Multi-Criteria Evaluation and Geographic Information Systems for Land-Use Planning and Decision Making

Photo: Antonio González

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4 / EL PAÍS
EL NUEVO DIA / domingo, 3 de noviembre de 2002

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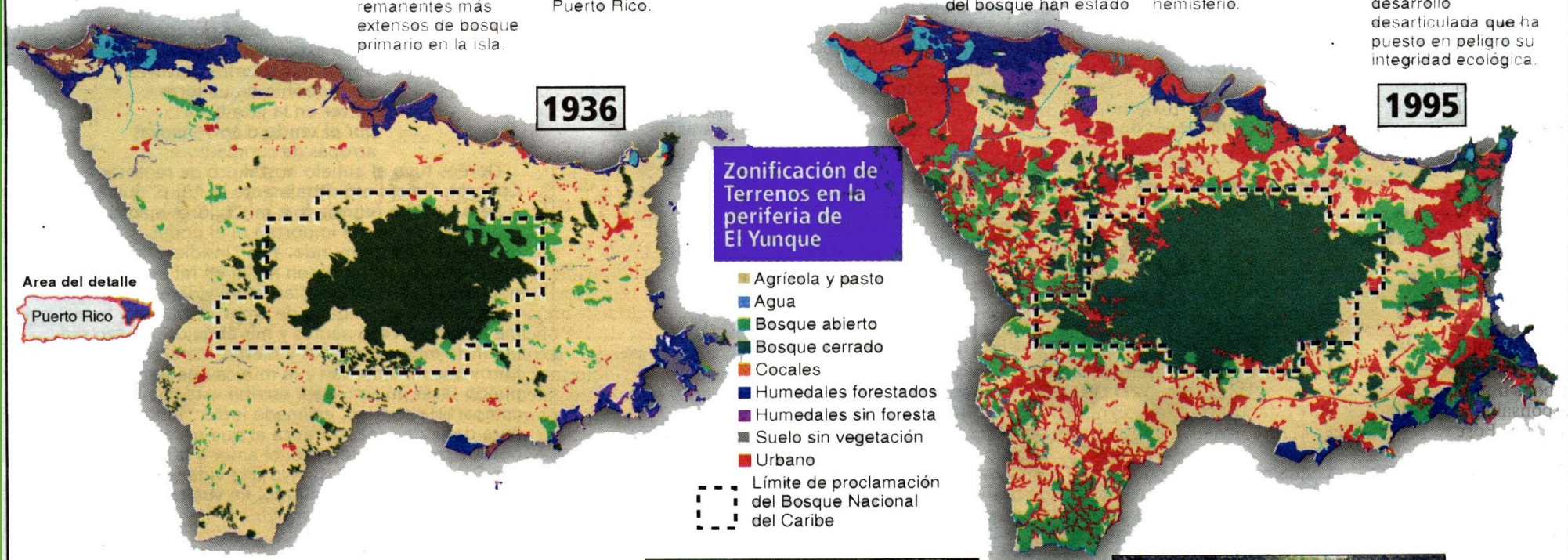
Amenaza voraz a un santuario

Acorralado El Yunque

Historia del área

Estas imágenes se basan en fotos aéreas tomadas entre 1936 y 1995. Las mismas revelan que la periferia de El Yunque era una zona agrícola con pocas áreas urbanas, pero poco a poco fue poblándose con desarrollos urbanos y comerciales a pesar de los reglamentos que se aprobaron para impedirlo.

- **EL BOSQUE DE EL YUNQUE** es la propiedad más grande de Puerto Rico que contiene los remanentes más extensos de bosque primario en la isla.
- **PROVEE 50 MILLONES** de galones diarios de agua para el 20% de la población de Puerto Rico.
- **ES UNA ATRACCIÓN TURÍSTICA** principal que seduce a turistas de todo el mundo.
- **FUE DESIGNADO POR** las Naciones Unidas como una Reserva Biosférica en 1976, aunque sectores del bosque han estado bajo protección oficial desde 1876. Esto hace de El Yunque una de las reservas naturales más antiguas del hemisferio.
- **DURANTE LOS ÚLTIMOS AÑOS**, la periferia de El Yunque ha estado sujeta a una presión de desarrollo desarticulada que ha puesto en peligro su integridad ecológica.



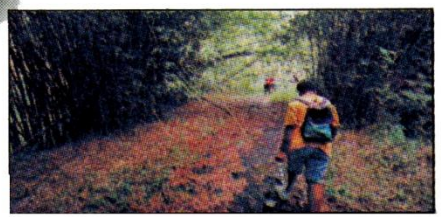
Zonificación de Terrenos en la periferia de El Yunque

- Agrícola y pasto
- Agua
- Bosque abierto
- Bosque cerrado
- Cocales
- Humedales forestados
- Humedales sin foresta
- Suelo sin vegetación
- Urbano
- Límite de proclamación del Bosque Nacional del Caribe

Consecuencias de la reducción de áreas verdes

- Se reduce la capacidad del hábitat para sostener especies de vida silvestre.

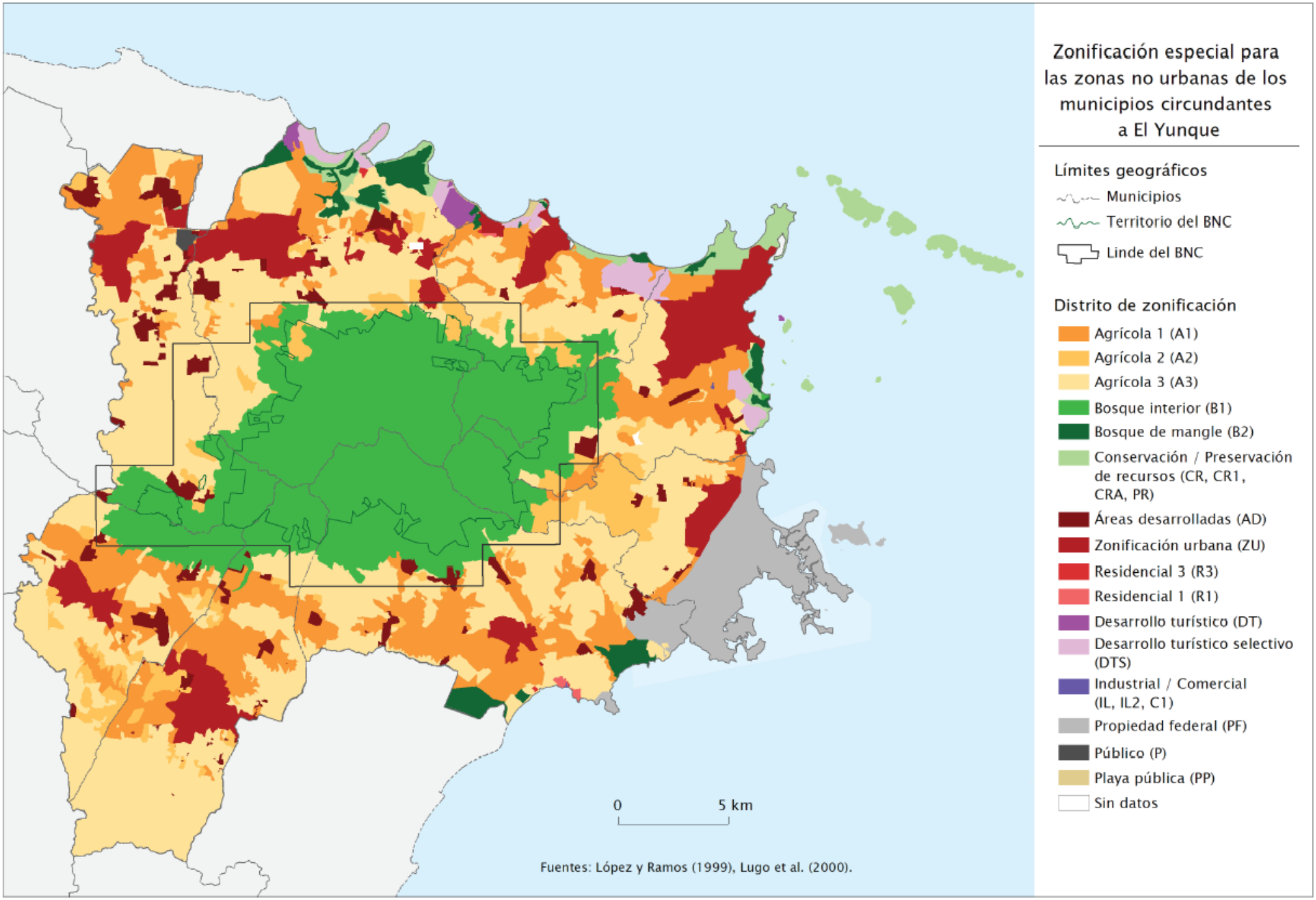
- Se reduce la cantidad de agua.



