Published in final edited form as:

J Land Use Sci. 2016 ; 11(4): 417–428. doi:10.1080/1747423X.2016.1172129.

Translating land use science to a museum exhibit

Javier A. Arce-Nazario [Associate Professor, Joint Appointment]

Biology and Institute of Interdisciplinary Research, University of Puerto Rico at Cayey

Abstract

For land use science to engage the general public it must successfully translate its concepts and conclusions and make them public outside of traditional scientific venues. Here we explore science-art exhibits, which blend artistic presentations with specific scientific data or themes, as a possible effective way of communicating scientific information and disrupting misconceptions. We describe the process of producing a science-art exhibit on remote sensing and Puerto Rican landscape history from 1937 to the present, sited at a rural Puerto Rican community museum, and examine the visitor experience and educational outcomes of the museum exhibit through analysis of survey data. The exhibit project engaged undergraduate students from a variety of academic backgrounds, introduced land use science concepts to the public in an engaging format, and was effective at reshaping visitors' misconceptions of Puerto Rico's landscape change history.

Keywords

landscape change; museum; Puerto Rico; remote sensing; science education; science-art

Introduction

Puerto Rico has served as a model of tropical land cover transformation for many scientists interested in land cover change. During the 1950s the economic focus of Puerto Rico drastically changed from an agrarian society to an industrial and service economy (Dietz, 1986). This transition resulted in the abandonment of large tracts of agricultural areas and a natural reforestation process that has resulted in an increase in forest cover, from less than 10% in the 1940s to more than 40% in 2000 (Grau et al., 2003). Reforestation occurred more commonly in the mountainous areas farthest from roads and on steeper slopes (Helmer, 2004; Thomlinson, Serrano, López Marrero, Aide, & Zimmerman, 1996). At the same time, many agricultural lands in the valleys became urbanized (López Marrero, Aide, & Thomlinson, 2001).

In different disciplines, researchers have focused on various impacts that these changes had on the natural resources of Puerto Rico. Ecologists have mostly focused on how the vegetation composition of secondary forest varied as a result of different land uses (Aide, Zimmerman, Pascarella, Rivera, & Marciano-Vega, 2000; Thompson et al., 2002). Others have analyzed how these patterns of change have shaped stream water quality (Uriarte,

Yackulic, Lim, & Arce-Nazario, 2011), bird populations (Acevedo & Restrepo, 2008), channel morphology (Clark & Wilcock, 2000), and climate variables (Torres-Valcárcel, Harbor, Torres-Valcárcel, & González-Avilés, 2015). Social scientists have evaluated the socio-economic drivers of change and its theoretical implications (Rudel, Perez-Lugo, & Zichal, 2000). The Puerto Rican model of transformation has inspired scientists to describe the current period of tropical forest change as the 'era of novel tropical forests' (Lugo, 2009).

The story of land cover change in Puerto Rico is not only discussed in scientific journals, but also in popular media such as local newspapers (Alvarado León, 2014, 2015). However, it is not clear how the general public is absorbing this information. There are some indications that popular narratives of deforestation in other tropical forests have led to a public misunderstanding of land cover change in Puerto Rico. For example, pre-tests administered to freshman students in 2012, 2013, and 2014 in a course on local environmental change revealed that most students believe that less forest covers Puerto Rico today than it did in the 1950s (Arce-Nazario, unpublished data). This is a reflection of more general difficulties in communicating scientific information about the environment to the nonscientific community: for example, climate change is a common theme in the media, yet the general public in the United States and in many countries in Europe still does not understand how anthropogenic causes of climate change work. Media researchers suggest that this is the result of how media news is constructed and consumed (Boykoff & Boykoff, 2007; Howell, 2014). Correctly understanding scientific information often requires a level of detail and focus that many print and broadcast media venues do not demand of their readers, listeners, or viewers. Those that do read thorough scientific news are often a small population of already informed enthusiasts (Nisbet & Scheufele, 2009).

Making the methods and results of land-use science accessible to the general public, and understanding the public's response, is especially important for a field with such direct links to public policy and is an expressed goal of several national and international land-use research organizations. While the education and outreach missions of these groups tends to be user- and practitioner-focused (NSF, 2011; IALE, 2016), some exceptions focus on public awareness: the USGS Climate and Land Use Change Science Strategy recommendations (USGS, 2013) include "improving external communications... to improve the public's understanding of global change research findings", while the Global Land Project (GLP, 2005) emphasizes the importance of understanding the way in which environmental change is perceived by local communities in its Science Plan and Implementation Strategy, noting that this is "an essential prerequisite for understanding the magnitude of potential reactions." With these goals in mind, research in land-use science education and outreach should prioritize both measuring and evaluating strategies to increase local awareness of the land use dynamics in an area, as well as informing the public about methods so they can understand results.

