SUSTENTABILIDAD PARA EL USO DEL SUELO EN PUERTO RICO

RESUMEN EJECUTIVO

Centro de Estudios para el Desarrollo Sustentable
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EQUIPO DE TRABAJO

Desarrollo del Modelo de Sustentabilidad

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El **Informe Final** con detalles de la metodología, los resultados y las recomendaciones está accesible en nuestra página electrónica de proyectos en línea: **www.proyectosambientales.info.**

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PUERTO RICO: UN RETO PARA LA SUSTENTABILIDAD

Puerto Rico enfrenta numerosos retos para lograr un desarrollo sustentable en la planificación del uso de su suelo. Por ser una pequeña isla caribeña, su escasa tierra constituye uno de sus recursos más valiosos. Sin embargo, un historial de ineficiencia en el manejo de su suelo ha traído como consecuencia toda una serie de retos ambientales, sociales y económicos a tal grado que, si las prácticas actuales continúan al mismo ritmo que en las últimas cinco décadas, el archipiélago puertorriqueño se convertirá en una megápolis suburbana en menos de 75 años, el tiempo de vida de una generación. Con una densidad poblacional de cerca de 450 habitantes por kilómetro cuadrado, una de las más altas en el mundo, a Puerto Rico le queda poco espacio y tiempo. La Isla también tiene su superficie territorial dividida en 78 municipios. Actualmente, todos los municipios están autorizados a preparar planes de ordenación territorial en sus respectivas jurisdicciones por virtud de la Ley de Municipios Autónomos de 1991 (Ley Núm. 81 del 30 de agosto de 1991). No obstante, todos carecen de un marco amplio y comprehensivo que guíe el desarrollo sustentable en el uso de su suelo. Aunque se han adoptado numerosas leyes y reglamentos para dirigir el uso del suelo en los pasados sesenta años, la secuencia de sus adopciones y su posterior implantación inefectiva han dejado al país sin un plan de uso de terrenos para todo el archipiélago puertorriqueño.

OBJETIVO DEL PROYECTO

El uso del suelo es medular para un desarrollo sustentable. El objetivo de este proyecto es proveer una serie de indicadores y un índice que en su conjunto constituyan un modelo accesible, de fácil entendimiento y manejo, y que se apoye en la mejor información disponible para conseguir la sustentabilidad en el uso del suelo. Esta información, a su vez, debe garantizar la aplicación del modelo en cada uno de los municipios de Puerto Rico. También, intentamos medir y verificar el impacto que los cambios en el uso del suelo tienen en su desarrollo sustentable a largo plazo.

METODOLOGÍA

Para alcanzar el objetivo propuesto, luego de revisar documentación pertinente al tema, este proyecto propone el Modelo para un Alcance Óptimo (o Modelo de Sustentabilidad) con el fin de conseguir la sustentabilidad en el uso del suelo. Este modelo permite identificar actividades que afectan a los municipios y las cuales deben modificarse si se quiere encauzar el uso del territorio municipal hacia el alcance de la sustentabilidad.