- Se fragmenta el hábitat de especies de flora y fauna.

El Nuevo Día / Evelio Cortés

Zoning plan (1983)



Urban land cover and zoning

United States
Department of
Agriculture

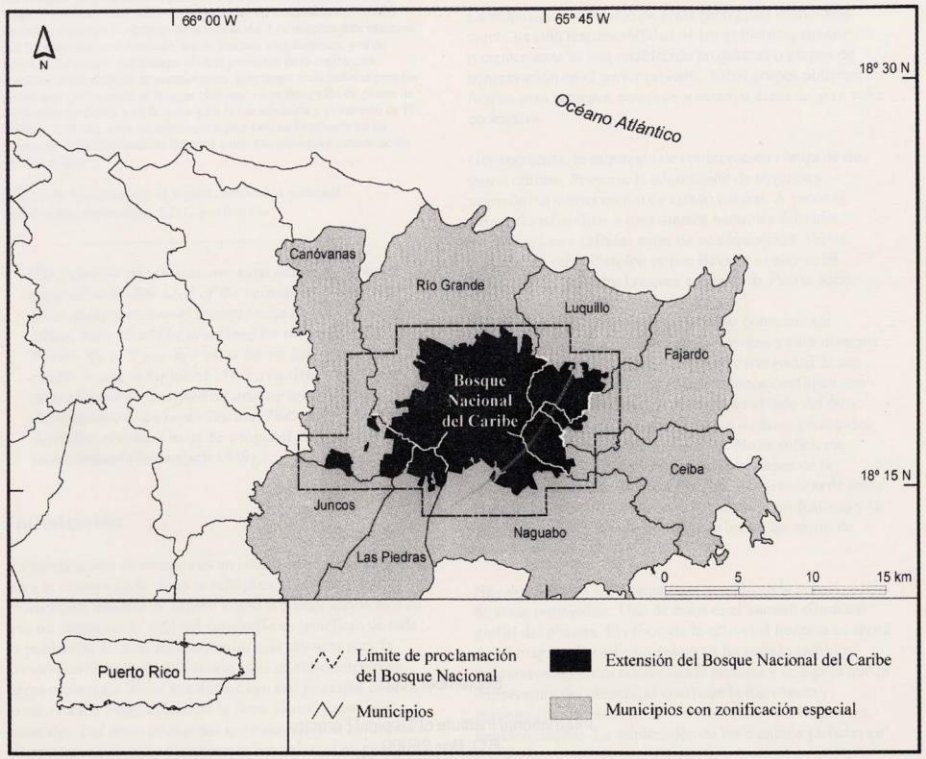
Forest Service

International Institute of Tropical Forestry

General Technical
Report IITF-16

Zonificación de Terrenos en la Periferia de El Yunque