In contrast to print and broadcast media, museum exhibits provide a venue for presenting scientific information in non-traditional forms that are not constrained by the time and bandwidth limitations of other media structures. Patrons of a museum are not necessarily looking for scientific information, but may be attracted to visit because of other aspects of

museum-going, such as entertainment through visual stimulation or socialization (Anderson, Kelling, Pressley-Keough, Bloomsmith, & Maple, 2003; Falk, 2009; Schwan, Grajal, & Lewalter, 2014). Previous studies on science exhibits in museums have shown their effectiveness at providing valuable information to the public (Schwan, Grajal, & Lewalter, 2014) and being a powerful tool for reaching people of different economic and socio-cultural backgrounds (Farrell & Medvedeva, 2010). Museum exhibits have even been shown to have an impact on peoples' attitudes towards the environment, and to foster conversations about science, technology, engineering and mathematics (STEM) among families (Haden et al., 2014).

Artistic representations provide yet another venue for engaging and educating the public about the environment. Ecology and conservation has long been integrated into artistic representations for educational purposes (Curtis, Reid, & Ballard, 2012; Jacobson, McDuff, & Monroe, 2007). Environmental educators have particularly searched for creative ways to use the arts to provide more effective ways of translating scientific information to children or to a non-scientific audience. There are multiple examples of environmental education presented through artistic media like dance (Reinsborough, 2008), music (Turner & Freedman, 2004), visual arts (Inwood & Taylor, 2012), theater (Gale, 2008), and festivals (Marks, Chandler, & Baldwin, 2016). Environmental educators have also provided evidence of the effectiveness of artistic approaches in teaching environmental concepts by incorporating assessment and evaluation into the environmental education activity (Jacobson, McDuff, & Monroe, 2006).

Remote sensing and the story of landscape change can lead to particularly compelling artistic representations. Remote sensed images have been central to acclaimed exhibits such as *Earth From Above* (Arthus-Bertrand, 2005) and *Politics of Snow* (Burko, 2012). Remote sensed images like those of Arthus-Bertrand allow the viewers to discover landscape patterns throughout the world and discover how some of those patterns are related to natural and socio-economic processes. The work of Diane Burko explores the analysis of climate change more directly by using sequences of paintings based on images of glacial landscapes. However, the focus of these types of artistic presentation is mostly on environmental education; these works do not emphasize how landscape patterns are analyzed or the value of remote sensing as a scientific tool.

Based on the popular appeal of artistic representations of environmental change and the effectiveness of museum exhibits in translating scientific information, we explored a growing class of exhibits as a non-traditional venue for education about landscape change research in Puerto Rico. Science-art exhibits are artistic presentations of scientific material. These exhibits incorporate science into museums and other spaces normally devoted to art, or alternatively, incorporate art into spaces normally devoted to science. Some recent examples of this genre of exhibit in traditionally science-focused spaces can be seen at the National Science Foundation (<http://news.itsnet.edu/Article2489.html>), the New York Hall of Science (<http://nysci.org/science-inspires-art-the-brain/>) and the Chemical Heritage Foundation Museum (<http://sensingchange.chemheritage.org/>). Inspired by scientific work, artists present their artistic work in forms including dance, music, paintings, and photography. Examples of scientific material presented in spaces traditionally focused on art

can be seen at many museums and galleries. Recent examples include Jason Walker's exhibit at the Bellvue Arts Museum (http://www.bellevuearts.org/exhibitions/jason_walker.html), and James Prosek's exhibit at the North Carolina Museum of Art (<http://ncartmuseum.org/exhibitions/view/11380>). There are even museums dedicated to the fusion of art and science such as Art.Science.Gallery. (<http://artsciencegallery.com/about/>), and spaces dedicated to the exploration of the interactions between art and science within spaces traditionally dedicated to scientific activity, such as the installation at the National Academies of Science (<http://www.cpnas.org/visit/about-cpnas.html>). Scientific institutions have provided support for art residencies such as the Swiss-artists-in-labs (<http://artistsinlabs.ch/>) and Arts@CERN (<http://arts.web.cern.ch/home>) projects. The emphasis in science-art exhibits is to promote a creative experience merging science with art, in contrast to museums that may have galleries dedicated to art or science under the same roof, but still maintain a disciplinary divide.