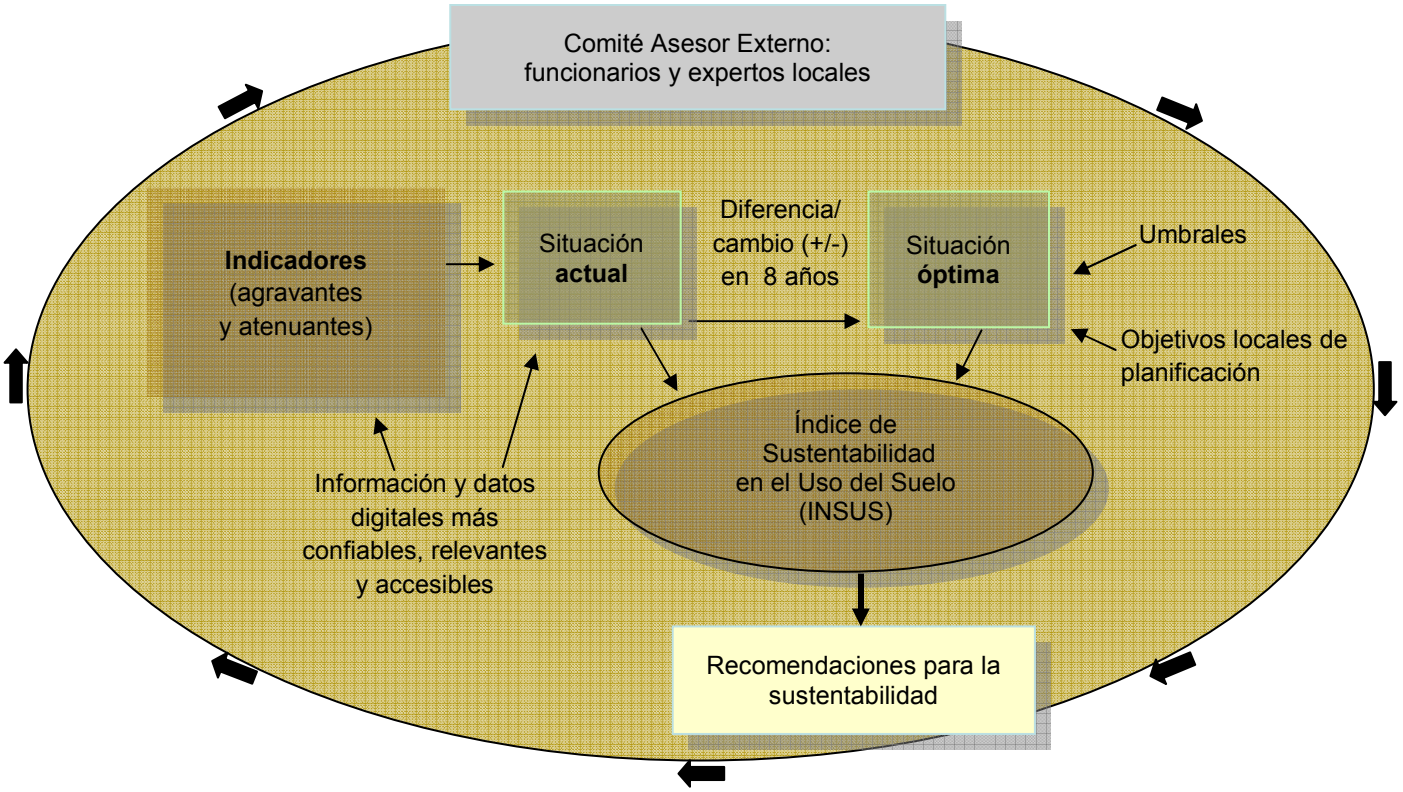

Figura 1. Modelo de Sustentabilidad

El Modelo define los indicadores como agravantes o atenuantes [1] del desarrollo sustentable. Mediante ellos brindamos información sobre la situación actual, pero también brindamos una situación óptima de modo que podamos medir el progreso o el retroceso habido con relación a la sustentabilidad, usando para ello umbrales específicos u objetivos de planificación. [2] Además, se le asigna a cada indicador un peso relativo en cada una de sus categorías para luego calcular un índice que comunique de manera sencilla y resumida el estatus de la sustentabilidad: desde una sustentabilidad muy baja hasta una sustentabilidad muy alta; y para medir el progreso alcanzado.

Un Comité Asesor Externo, compuesto por funcionarios y expertos locales, (tanto del sector público como del privado), fue parte integral del Modelo para tomar las decisiones fundamentales.

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1 Los indicadores agravantes se definen como factores que reducen la sustentabilidad y los indicadores atenuantes son aquellos que mejoran la sustentabilidad.

2 Como umbrales, el proyecto adoptó objetivos de política pública locales, internacionales o científicamente aceptados. Cuando no hubo umbrales, el proyecto adoptó objetivos de planificación para Puerto Rico, propuestos y acordados en consenso por funcionarios y expertos locales del Comité Asesor Externo del proyecto.

El período de evaluación propuesto es de ocho años, dado que los planes de ordenación territorial deben de ser revisados por lo menos cada ocho años, según establece la Ley Núm. 81 de 1991.