Ariel E. Lugo, Tania del M. López y Olga M. Ramos



USDA

United States
Department of
Agriculture

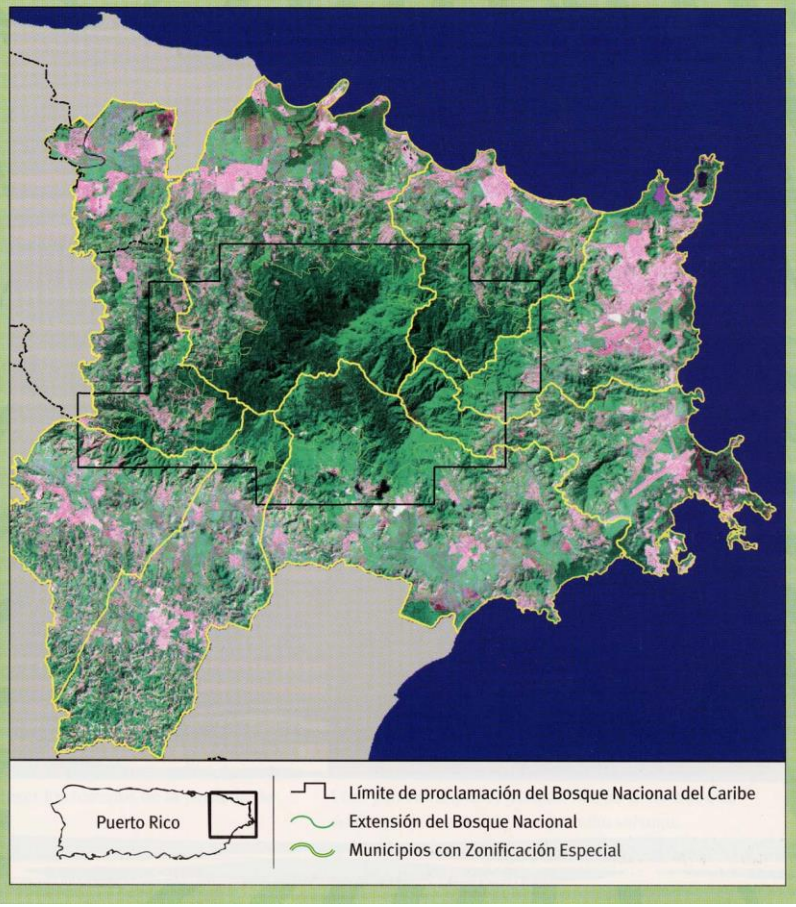
Forest
Service

diciembre 2004

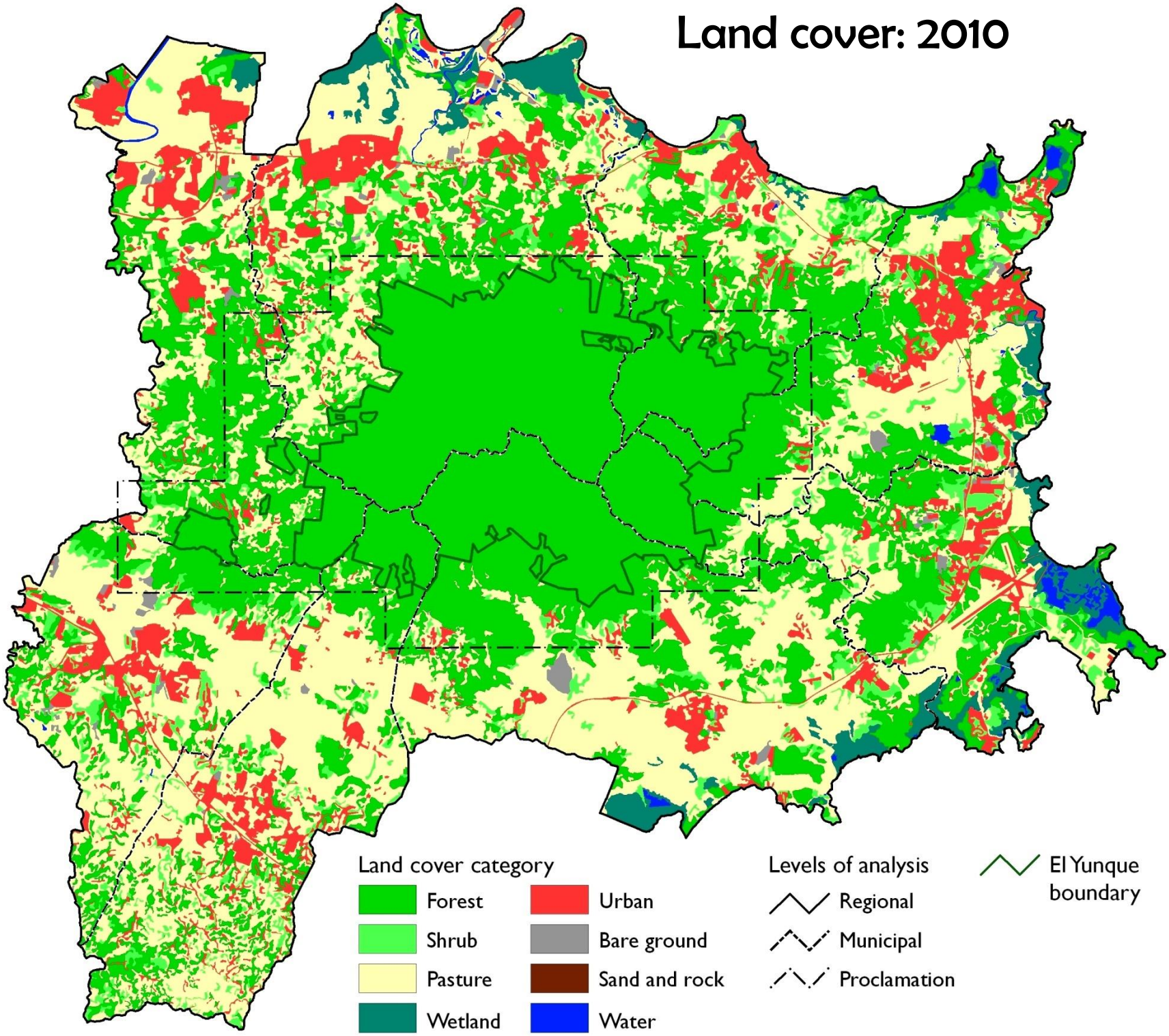
Gen. Tech.
Report WO-66

Urbanización de los terrenos en la periferia de El Yunque

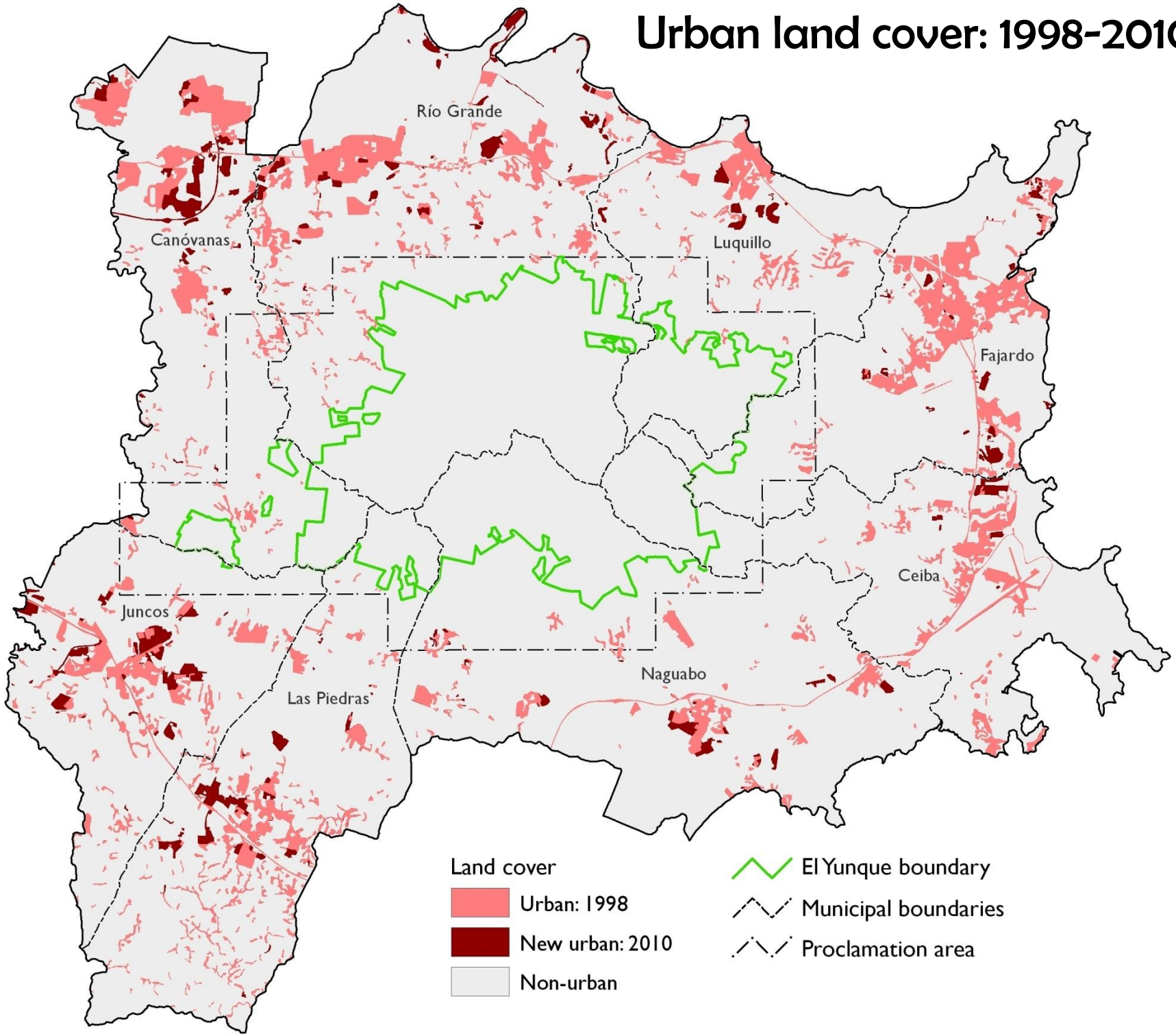
Ariel E. Lugo, Tania del M. López, Olga M. Ramos González y
Linda L. Vélez