We explored the science-art form of presentation because these may be especially well-suited to treating themes such as scale and space, as exemplified by the *Macro or Micro?* exhibit by Young & Kelley (Gambino, 2013). In addition, the necessary collaborations and cross-disciplinary techniques required to create such an exhibit presented an opportunity to engage students in the challenge of finding ways to integrate land use science with art, and to collaborate with artists to make effective and engaging presentations. We attempted to quantify how well the local public perception of land use change in Puerto Rico corresponds to the scientific understanding, and also to evaluate the effectiveness of a science-art exhibit in conveying the scientific view of land use change in the area. Hence, this project specifically aimed to evaluate (1) the public perception of land use change in Puerto Rico, (2) ways to integrate land use science with art, and (3) if such an exhibit is an effective method for teaching the general public about land use change.

Methods

The project consisted of selecting and rectifying historical images that would illustrate the land-cover change history of Puerto Rico, creating the artistic presentation of these images and arranging them in the venue, adding educational materials and information to the venue displays, interviewing participants and analyzing their responses to assess their experience and its educational impact.

Image manipulation

The images presented in the exhibit are based on a set of more than 800 aerial photographs of Puerto Rico taken between 1930 and 2010, focusing on the central, mountainous region of Cayey, Puerto Rico, which was the designated venue for the exhibit. The region covered corresponds to 2100 km², or about 23% of Puerto Rico. These images were spatially rectified using ERDAS LPS Photogrammetry Suite, by referencing them to orthorectified images from 2010 obtained from the United States Army Corps of Engineers ADS-40 sensor remote sensing project. These 2010 images were used to obtain control points to orthorectify the raw black and white (bw) images from earlier than 1990. The images from the 1930s were obtained from the Department of Transportation of Puerto Rico, and images from 1958 to 1995 were obtained from the USGS. Orthorectified images were organized in a GIS

database using a combination of GIS software tools (ESRI ArcGIS 10, QGIS, ERDAS). We also used these GIS software packages to make mosaics and perform edge-matching. Using the GIS software allowed us to preserve the geometric rectification and projection during the creation of maps. Anaglyph maps were created using stereo pairs of images using ERDAS Stereo Analysis. Maps were further manipulated using GIMP 2.8 to include text and other artistic features.

Museum exhibit design

An interdisciplinary team including the author and three undergraduate students – one from the natural sciences, one from social sciences and one from the humanities – met weekly from January 2014 to April 2014 to discuss possible themes and approaches to displaying land cover transformation within the available exhibit space. We started by selecting cloudless remote sensing images of Puerto Rico that we considered effective in presenting changes in terrestrial and aquatic features, as well as changes in the lowlands, coasts, mountains, and towns. To plan the spatial arrangement of the exhibit, we developed a 3-D model of the venue using Sketchup 2014 (figure 1). The venue was a community center located in a historical building near the town center. Since the venue space had three halls, we divided the exhibit into three mapping themes, described in detail below.

Each hall included a large placard with information about landscape transitions, and about the methods used for analyzing land use change. Every map included a description of the location, date, source, scale and north direction. Information about landscape patterns was placed under the heading ‘*Did you notice?*’. Outside of the three halls, there was also a small interactive space for visitors to view sets of two stereo images through a stereoscope. A virtual tour of the exhibit can be seen at <https://sites.google.com/site/prlandchange/virtual>.

Theme 1: Triptychs and interactive landscapes of change—In this hall we presented groups of three contiguous images of the same spatial region in chronological order, showing the transformation of the landscape. Even though we could have created sets of more than three historical events, we decided to use three sets of images for two reasons. The first reason was aesthetic, as the use of more than three images would overcrowd the available space. The second reason was that we wanted to produce an immersive but not overwhelming experience for the visitors, which can be encouraged through the modest use of interactive components (Harvey, Loomis, Bell, & Marino, 1998). The organization into three images also makes reference to the medieval art form of triptychs. In each triptych, images from 1930, 1960, and 2010 were presented. The images from 2010 were presented in color, the images from 1960s were presented in black-and-white, and the images from the 1930s in sepia (figure 1A). We anticipated that the color-coding would help the visitor to quickly recognize the year. We also prepared a wall where sets of two images were placed with one covering the other. The visitor had to raise the bw 1960s image to observe the color 2010 image in the background (figure 2A).