Se utilizaron cuatro municipios como casos de estudio porque representaban diferentes escenarios socioeconómicos y geográficos: Barceloneta, Caguas, Carolina y Ponce.

Luego de seleccionar los indicadores y aplicarles a cada uno de ellos los umbrales o los objetivos de planificación, así como los pesos relativos, se calculó el Índice de Sustentabilidad en el Uso del Suelo **(INSUS)**, que es un índice compuesto. Los indicadores agravantes (n) son indexados y agregados al Índice Agravante **(IA)** de la siguiente manera:

$$IA = X_1^{\alpha} X_2^{\beta} X_3^{\gamma} \ldots X_n^{\zeta}$$

Los indicadores atenuantes (m) fueron entonces indexados y agregados al Índice Propiciador **(IP)** de la siguiente manera:

$$IP = Y_1^{\alpha} Y_2^{\beta} Y_3^{\gamma} \ldots Y_m^{\zeta}$$

Ambos índices se combinaron luego en uno solo, para medir la sustentabilidad:

$$INSUS = \sqrt{\frac{IP}{IA} x 100}$$

La multiplicación por 100, así como la raíz cuadrada, no son sino transformaciones matemáticas diseñadas para generarle al INSUS una escala fácil de leer. El INSUS puede asumir valores que pueden ir desde 1 hasta 100. Un valor de 100 representa el mejor escenario, mientras que un valor de 1 representa el peor. Un valor de 10 se registra cuando el IA y el IP ostentan los mismos valores, en cuya situación se cancelan mutuamente. Cuando los valores son por debajo de 10, el IA es mayor al IP y el INSUS es dominado por los factores agravantes. Cuando los valores son mayores de 10, el INSUS es dominado por factores atenuantes o propiciadores de la sustentabilidad. Una lectura de 10 implica un empate de los factores agravantes y atenuantes y marcaría el comienzo de un umbral para la sustentabilidad.

El siguiente diagrama presenta la interpretación del INSUS. La Tabla 3 contiene los resultados finales.

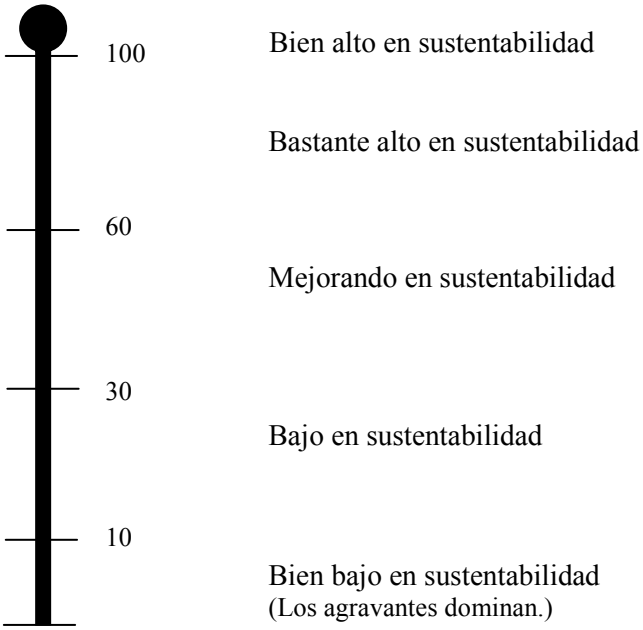

Figura 2. Valores del INSUS

RESULTADOS

Inicialmente, se identificaron más de 50 indicadores. Tras una evaluación exhaustiva, se propuso un grupo de 22 indicadores. El Comité Asesor Externo los seleccionó por consenso, a base de criterios específicos de control de calidad: confiabilidad y disponibilidad de los datos (la mejor información disponible), si estos podían ser objeto de medición a través del tiempo y si estaban accesibles a los municipios. Luego de su selección, los indicadores se dividieron en cuatro categorías: ambientales, socioeconómicos, infraestructurales e institucionales. La **Tabla 1** (próxima página) demuestra los resultados de este proceso de evaluación.