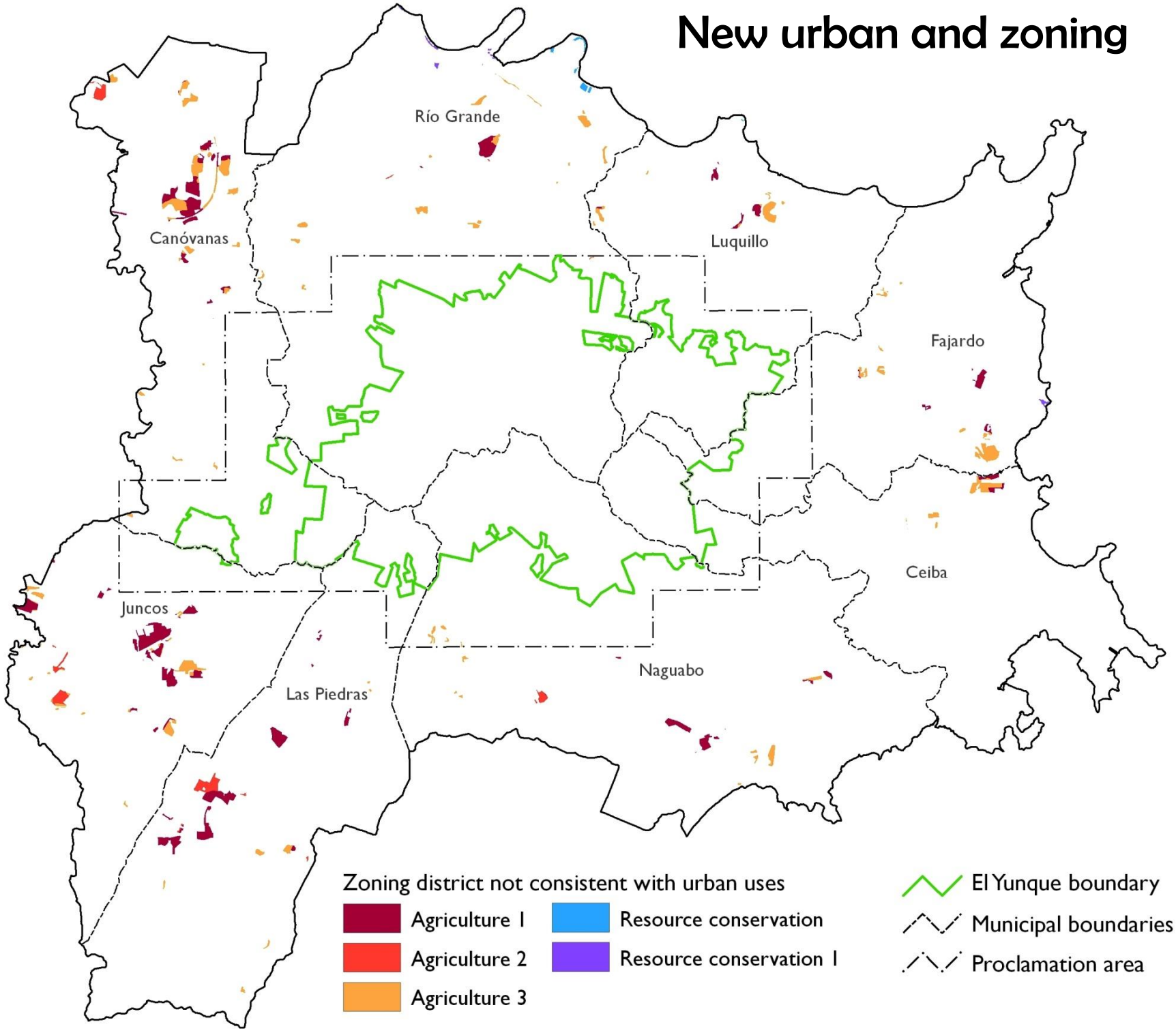
Land cover: 2010



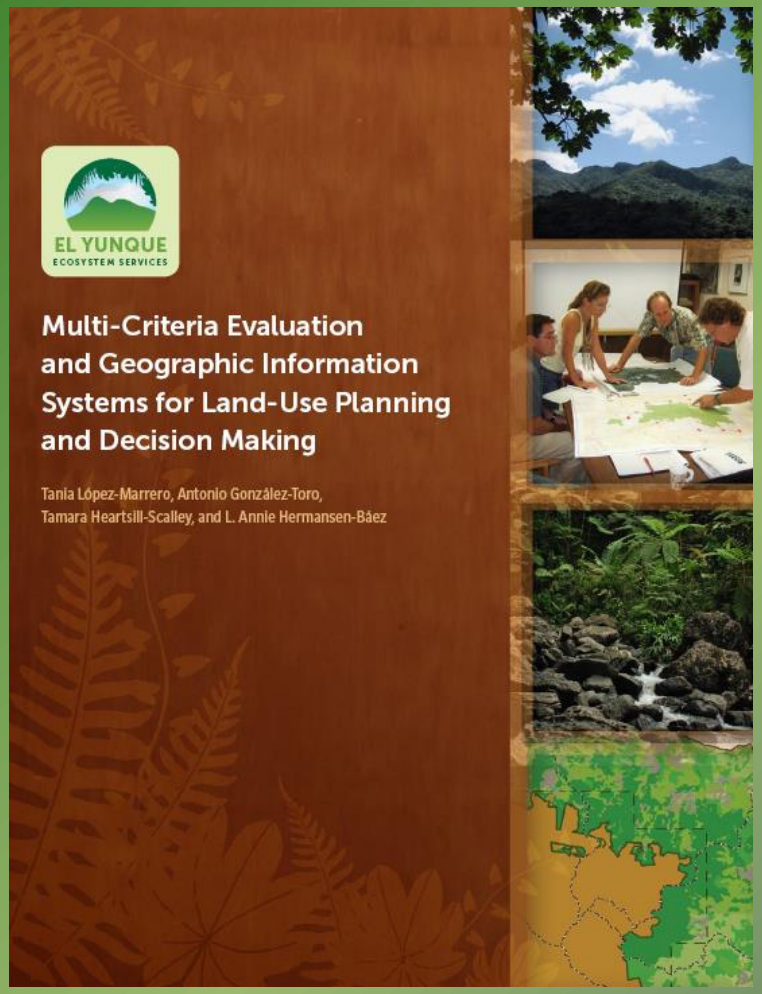
Urban land cover: 1998-2010



New urban and zoning



Multi-criteria evaluation and GIS for decision making



EL YUNQUE
ECOSYSTEM SERVICES

El Yunque Ecosystem Services: A Participatory Research Approach

Tania López-Marrero and L. Annie Hermansen-Báez

Introduction

Forest ecosystem services (benefits provided by forests to people and other living organisms) result from a variety of ecosystem processes and functions. Yet, the availability and the potential to provide these services do not depend on forest processes and functions alone. They also depend on policies, regulations, decisions, and actions people make regarding the use and management of forests and the services forests provide. Hence, any effort to promote conservation of ecosystem services and their wise use requires the integration of the different stakeholders that use and affect these services into the development and implementation of conservation strategies. Moreover, promoting the participation of stakeholders is especially important in locations where centralized, top-down approaches to resource conservation have not produced the expected results.

El Yunque National Forest, located in eastern Puerto Rico, provides a variety of ecosystem services—including clean air, water, and recreation—that are essential to the well-being of people in communities surrounding the forest and beyond (Figure 1). Rapid changes in urban and built-up areas in eastern Puerto Rico have put El Yunque under high pressure for urban development (Figure 2). These changes can alter forest processes and functions, and thus the services provided by the forest. Zoning regulations for guiding urban expansion and minimizing its effects on the forest have had limited success; much of the urban expansion during the past decades has occurred within zoning districts where urban uses were not originally planned. This limited success has resulted from poor enforcement of zoning regulations; it could also be a result of the implementation of top-down models of land use and resource management that often excludes people at different levels, such as local communities and other stakeholders.

Photo Credit: Antonio González Toro

Figure 1. El Yunque provides a variety of ecosystems services, such as clean water and recreation, that benefit surrounding communities.

Photo Credit: Tania López Marrero

Figure 2. Urban expansion is considered one of the main factors affecting El Yunque National Forest and the services that it provides.

To begin to address these issues, we developed a study that incorporated the views and perspectives of different stakeholders regarding the ecosystem services provided by El Yunque. We developed a methodology that integrates different research methods and participatory techniques. The techniques can help natural resource managers, specialists, and researchers of other national and state forests better understand people's knowledge and awareness of ecosystem services and the factors affecting these services. The techniques and the products resulting from them can be used to assist in the management and planning of land use, ecosystem services, and natural resources in general.