Theme 2: Blended transformation—This hall presented chronological transitions by blending images from different years within the same canvas. This approach contrasted with the triptych hall, in which every canvas was composed of images from just one year. To

create the blended transformation, we created maps at the same scale and projection for each year, and further manipulated the images in GIMP 2.8. We utilized metaphors of time's passage, such as spirals (figure 1B) and clocks, to provide the viewer a sense of transition in the images. Permanent features such as rivers and roads created a stronger sense of continuity across the images of different years.

Theme 3: Stereo-images—The third hall presented red-blue anaglyph images of the town of Cayey for four different years (1937, 1962, 1977 and 2010). Visitors were given red-blue anaglyph glasses to observe the images in this hall (figure 2B). Unlike the presentation in other halls, each image in this hall generally presented the same spatial region, but at different scales and with the north side of the image oriented in different directions. The variation in orientation was necessary due to the constraints from the stereo image pair, which were obtained from consecutive air-photos and were thus oriented according to the airplane's flight direction. The location of the hall selected to present the anaglyphs was chosen to be very close to the entrance of the venue and visible from the sidewalk. We hoped that additional foot-traffic would be attracted to the exhibit by the unusual sight of other visitors all wearing anaglyph glasses (figure 2B).

Publicity

The exhibit was publicized by posting on the list-serve of the neighboring universities, by direct outreach to local community groups, and by placing a sign in the community center. It remained open for seven days and received 110 visitors.

Visitor Interviews

A questionnaire, which was approved by the IRB, was developed and used to interview visitors to the exhibit. Parts of the questionnaire had been tested on students between 2012 and 2014 in a classroom setting. Visitors were randomly selected for interviews both entering and leaving the exhibit; thus some visitors were interviewed twice. The interview first determined whether the interviewee had seen the exhibit or not. It included questions to determine the interviewee's age, gender, county of residence and educational background. Short, closed questions probed the visitor's understanding about when Puerto Rico's landscape had the greatest amount of agricultural, urban, and forest cover. Subsequent open-ended questions allowed visitors to express why they thought changes had occurred in Puerto Rico, and also probed which aspects of the exhibit they liked or disliked the most. They were also given the opportunity to suggest improvements to the exhibit. Two students were present at the entrance of the exhibit hall verbally administering the questionnaire. Open-ended answers were collected with a digital recorder and later transcribed. Interviews were conducted in Spanish, and both questions and answers have been translated for presentation here by the research team. The answers to closed-form questions were analyzed using R 3.2.3 for statistical analysis. The answers to open-ended questions were statistically analyzed after manual coding, with coding categories determined *a posteriori*. The research team also observed the visitors, and made notes about their interactions and behaviors in the halls. Finally, we placed a suggestion box at the exit of the exhibit.

Results

Of the 110 visitors to the exhibit, 26 of them were interviewed before seeing the exhibit and 29 people were interviewed after their visit. Visitors came from different counties in Puerto Rico, with the majority coming from the municipality of the venue (Cayey). 58% of the people interviewed before the exhibit believed that Puerto Rico had the most forest cover between the 1930s and the 1950s. Only 3% of the interviewees questioned after the exhibit believed that Puerto Rico had the most forest cover during the 1930-1950 era. While interviewees' perceptions of forest cover change was significantly different in interviews before and after the exhibit, responses related to urban cover and agricultural cover remained relatively the same. Interviews collected before and after visiting the exhibit showed that the public understood that Puerto Rico was more covered by agricultural lands during the period from 1930-1950 than in the present. Similarly, the public perception of the history of urbanization in Puerto Rico was relatively similar before and after the exhibit, with most respondents believing that one of the two suggested time periods after 1950 represented the peak in urban land cover (figure 3).

The open-ended questions before the exhibit provided valuable information about the possible reasons for the common misunderstandings of land cover change patterns in Puerto Rico. 75% of the respondents who believed that Puerto Rico was mostly forested between 1930 and 1950 based their decision on the fact that Puerto Rico is currently more populated, urbanized and industrialized than it was in the past. For example, an interviewee between 20 and 30 years old who was asked to explain his response that forest cover was the greatest in the 1930s said: 'Well, it is common sense; in the past there were fewer people, and now there are more people and more construction'. Other interviewees (12%) answered that they based their perceptions on what they could see in the landscape. Interestingly, even some respondents born in the 1940s who were asked about why they considered the period between 1930 and 1950 to be the era with the greatest extent of forest cover answered: 'I know this because I lived it. I was born in 1941 in Cayey, and when you traveled from Cayey to Caguas or to Salinas you would see forests on both sides. I lived this, I did not imagine it'.