La decisión del nombre y de la categoría de cada indicador seleccionado se basó en:

- La naturaleza sustantiva y el propósito de cada indicador.
- El umbral u objetivo de planificación asignado a cada indicador para demostrar el progreso o retroceso hacia la sustentabilidad a base de las idiosincrasias, retos y necesidades locales, y las personas responsables de su ejecución.
- La estrategia de comunicación del indicador para incitar la atención de la audiencia deseada y los gestores de política pública.

Tabla 1. Indicadores y Categorías de Indicadores para la Sustentabilidad en el Uso del Suelo

Ambientales
1. Riesgo de contaminación de los cuerpos de agua por falta de conexión al sistema de alcantarillado sanitario
2. Presión de desarrollo sobre el suelo rural
3. Accesibilidad a espacios naturales públicos en áreas urbanas
4. Generación, por residente, de desperdicios sólidos no peligrosos
5. Total de desperdicios sólidos no peligrosos reciclados
6. Riesgo de inundaciones costeras
7. Emisiones de CO^2 por hogar
8. Emisiones de sustancias tóxicas al ambiente por parte de las industrias
9. Consumo de agua por hogar
Socioeconómicos
10. Suelo de alto valor agrícola
11. Suelo en uso agrícola
12. Residentes que trabajan donde viven
13. Repoblamiento de las áreas urbanas
14. Residentes que viven en los cauces de inundación
15. Índice Socioeconómico
Infraestructurales
16. Inaccesibilidad a la transportación pública
17. Uso de la transportación pública para llegar al trabajo
18. Huella de la red vial
19. Inaccesibilidad a agua potable
Institucionales
20. Plan de Ordenación Territorial aprobado
21. Índice de Fragilidad Fiscal
22. Suelo oficialmente protegido

Tabla 2. Resultados por Indicador

		PONCE	CAGUAS	BARCELONETA	CAROLINA	UMBRAL U OBJETIVO DE PLANIFICACIÓN EN 8 AÑOS	AGRAVANTE O PROPICIADOR	PESO RELATIVO ASIGNADO
AMBIENTALES		**Situación Actual**				**Situación Óptima**		
1	**Riesgo de contaminación de los cuerpos de agua por falta de conexión al sistema de alcantarillado sanitario** Por ciento (%) de unidades de vivienda sin conexión al sistema de la AAA del total de unidades.	34.0%	30.0%	46.0%	25.0%	Reducir un 5.5%	A	0.5
2	**Presión de desarrollo sobre el suelo rural** Densidad de unidades de vivienda en Suelo Rústico Común por km^2.	50	132	299	131	Que no aumente	A	1.3
3	**Accesibilidad a espacios naturales públicos en áreas urbanas** Por ciento (%) de residentes en áreas urbanas a una distancia de 15 minutos caminando (500 metros) de un parque u otro espacio público abierto y natural, del total de residentes urbanos.	89.0%	73.0%	72.0%	89.0%	Que todos los residentes urbanos tengan accesibilidad	P	1.5
4	**Generación por residente de desperdicios sólidos no peligrosos** Generación en libras por residente por día del total que se genera.	7.51	6.66	10.63	4.85	3.6 libras máx. / persona / día	A	0.6
5	**Total de desperdicios sólidos no peligrosos reciclados** Por ciento (%) que se recicla del total que se genera anualmente.	2.3%	3.2%	0.8%	6.8%	Un mínimo de 35%	P	3.9
6	**Riesgo de inundaciones costeras** Cantidad de unidades de vivienda que pueden ser afectadas en la Zona VE, según los mapas de FEMA.	53	N/A	54	968	Cero unidades de vivienda	A	0.5
7	**Emisiones de CO^2 por hogar** Emisiones anuales de CO^2 en libras por Kwh de consumo anual de electricidad por hogar.	8,327	11,416	8,326	10,522	Reducir un 16%	A	0.4
8	**Descargas de substancias tóxicas al ambiente por parte de las industrias** Descarga anual en el lugar, de substancias tóxicas en libras por km^2, de las industrias reguladas por la ley federal EPCRA.	258	5	5,514	720	Que no aumente	A	0.7
9	**Consumo de agua por hogar** Consumo en galones por día por hogar de los clientes de la AAA.	142	164	182	143	Reducir un 27%	A	0.6
								10
SOCIOECONÓMICOS								
10	**Suelo de alto valor agrícola** Por ciento (%) del total del Suelo Rústico.	5.8%	19.9%	61.0%	32.6%	Que no cambie	P	1.6
11	**Suelo en uso agrícola** Por ciento (%) del total del Suelo Rústico.	41.7%	21.0%	28.0%	30.3%	Que no cambie	P	1.0
12	**Residentes que trabajan donde viven** Por ciento (%) del total de residentes trabajadores que laboran en el mismo municipio.	86.4%	56.1%	56.2%	41.8%	Que al menos un 60% de los residentes laboren en su municipio	P	1.9
13	**Repoblamiento de las áreas urbanas** Densidad de población (personas por km^2) en Suelo Urbano.	1,396	2,513	646	3,529	Aumentar un 11%	P	2.2
14	**Residentes que viven en los cauces de inundación** Total de residentes expuestos a los riesgos de inundación en la zona identificada como AE Floodway por FEMA.	3,236	3,839	669	1,410	Cero residentes	A	0.9
15	**Índice Socioeconómico** Índice de la actividad socioeconómica en el municipio.	95.80	109.15	82.78	132.55	100	P	2.4
								10