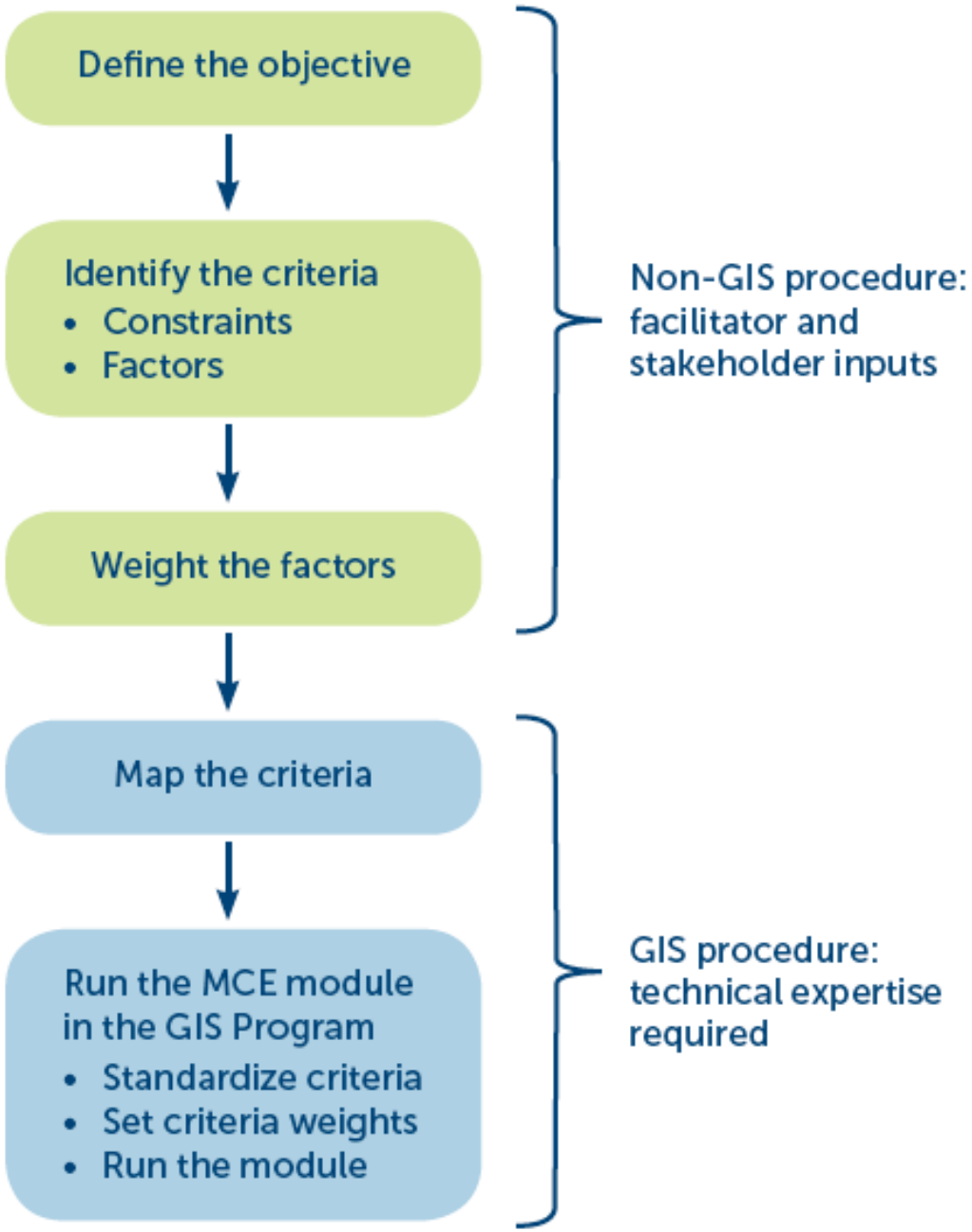
Multi-criteria evaluation analysis (MCEA) - the implementation of decision-making rules to identify and enable the combination of many criteria, in the form of GIS layers, into a single map - and **Geographic Information Systems** are two examples of tools that aid in the development of geographic data and maps for different purposes.

We used MCE analysis and GIS tools to develop a map that shows areas in which protection against urban expansion would help to ensure the continued provision of the El Yunque's ecosystem services.

Ecosystem services are the benefits that the functions of ecosystems provide to people and other organisms. These services have been classified into four groups of benefits: provisioning, regulating, socio-cultural, and supporting.

- **Provisioning services** are the products and goods produced by ecosystems and obtained directly from them. These are the most tangible benefits derived from ecosystems.
- **Regulating services** are the benefits obtained through the natural regulation of ecosystem processes.
- **Socio-cultural services** are the benefits to human well-being that are received from ecosystems. Most of these benefits are non-material and sometimes they are intangible.
- **Supporting services** are the ecosystem processes that are necessary for the production and delivery of all other ecosystem services. Their benefits are indirect and play out through the capacity of ecosystems to supply all other services.

Generalized procedure for conducting a MCEA using GIS



Step 1: Define the objective of the analysis

Project's objective:
Identify lands wherein protection from urban expansion would help to ensure the continued provision of El Yunque's ecosystem services.

Step 2: Identify the criteria

- Constraints are criteria that exclude areas from the analysis.

- Factors are criteria that influence (enhance or detract) the viability of the objective under consideration.

Project's constraints:
Areas that were already covered by built-up land, and areas that have a formal conservation status or designation,

Identifying the factors...

Pair-wise matrix comparison

Step 3: Weight the factors

Box 1. Factors, their relative importances, and scores

FACTOR	D RIVER	D EYNF	FOREST	NE QUAD	LAND CONN	WETLAND	SCORE
D RIVER		D River	D River	D River	D River	Wetland	4
D EYNF			D EYNF	NE Quad	D EYNF	D EYNF	3
FOREST				NE Quad	Land Conn	Forest	1
NE QUAD					Land Conn	NE Quad	3
LAND CONN						Land Conn	3
WETLAND							1

Six final factors:

- Distance from rivers
- Distance from El Yunque's boundary
- Forest land cover
- Northeastern portion of the study area
- Landscape connectivity
- Wetland land cover

Box 2. Factors and their weights

FACTOR	WEIGHT
Distance from rivers	0.2667
Distance from El Yunque	0.2000
Forest land cover	0.0667
Northeast quadrant	0.2000
Landscape connectivity	0.2000
Wetland cover	0.0667
Total	**1.00**

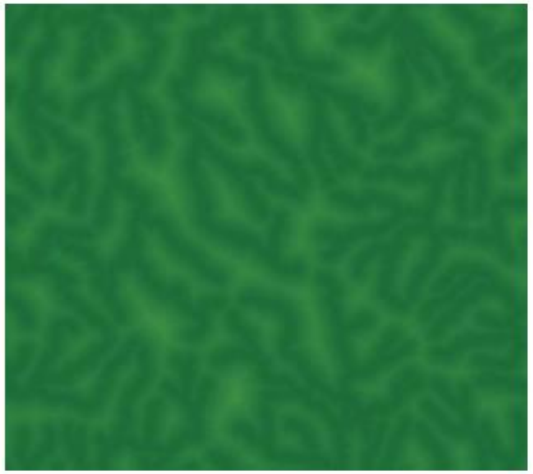
Step 4: Map the criteria

- A GIS layer was generated for each criterion: constraint and factors

- Layers were either continuous or categorical:

Constraint: Categorical layer

- Built-up + protected areas



Factors: Continuous layers

- Distance from rivers
- Distance from El Yunque's boundary
- Landscape connectivity