Those who did correctly identify the current era (1990 – 2010) as the peak period for forest cover had various explanations for their belief. Many (27%) people mentioned that they knew it because in the past, the land cover was mostly agricultural, and that it is necessary to clear forested land for agriculture. Others (8%) who gave correct responses explained their answer by saying that they had noticed this pattern based on their previous exposure to old photographs of Puerto Rico where the mountains are obviously stripped of trees. Still others (12%) cited a book or an academic resource, such as a friend involved in research or a teacher.

The open-ended questions in the interviews with visitors leaving the exhibit also provided valuable information about the visitor's learning experience. Visitors that recognized the process of reforestation in Puerto Rico generally indicated that the clear patches in the landscape in the 1930s were obvious, and that their transition as they became reforested though time was clearly presented. They also mentioned the importance of the student guides and the textual information presented in the halls. Several of the visitors who were

interviewed twice were clearly satisfied to have reevaluated their understanding of landscape change in Puerto Rico, their visit, as evidenced by responses such as: 'This exhibit is interesting because my answers (to the interview) before were wrong, and things have not happened the way my logic suggested.' Only one interviewee still considered that Puerto Rico was more forested in the 1930s. This visitor made reference to the fact that Puerto Rico is currently more urbanized, and also commented that he had only seen the 3D images, and needed more time to visit the other halls in the future.

Interviewees also revealed other information they had learned from the exhibit. While land cover transformation in Puerto Rico was the most commonly mentioned acquired concept, respondents also indicated that they learned other new concepts which form important elements of landscape research. For example, interviewees (17%) mentioned that they learned that rectilinear features in landscape images are often the product of human intervention. Responders were particularly impressed with the images of transitions observed in the Bayamón river valley, where the meandering river was channelized to a straight line and where most farms became residential neighborhoods. These images allowed the visitors to visualize how the shape of patches and boundaries can be related to human intervention, usually with more geometric and rectilinear features related to anthropogenic disturbances. Interviewees (17%) mentioned interest in the concept of forest succession, and 7% were also interested in patterns related to historical contingencies and connectivity (Cadenasso, Pickett, & Grove, 2006), such as the importance of farm hedges as seedbanks in the reforestation of Puerto Rican mountains, and as indicators of where future roads and development would occur in the flatlands. 13% of visitors expressed enthusiasm about learning how stereophotogrammetry works.

The informal observations of the visitors' interactions allowed the research team to appreciate that many visitors had conversations while viewing the exhibit. Many discussions centered on the visitors' past histories and how things in the region had changed. Another common theme of discussion noted through these observations was how urban planning could be changed, and what landscape features might be important to conserve.

Discussion and Conclusion

The exhibit provided a useful venue for assessing the public's understanding of specific elements of Puerto Rico's land-use history, and was effective at transmitting basic concepts of land use science, remote sensing and landscape ecology. After seeing the exhibit, visitors were able to visually interpret remote-sensing images, and most corrected their misunderstanding of land cover change in Puerto Rico. Many were also able to relate land cover patterns to landscape processes. This level of success in transmitting information may be attributed to the fact that the exhibit had a highly specific theme (Moscardo & Pearce, 1986).

The anaglyph images were the preferred form of presentation of remote sensing imagery (53%), followed by the triptychs (20%), the blended images (17%) and the interactive images (10%). This is an important result since it suggests that the varied forms of presentation in the exhibit were effective in appealing to a diverse audience, and different

ways to interpret change. For example, the few visitors that had some knowledge of mapping and remote sensing spent more time looking and admiring the blended images, especially the clocks. These images required a higher level of abstraction compared to the triptych. Allen (2004) suggests that in designing science museum exhibits it is important to present multiple levels of complexity to allow visitors to receive a certain level of satisfaction at multiple stages of the museum experience.

There are naturally several factors limiting the interpretation of this study. While 110 visitors in a week is considerable for an exhibit presented at a small community center in Puerto Rico, a larger number of visitors and a larger sample of interviews would both be desirable. The demographic composition of the visitors was also affected by the venue and its proximity to the nearby university, as well as the advertisement of the exhibit through university channels.