	INFRAESTRUCTURALES							
16	**Inaccesibilidad a la transportación pública** Del total de barrios, por ciento (%) que no son servidos, por lo menos, por una ruta de transporte público al centro urbano.	55%	9%	0%	23%	100% (que todos los barrios sean servidos)	A	5.8
17	**Uso de la transportación pública para llegar al trabajo** Cambio en puntos porcentuales en el uso del transporte público para llegar al trabajo de la cantidad de residentes trabajadores que han estado usando este medio en la última década.	-4.9%	-7.0%	-7.4%	-3.8%	Que aumente 6 puntos porcentuales	P	1.1
18	**Huella de la red vial** Kilómetros de carreteras por km^2 del total del territorio municipal.	4.36	5.18	4.6	6.11	Que no aumente	A	1.5
19	**Inaccesibilidad a agua potable** Total de residentes, clientes o no clientes de la AAA, que son servidos por sistemas de agua potable que no cumplen de forma significativa con la reglamentación federal sobre calidad del agua potable.	2,865	649	0	0	Cero residentes o cero sistemas que no cumplen de manera significativa	A	1.6
								10
	INSTITUCIONALES							
20	**Plan de Ordenación Territorial aprobado** Plan aprobado por la Junta de Planificación.	1	1	1	1	Aprobado	P	3.8
21	**Índice de Fragilidad Fiscal** Índice que mide la situación fiscal del municipio.	13.53	-9.51	0.22	0.06	0	A	4.4
22	**Suelo oficialmente protegido** Por ciento (%) del territorio del municipio que está protegido oficial y activamente, ya sea por adquisición o manejo de los gobiernos federales, estatales o municipales, o de una ONG, y están clasificados como Suelo Rústico Especialmente Protegido.	33.1%	4.5%	52.6%	22.5%	Que no reduzca	P	1.8
								10

Luego de dividir los indicadores entre agravantes y atenuantes, y de asignarles un umbral o un objetivo de planificación y un peso relativo a cada uno (**Tabla 2**, páginas anteriores), se calculó el INSUS.

La siguiente tabla demuestra los valores del INSUS:

Tabla 3. Resultados de los índices Atenuante (Propiciador), Agravante e INSUS

ÍNDICE	PONCE	CAGUAS	BARCELONETA	CAROLINA
Índice Atenuante (IP)	15.0416	14.9922	14.6850	15.2824
Índice Agravante (IA)	19.4268	19.4044	18.1049	18.9020
INSUS	8.7993	8.7899	9.0061	8.9917

Los cuatro municipios estudiados alcanzaron en el índice compuesto INSUS una puntuación "bien baja" en sustentabilidad. En otras palabras, actualmente no son sustentables. La situación actual de cada uno de estos municipios respecto a los 22 indicadores seleccionados contribuyó significativamente a esta baja puntuación, lo cual refleja las malas prácticas de planificación del uso del suelo que se extienden a lo largo y a lo ancho del archipiélago puertorriqueño.