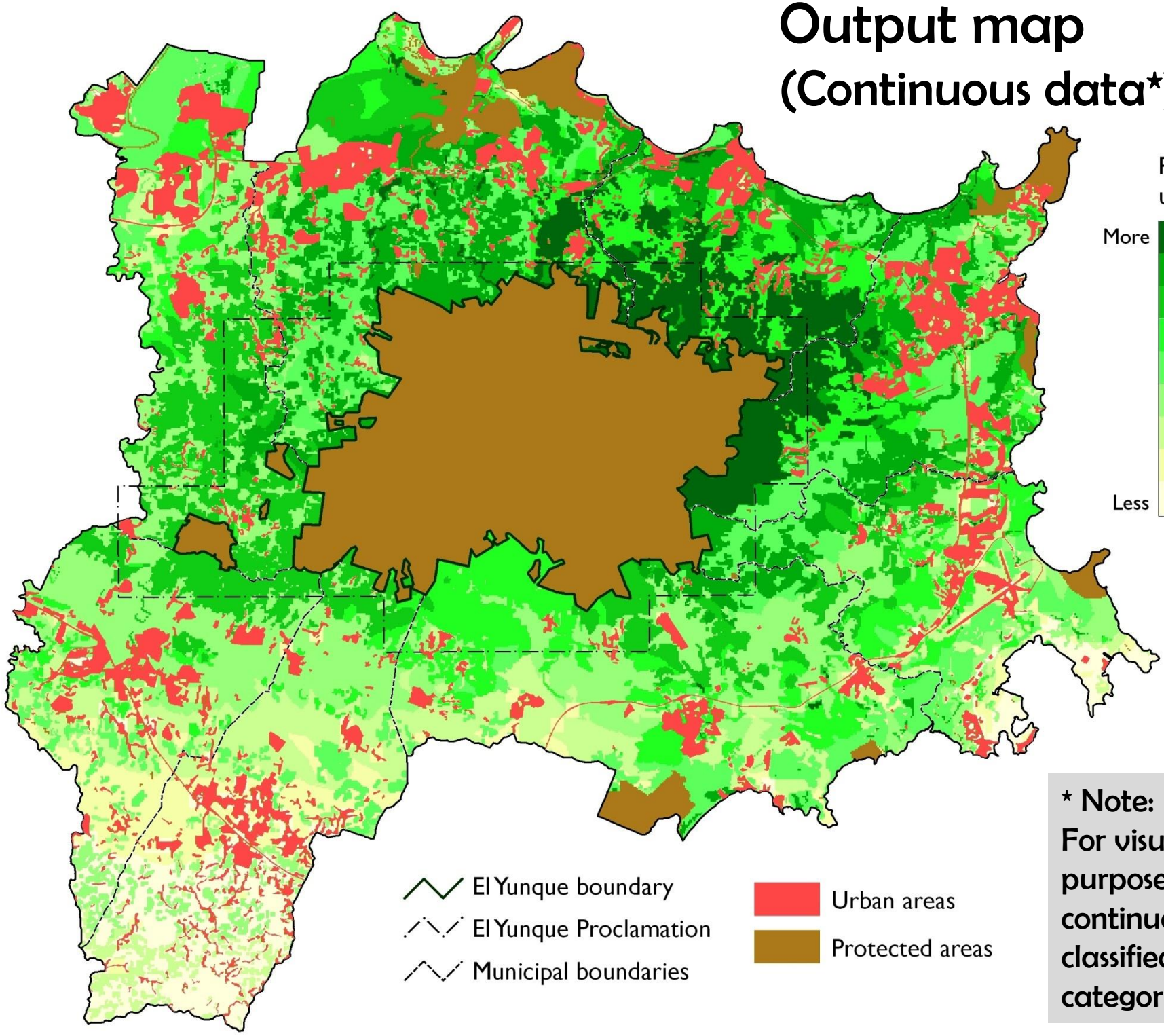
Factors: Categorical layers

- Forest land cover
- Northeastern portion of the study area
- Wetland land cover

Step 5: Run the MCE module in the GIS Program, in this case using IDRISI

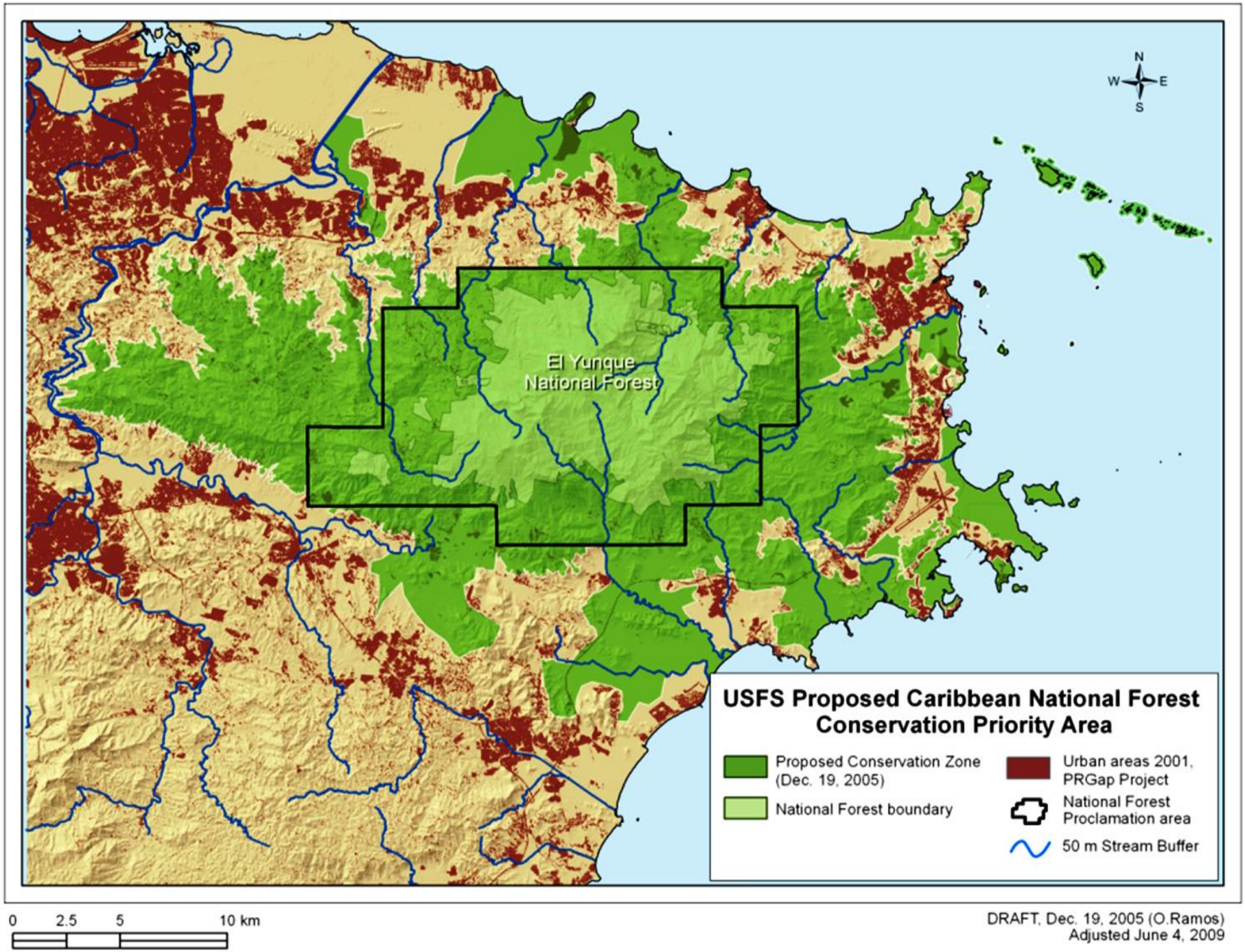
- Steps carried out using the Decision Support Wizard:
  - Specify the objective (enter a file name)
  - Indicate the file names for the GIS layers representing the constraint and factors
    *Establish factor's relationship with objective
  - Each factor is standardized (scale 0 – 255)
  - Enter the weights already calculated
  - Run the MCE module to create the final map by following the wizard.