The exhibit also allowed for conversation among visitors, and the effects of these interactions were not accounted for in the interviews or their interpretation. The informal observations of these conversations suggest that the venue provided a space to discuss other valuable concepts in landscape ecology, such as cultural sustainable landscapes (Nassauer, 1997) and urban sustainability (Wu, 2008). Visitors discussed issues of agricultural land conservation and the need of local participation in the municipal development plans. Thus it appears that a science-art exhibit at a local community venue could be an effective way to integrate landscape science into local practice, which has been identified as a major element needed to strengthen the field of landscape ecology (Opdam et al. 2013). Future studies integrating exhibits and other interdisciplinary methods could evaluate not only the knowledge acquisition but also changes in interests, beliefs and behavior.

By its nature, land use science is a field that uses data in ways that can lead to very appealing images and other figures. The highly visual aspects of land use science present a unique opportunity to collaborate with the humanities in productive ways that can inform the general public about the values of land use science. By translating land use science to a museum exhibit, our project was able to inform the general public about the complex drivers of change. Our use of mixed method interviews in the exhibit experience presented the opportunity to understand landscape perceptions among the public and to probe how these perceptions can be transformed by the result of our research. Bringing land use science into to a museum context thus allows for the generation of new research questions, unique forms of artistic expression, and new forms of pedagogy.

Acknowledgements

This project was possible thanks to the passion and patience of many of the UPR Cayey students that rectified many of the historical images and the institutions that donated the imagery and time to scan historical images. The 1930s images were donated from the Department of Public Transportation in Puerto Rico (DTOP). Special thanks at the DTOP to Ivette Nazario, Jose Polaco, Caridad Ronda and Lester Ojeda. The images from 1950-2000 were obtained from the USGS, and the 2010 were obtained from the USACE, special thanks to Theodore N. Schall and Jim Suggs at the USACE. The students involved in georectifying, interviews and preparing the venue were Armando Meléndez, Faviola Castrodad, Carlos Figueroa, Luis Pérez, Wilamarie Morales, and Luis Martínez. Thanks to the Casa del Caminero for providing the space and the Institute of Interdisciplinary Research for logistic support.

This work was supported in part by the National Science Foundation under Grant #1151458; the National Institutes of Health under Grant #P20 MD0006144, and the University of Puerto Rico Seed Grants. Any opinions, findings,

and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of any of the granting agencies or institutions that provided their imagery.

References

- Acevedo MA, Restrepo C. Land-cover and land-use change and its contribution to the large-scale organization of Puerto Rico's bird assemblages. *Diversity and Distributions*. 2008; 14:114–122. doi: 10.1111/j.1472-4642.2007.00435.x.
- Aide TM, Zimmerman JK, Pascarella JB, Rivera L, Marciano-Vega H. Forest regeneration in a chronosequence of tropical abandoned pastures: implications for restoration ecology. *Restoration Ecology*. 2000; 8:328–338. doi:10.1046/j.1526-100x.2000.80048.x.
- Allen S. Designs for learning: Studying science museum exhibits that do more than entertain. *Science Education*. 2004; 88:S17–S33. doi:10.1002/sce.20016.
- Alvarado León, GE. Proponen reducir las áreas de bosques.. *El Nuevo Día*. Jan 1. 2014 Retrieved from <http://www.elnuevodia.com/noticias/locales/nota/proponenreducirlasareasdebosques-1639450/>
- Alvarado León, GE. Cubierta forestal en Puerto Rico se duplica.. *El Nuevo Día*. Feb 1. 2015 Retrieved from <http://www.elnuevodia.com/ciencia/ciencia/nota/cubiertaforestalenpuertoricoseduplica-2002021/>
- Anderson US, Kelling AS, Pressley-Keough R, Blooms Smith MA, Maple TL. Enhancing the zoo visitor's experience by public animal training and oral interpretation at an otter exhibit. *Environment and Behavior*. 2003; 35:826–841. doi:10.1177/0013916503254746.
- Arthus-Bertrand, Y. *Earth from Above*. Harry N. Abrams; New York, NY: 2005.
- Boykoff MT, Boykoff JM. Climate change and journalistic norms: A case-study of US mass-media coverage. *Geoforum*. 2007; 38:1190–1204. doi:10.1016/j.geoforum.2007.01.008.
- Burko D. Politics of Snow. AGU Fall Meeting Abstracts. 2012; 1:04. Retrieved from <http://adsabs.harvard.edu/abs/2012AGUFMPA21B..04B>.
- Cadenasso ML, Pickett STA, Grove JM. Dimensions of ecosystem complexity: Heterogeneity, connectivity, and history. *Ecological Complexity*. 2006; 3(1):1–12. doi:10.1016/j.ecocom.2005.07.002.
- Clark JJ, Wilcock PR. Effects of land-use change on channel morphology in northeastern Puerto Rico. *Geological Society of America Bulletin*. 2000; 112:1763–1777. doi: 10.1130/0016-7606(2000)112<1763:EOLUCO>2.0.CO;2.
- Curtis DJ, Reid N, Ballard G. Communicating ecology through art: What scientists think. *Ecology and Society*. 2012; 17:3. doi:10.5751/ES-04670-170203.
- López Marrero T, Aide TM, Thomlinson JR. Urban expansion and the loss of prime agricultural lands in Puerto Rico. *Ambio: A Journal of the Human Environment*. 2001; 30:49–54. doi: 10.1579/0044-7447-30.1.49.
- Dietz, JL. *Economic history of Puerto Rico: Institutional change and capitalist development*. Princeton University Press; Princeton, NJ: 1986.
- Falk, JH. *Identity and the museum visitor experience*. Left Coast Press; Walnut Creek, CA: 2009.
- Farrell, B., Medvedeva, M. *Demographic transformation and the future of museums*. AAM Press; Washington, DC: 2010.
- Gale H. How does drama work in environmental education? *Earth & Environment*. 2008; 3:159–178.
- Gambino, M. Macro or micro? Test your sense of scale.. *Smithsonian*. Oct. 2013 Retrieved from <http://www.smithsonianmag.com/science-nature/macro-or-micro-test-your-sense-of-scale-2208824/?no-ist>
- GLP. Science plan and implementation strategy. 2005. (IGBP Report No. 53/IHDP Report No. 19). Retrieved from IGBP website: http://www.igbp.net/download/18.1b8ae20512db692f2a680006384/1376383121392/report_53-GLP.pdf
- Grau HR, Aide TM, Zimmerman JK, Thomlinson JR, Helmer E, Zou X. The ecological consequences of socioeconomic and land-use changes in postagriculture Puerto Rico. *BioScience*. 2003; 53:1159–1168. doi:10.1641/00063568(2003)053[1159:TECOSA]2.0.CO;2.

