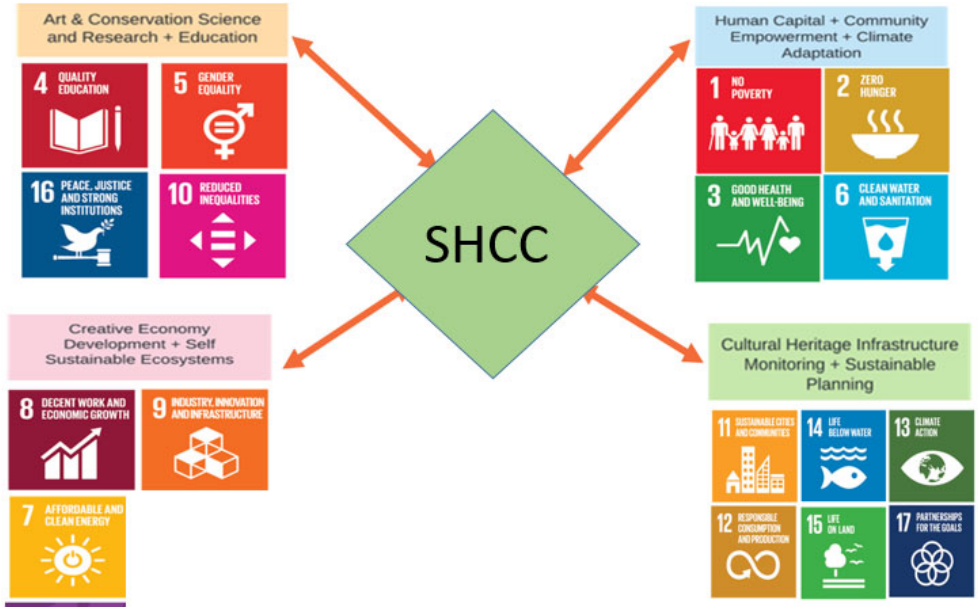

Figure 3: Outline of the Sustainable Heritage Community Complex matrix [24].

3 A PILOT COLLABORATION IN HERITAGE CONSERVATION AT A HISTORIC JUNCTION

The collaboration between Lugo-Vega and Feliciano took place at the historic moment of the post hurricane recovery years in Puerto Rico and encompassed an extension of UNESCO's SDGs to the island. It leveraged Lugo-Vega's leadership of the Cultural Heritage Innovation Program (CHIP) at the Puerto Rico Science and Technology Trust, serving as a case study of intergovernmental partnership and resources sharing. The initiative intended to support the Forest Service in the acquisition of technology that could expedite the recordation and restoration of damaged historic recreation infrastructure. The restoration of the properties would in turn help support the reestablishment of the local tourism economy facilitated by the heritage sites. At the same time, it represented an opportunity for testing the positive virus model within a natural disaster recovery setting.

3.1 Advancing digital recordation for heritage conservation at La Mina Recreation Area

The project completed the recordation of two significant properties damaged by the hurricanes using cutting-edge technology tools. The two heritage properties documented in the pilot collaboration were the Stone House (Fig. 4) and the La Mina Trail Bridge (Fig. 5). The Stone House's historical significance rested on it being the first permanent ranger station constructed by the CCC in the Caribbean. The building modelled as the prototype for all other similar edifices constructed during the era in the forest reserves of Puerto Rico [15]. The La Mina Trail Bridge facilitated pedestrian traffic to the most famous waterfall in Puerto Rico and served as an observation platform for the tens of millions of visitors that have experienced the majestic natural feature. The fabric and structural integrity of both properties were adversely affected by the hurricanes. Being some of the earliest constructions by the CCC in the forest, both properties had been created using artisanal techniques and lacked any architectural records. This lack of archival data complicated the process of developing restoration alternatives to guide the repairs. Competing priorities and limited assets during the post hurricane recovery work made it difficult to acquire expertise and resources to inform the restoration efforts. The pressures to document, repair and reopen the damaged recreation sites to restart the tourism economy was a pressing concern leading to the need to find the most efficient and expedient methods to accelerate the restoration procedures.