Output map (Continuous data*)



*** Note:**
For visualization purposes, the continuous data were classified into nine categories.

Related analysis: Categorical/binary map output…

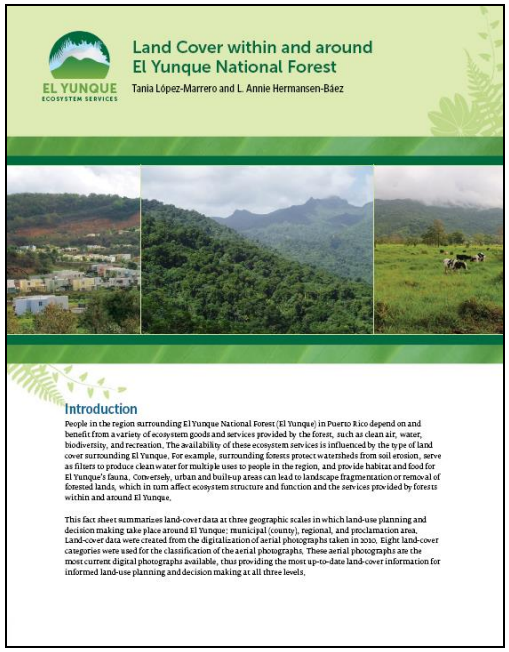


Multi-criteria evaluation and GIS for decision making
Potential applications and further analyses, next steps...

Thank you!

Acknowledgements:
Annie Hermansen-Báez and Tamara Heartsill-Scalley

El Yunque Ecosystem Services Project: Fact sheets and Guides



EL YUNQUE ECOSYSTEM SERVICES

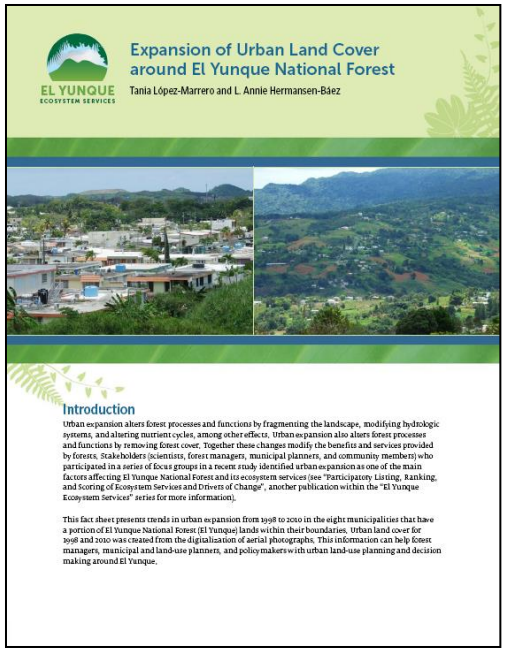
Land Cover within and around El Yunque National Forest

Tania López-Marrero and L. Annie Hermansen-Báez

Introduction

People in the region surrounding El Yunque National Forest (El Yunque) in Puerto Rico depend on and benefit from a variety of ecosystem goods and services provided by the forest, such as clean air, water, biodiversity, and recreation. The availability of these ecosystem services is influenced by the type of land cover surrounding El Yunque. For example, surrounding forests protect watersheds from soil erosion, serve as filters to produce clean water for multiple uses to people in the region, and provide habitat and food for El Yunque's fauna. Conversely, urban and built-up areas can lead to landscape fragmentation or removal of forested lands, which in turn affect ecosystem structure and function and the services provided by forests within and around El Yunque.

This fact sheet summarizes land-cover data at three geographic scales in which land-use planning and decision making take place around El Yunque: municipal (county), regional, and proclamation area. Land-cover data were created from the digitalization of aerial photographs taken in 2010. Eight land-cover categories were used for the classification of the aerial photographs. These aerial photographs are the most current digital photographs available, thus providing the most up-to-date land-cover information for informed land-use planning and decision making at all three levels.



EL YUNQUE ECOSYSTEM SERVICES

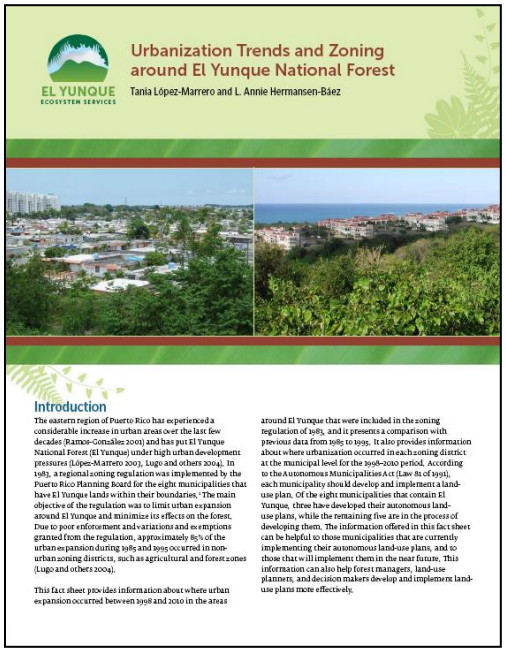
Expansion of Urban Land Cover around El Yunque National Forest

Tania López-Marrero and L. Annie Hermansen-Báez

Introduction

Urban expansion alters forest processes and functions by fragmenting the landscape, modifying hydrologic systems, and altering nutrient cycles, among other effects. Urban expansion also alters forest processes and functions by removing forest cover. Together these changes modify the benefits and services provided by forests. Stakeholders (scientists, forest managers, municipal planners, and community members) who participated in a series of focus groups in a recent study identified urban expansion as one of the main factors affecting El Yunque National Forest and its ecosystem services (see "Participatory Listing, Ranking, and Scoring of Ecosystem Services and Drivers of Change", another publication within the "El Yunque Ecosystem Services" series for more information).

This fact sheet presents trends in urban expansion from 1998 to 2010 in the eight municipalities that have a portion of El Yunque National Forest (El Yunque) lands within their boundaries. Urban land cover for 1998 and 2010 was created from the digitalization of aerial photographs. This information can help forest managers, municipal and land-use planners, and policymakers with urban land-use planning and decision making around El Yunque.



EL YUNQUE ECOSYSTEM SERVICES

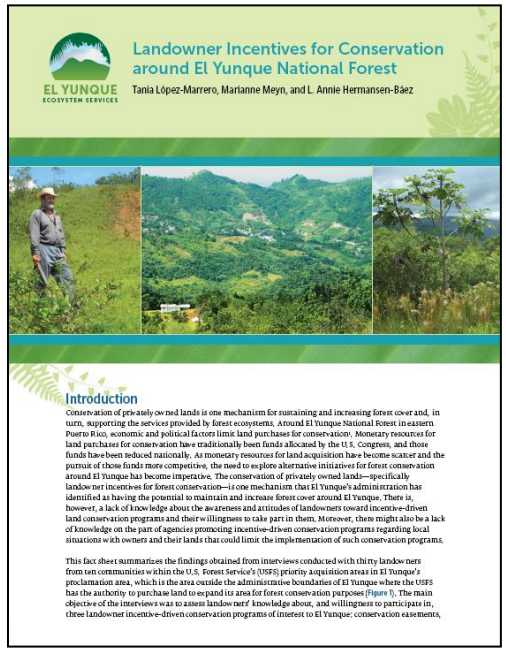
Urbanization Trends and Zoning around El Yunque National Forest

Tania López-Marrero and L. Annie Hermansen-Báez

Introduction

The eastern region of Puerto Rico has experienced a considerable increase in urban areas over the last few decades (Ramos-González 2003) and has put El Yunque National Forest (El Yunque) under high urban development pressures (López-Marrero 2003, Lugo and others 2004). In 1983, a regional zoning regulation was implemented by the Puerto Rico Planning Board for the eight municipalities that have El Yunque lands within their boundaries.[1] The main objective of the regulation was to limit urban expansion around El Yunque and minimize its effects on the forest. Due to poor enforcement and variations and exemptions granted from the regulation, approximately 85% of the urban expansion during 1985 and 1995 occurred in non-urban zoning districts, such as agricultural and forest zones (Lugo and others 2004).