- Haden CA, Jant EA, Hoffman PC, Marcus M, Geddes JR, Gaskins S. Supporting family conversations and children's STEM learning in a children's museum. *Early Childhood Research Quarterly*. 2014; 29:333–344. doi:10.1016/j.ecresq.2014.04.004.
- Harvey ML, Loomis RJ, Bell PA, Marino M. The influence of museum exhibit design on immersion and psychological flow. *Environment and Behavior*. 1998; 30:601–627. doi: 10.1177/001391659803000502.
- Helmer EH. Forest conservation and land development in Puerto Rico. *Landscape Ecology*. 2004; 19:29–40. doi:10.1023/B:LAND.0000018364.68514.fb.
- Howell RA. Investigating the long-term impacts of climate change communications on individuals' attitudes and behavior. *Environment and Behavior*. 2014; 46:70–101. doi: 10.1177/0013916512452428.
- IALE Outreach Working Group (IOWG). [March 1, 2016] from <http://www.landscape-ecology.org/index.php?id=91>
- Inwood H, Taylor RW. Creative approaches to environmental learning: Two perspectives on teaching environmental art education. *International Electronic Journal of Environmental Education*. 2012; 2:65–75.
- Jacobson, SK., McDuff, MD., Monroe, MC. Conservation education and outreach techniques. Oxford University Press; Oxford: 2006.
- Jacobson SK, McDuff MD, Monroe MC. Promoting conservation through the arts: Outreach for hearts and minds. *Conservation Biology*. 2007; 21:7–10. doi: 10.1111/j.1523-1739.2006.00596.x. [PubMed: 17298502]
- Lugo AE. The emerging era of novel tropical forests. *Biotropica*. 2009; 41:589–591. doi:10.1111/j.1744-7429.2009.00550.x.
- Marks M, Chandler L, Baldwin C. Re-imagining the environment: Using an environmental art festival to encourage pro-environmental behaviour and a sense of place. *Local Environment*. 2016; 21:310–329. doi:10.1080/13549839.2014.958984.
- Moscardo G, Pearce PL. Visitor centres and environmental interpretation: An exploration of the relationships among visitor enjoyment, understanding and mindfulness. *Journal of Environmental Psychology*. 1986; 6:89–108. doi:10.1016/S0272-4944(86)80011-1.
- Nassauer, JI. Cultural sustainability: Aligning aesthetics and ecology.. In: Nassauer, JI., editor. *Placing nature: Culture and landscape ecology*. Island Press; Washington, DC: 1997. p. 67-83.
- NSF. National Science Foundation Geography and Spatial Sciences Program Strategic Plan (GSS Program Solicitation NSF 14-537). 2011. Retrieved from http://www.nsf.gov/sbe/bcs/grs/GSS_StrategicPlan_2011.pdf
- Nisbet MC, Scheufele DA. What's next for science communication? Promising directions and lingering distractions. *American Journal of Botany*. 2009; 96:1767–1778. doi:10.3732/ajb.0900041. [PubMed: 21622297]
- Opdam P, Nassauer JI, Wang Z, Albert C, Bentrup G, Castella J-C, Swaffield S. Science for action at the local landscape scale. *Landscape Ecology*. 2013; 28:1439–1445. doi:10.1007/s10980-013-9925-6.
- Reinsborough L. This revolution can dance: Environmental education through community arts. *Canadian Journal of Environmental Education (CJEE)*. 2008; 13(1):42–56. Retrieved from <http://files.eric.ed.gov/fulltext/EJ842768.pdf>.
- Rudel TK, Perez-Lugo M, Zichal H. When fields revert to forest: Development and spontaneous reforestation in post-war Puerto Rico. *The Professional Geographer*. 2000; 52:386–397. doi: 10.1111/0033-0124.00233.
- Schwan S, Grajal A, Lewalter D. Understanding and engagement in places of science experience: Science museums, science centers, zoos, and aquariums. *Educational Psychologist*. 2014; 49:70–85. doi:10.1080/00461520.2014.917588.
- Thomlinson JR, Serrano MI, Lopez Marrero T, Aide TM, Zimmerman JK. Land-use dynamics in a post-agricultural Puerto Rican landscape (1936-1988). *Biotropica*. 1996:525–536. doi: 10.2307/2389094.