As mentioned, the use of cutting-edge technology was fundamental to expedite the documentation process, retrieve the most accurate data, and create a database of information of the heritage properties that did not exist before. The difficulty presented by the natural environment where the work was to be completed compelled the need for the use of the most accurate and efficient recordation methods available. The remote location of one of the sites (La Mina Trail Bridge), and the rainforest environment plagued by constant downpours made the need for efficiency clear. In the development of the project scope of work it was decided

Figure 4: View of the Stone House's main façade.

Figure 5: View of La Mina Trail Bridge (looking upstream).

that the use of LiDAR to produce three-dimensional models of the resources (Figs 6–8), along with photogrammetric recordation and the use of drone scanning, were the most cost efficient and accurate means to complete the documentation of the properties. They employed a DJI Phantom Mini 2 (38 minute flight time, 32,800 ft (6.2 mi) video transmission range) quadcopter drone for aerial recordation of the features with a 4K HDR 1/1.3 inch sensor with support, dual native ISO, an f/1.7 aperture, and large 2.4 μm pixel camera. LiDAR scanning was performed using a Trimble® X7 Camara Scanner with a laser wavelength of 1,550 nm (scan speed of 500 Hz, within a range of 0.6–80 m in 360 × 282° field). Photogrammetry was used to document the properties surface and overlay texture over the scanned point cloud with an accuracy of 2.4 mm @ 10 m, 3.5 mm @ 20 m and 6.0 mm @ 40 m. The scanner had a resolution of 3840 × 2746 pixels for optical image integration and a scanning accuracy of [1,598 images −158 MP] – [1 minute HDR 3–6 minutes]. All the data was processed with a commercially available computer aided design software. All data was georeferenced using geographic positioning system referenced to the NAD 83/PRVD 2002 geographically referenced grid and stored in digital format.

Although in recent years the use of advanced technologies in the disciplines of archaeology and restoration have become more commonplace in tropical Latina American archaeological areas [25]–[27], and in lesser degree in Puerto Rico [28]–[31], the use of these tools was somewhat limited on the island prior to 2017 [8]. The reasons range from the scarcity of availability of tools on island, the high entry cost, the lack of technical training and expertise for their use, and significantly enough, a lack of a market for its employment. Those circumstances started to rapidly change in the last eight years due to an influx of more affordable equipment, newly trained specialists and the pressing need to increase efficiency in the reconstruction and recovery efforts on the island. The collaboration with the Puerto Rico Science, Technology and Research Trust facilitated the acquisition of that expertise and

Figure 6: Example of 3D point cloud model of the exterior of the Stone House.

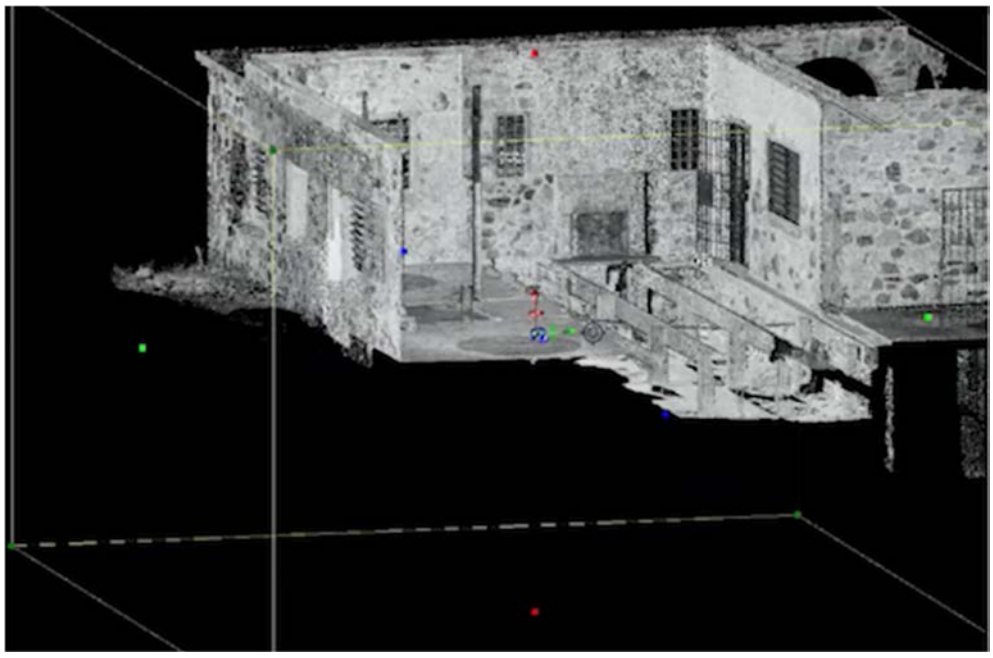

Figure 7: Example of 3D point cloud model of the interior of the Stone House.