This fact sheet provides information about where urban expansion occurred between 1998 and 2010 in the areas around El Yunque that were included in the zoning regulation of 1983, and it presents a comparison with previous data from 1985 to 1995. It also provides information about where urbanization occurred in each zoning district at the municipal level for the 1998–2010 period. According to the Autonomous Municipalities Act (Law 81 of 1991), each municipality should develop and implement a land-use plan. Of the eight municipalities that contain El Yunque, three have developed their autonomous land-use plans, while the remaining five are in the process of developing them. The information offered in this fact sheet can be helpful to those municipalities that are currently implementing their autonomous land-use plans, and to those that will implement them in the near future. This information can also help forest managers, land-use planners, and decision makers develop and implement land-use plans more effectively.



EL YUNQUE ECOSYSTEM SERVICES

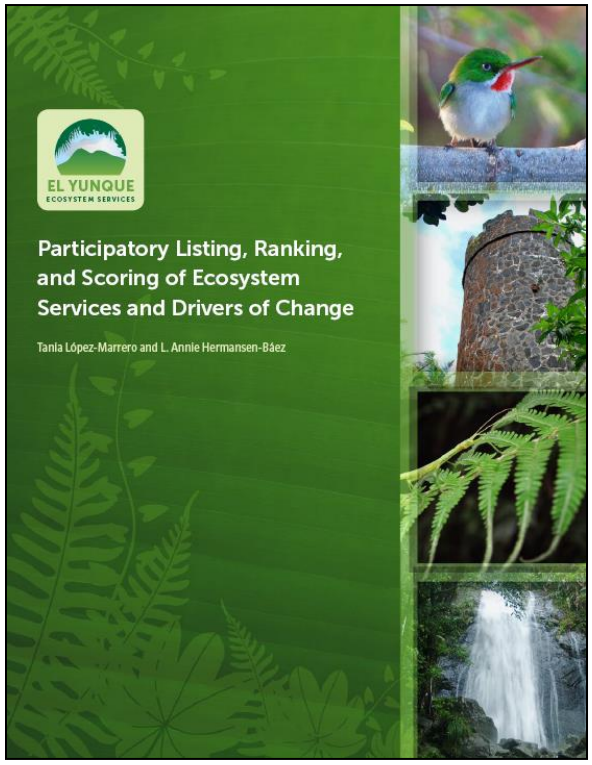
Landowner Incentives for Conservation around El Yunque National Forest

Tania López-Marrero, Marianne Meyn, and L. Annie Hermansen-Báez

Introduction

Conservation of privately owned lands is one mechanism for sustaining and increasing forest cover and, in turn, supporting the services provided by forest ecosystems. Around El Yunque National Forest in eastern Puerto Rico, economic and political factors limit land purchases for conservation.[1] Monetary resources for land purchases for conservation have traditionally been funds allocated by the U.S. Congress, and those funds have been reduced nationally. As monetary resources for land acquisition have become scarcer and the pursuit of those funds more competitive, the need to explore alternative initiatives for forest conservation around El Yunque has become imperative. The conservation of privately owned lands—specifically landowner incentives for forest conservation—is one mechanism that El Yunque's administration has identified as having the potential to maintain and increase forest cover around El Yunque. There is, however, a lack of knowledge about the awareness and attitudes of landowners toward incentive-driven land conservation programs and their willingness to take part in them. Moreover, there might also be a lack of knowledge on the part of agencies promoting incentive-driven conservation programs regarding local situations with owners and their lands that could limit the implementation of such conservation programs.

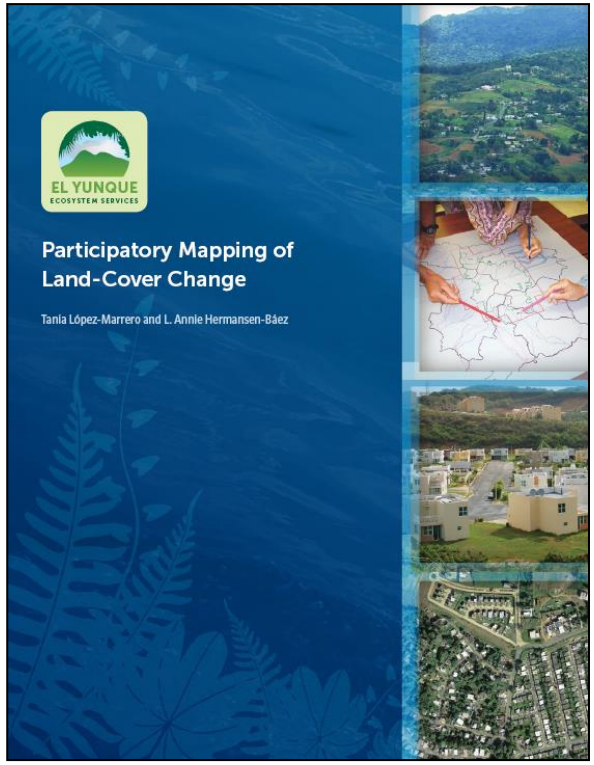
This fact sheet summarizes the findings obtained from interviews conducted with thirty landowners from ten communities within the U.S. Forest Service's (USFS) priority acquisition areas in El Yunque's proclamation area, which is the area outside the administrative boundaries of El Yunque where the USFS has the authority to purchase land to expand its area for forest conservation purposes (Figure 1). The main objective of the interviews was to assess landowners' knowledge about, and willingness to participate in, three landowner incentive-driven conservation programs of interest to El Yunque: conservation easements,



EL YUNQUE ECOSYSTEM SERVICES

Participatory Listing, Ranking, and Scoring of Ecosystem Services and Drivers of Change

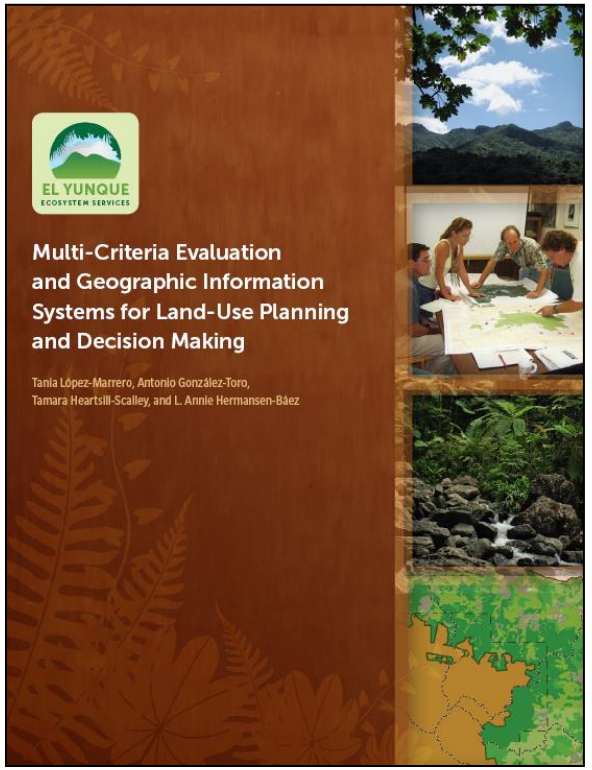
Tania López-Marrero and L. Annie Hermansen-Báez



EL YUNQUE ECOSYSTEM SERVICES

Participatory Mapping of Land-Cover Change

Tania López-Marrero and L. Annie Hermansen-Báez



EL YUNQUE ECOSYSTEM SERVICES

Multi-Criteria Evaluation and Geographic Information Systems for Land-Use Planning and Decision Making

Tania López-Marrero, Antonio González-Toro, Tamara Heartsill-Scalley, and L. Annie Hermansen-Báez

To learn more about the project:

IntersaceSouth, USDA Forest Service

http://www.interfacesouth.org/projects/ el-yunque

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