- Thompson J, Brokaw N, Zimmerman JK, Waide RB, Everham EM III, Lodge DJ, Fluet M. Land use history, environment, and tree composition in a tropical forest. *Ecological Applications*. 2002; 12(5):1344–1363. doi:10.2307/3099976.
- Torres-Valcárcel ÁR, Harbor J, Torres-Valcárcel AL, González-Avilés CJ. Historical differences in temperature between urban and non-urban areas in Puerto Rico. *International Journal of Climatology*. 2015; 35:1648–1661. doi:10.1002/joc.4083.
- Turner K, Freedman B. Music and environmental studies. *The Journal of Environmental Education*. 2004; 36:45–52. doi:10.3200/JOEE.36.1.45-52.
- Uriarte M, Yackulic CB, Lim Y, Arce-Nazario JA. Influence of land use on water quality in a tropical landscape: A multi-scale analysis. *Landscape Ecology*. 2011; 26:1151–1164. doi:10.1007/s10980-011-9642-y. [PubMed: 26146455]
- U.S. Geological Survey. U.S. Geological Survey climate and land use change science strategy—A framework for understanding and responding to global change. U.S. Geological Survey Circular 1383–A; 2013. Retrieved from <http://pubs.usgs.gov/circ/1383a/circ1383-A.pdf>
- Wu JJ. Making the case for landscape ecology an effective approach to urban sustainability. *Landscape Journal*. 2008; 27:41–50. doi:10.3368/lj.27.1.41.

Figure 1.

Examples of 3D models of the exhibit hall created using Sketchup. Creating a 3D model of the exhibit hall was a valuable step in designing the organization of the exhibit. Figure A is a perspective within the hall that exhibited the triptychs. The triptychs color-coded with the image from 1937 in sepia, the images from the 1960s in black and white and the images of 2010 in color. Figure B is a perspective within the hall that exhibited the merged images. This perspective allows seeing some of the examples of the spirals and clocks that were designs as metaphors of time.

Figure 2. Visitors participating in the exhibit. (A) shows visitors interacting with the image overlays of 1960s black and white images, over color images of 2010. (B) presents a visitor with anaglyph glasses enjoying a color stereo image of 2010 obtained from an ADS-40 sensor.

Figure 3.

Polling results before and after visiting the exhibit. Results are presented as the percentage of responses for responders polled before entering the exhibit (in yellow) and after visiting the exhibit (in blue). Visitors were asked in Spanish (a) “When did Puerto Rico have the most forest cover?,” (b) “When was there a rapid increase in suburbs in Puerto Rico?,” (c) “When did Puerto Rico have the most agricultural cover?”