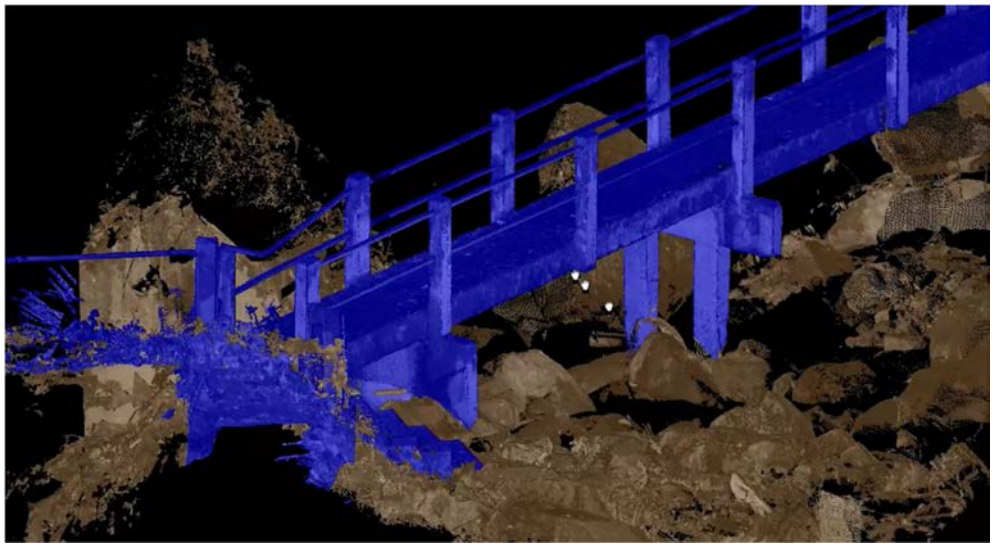

Figure 8: Example of 3D point cloud model of La Mina Trail Bridge.

the equipment which was not readily available to the Forest Service. This project was an example of the collaboration between two entities towards the goal of achieving the SHCC model intent. The collaborative project enabled the documentation of two heritage properties in a fraction of time and at a fraction of the cost of what would have taken complete it manually. The use of LiDAR scanning, drones, and high-resolution 3D photography produced an impeccable level of detail, much more quickly than expected, allowing the Forest Service to obtain the level of precision mandated by Historic American Buildings Survey and Historic American Engineering Record (HABS-HAER) standards [32]. The data produced for the first time an archival record of the design and existing condition of the properties. This in turn allowed the Forest Service to plan, design and execute the restoration of the recreation assets. That in turn is allowing the local tourism economy to recover and the connection to the people with the forest to get reestablished once again.

4 CONCLUSIONS

All intended goals of the pilot partnership were met, including the creation of new data sets and the development of accurate records for planning and preservation purposes. The initiative proved highly successful in providing the first guidelines for the application of pre-emptive mitigations to safeguard heritage assets against the potential effects of climate change at El Yunque National Forest. The collaboration showed the feasibility for the use of the 'Positive Virus' model in support of heritage preservation and sustenance of cultural resource dependent economies, such as tourism. The testing of the model showed that its implementation can be viable for establishing and developing the systemic interdependences of the model between sustainability, climate adaptation, economic development, historic preservation, and facilitation of human experiences. The collaboration hinted that similar initiatives could help in circumnavigating common obstacles in historic preservation, through the leveraging of connections, budget supplementation, resource sharing and mutual support in times of crisis. It also suggested that the development of inventories of heritage resources could be achieved even when one entity or sector lacks the internal expertise, tools, or

personnel to achieve those goals on its own. The success of this pilot could be used as an example for the testing and use of the 'Positive Virus' model in other settings sharing similar conditions to the context previously outlined for El Yunque National Forest in Puerto Rico.

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