La combinación de los pesos relativos asignados y de los umbrales o los objetivos de planificación más exigentes hace que algunos indicadores más que otros contribuyan a los resultados del índice. En lo particular, los municipios estudiados deben prestar atención especial a los resultados de los siguientes indicadores agravantes: *Inaccesibilidad a la transportación pública, Índice de Fragilidad Fiscal, Huella de la red vial* e *Inaccesibilidad a agua potable.* Considerando los indicadores atenuantes, la atención debe centrarse en los siguientes: *Total de desperdicios sólidos no peligrosos reciclados, Suelo en uso agrícola* y *Uso de la transportación pública para llegar al trabajo.* Los resultados de estos indicadores contribuyeron sustancialmente a la baja calificación obtenida por estos municipios.

RECOMENDACIONES PRINCIPALES

Los resultados obtenidos confirman la necesidad urgente que existe de completar e implantar el Plan de Uso de Terrenos para todo Puerto Rico, como lo requiere la Ley 550 del 3 de octubre de 2004 o ley para el Plan de Uso de Terrenos del Estado Libre Asociado de Puerto Rico. El Plan debe contener, entre otros elementos, distritos de zonificación y políticas y guías inteligentes para el uso del suelo, así como otros tipos de acciones ambientales, socioeconómicas, infraestructurales e institucionales en al ámbito de los poderes y atribuciones del gobierno central y de los gobiernos municipales. Ayudaría a que los municipios cuenten con un marco

de referencia que guíe los planes y actividades relacionados con el uso del suelo en sus respectivas jurisdicciones.

La regionalización y la municipalización también se recomiendan como herramientas útiles para responder con rapidez y eficiencia a los retos de la sustentabilidad, sobre todo en la implantación de políticas públicas, programas y planes para estos fines, tal y como se ha hecho en otras partes del mundo y como recomienda la Organización de las Naciones Unidas. Deben emplearse mayores recursos para involucrar y educar a los gestores locales y así lograr acciones consistentes y eficaces hacia la sustentabilidad.

Por último, Puerto Rico cuenta con suficiente reglamentación, planes y programas para lograr un desarrollo sustentable en el uso del suelo. El reto está en la falta de implantación. La Isla no necesita más normativas; sólo la implantación eficaz de estas normativas y, de ser preciso, que sean enmendadas y atemperadas a las realidades y los retos del siglo XXI.

LOGROS Y CONTRIBUCIONES DE ESTE PROYECTO

Esta es la primera vez que se realiza este tipo de proyecto en Puerto Rico, en el cual se recopilaron y estudiaron datos relevantes para el desarrollo de un modelo de sustentabilidad para el uso del suelo, compuesto por indicadores y un índice. Esperamos que constituya un primer paso en el proceso de evaluar el progreso o retroceso de Puerto Rico con respecto a la sustentabilidad, usando los municipios como unidad de planificación.

El modelo propuesto es accesible, fácil de usar y viable. También cumple con los criterios de selección de los indicadores. Permite dos niveles de comunicación para las personas interesadas. Por un lado, brinda información detallada de las fuentes de datos y de las metodologías empleadas, lo que permite su revisión técnica y futuras investigaciones para mejorar los datos y el modelo mismo. Por otro lado, brinda en un lenguaje sencillo información resumida para comenzar a analizar tendencias útiles al tomar decisiones e implantar políticas públicas.

El proyecto obtuvo un gran respaldo de representantes de los sectores público y privado dentro del Comité Asesor Externo. La participación de estos representantes en el Comité fue de un 70%. El proyecto también permitió el trabajo en equipo de forma eficiente de técnicos y personas que toman decisiones en áreas programáticas similares en diversos niveles del gobierno (federal, central y municipal), así como de expertos de universidades y organizaciones profesionales.

Contribuciones Específicas

Una herramienta para tomar decisiones: Los municipios pueden utilizar sus propios datos y tendencias históricas y empezar a autoevaluarse. También pueden compararse con otros municipios. Este proyecto es único en este particular.

Una herramienta de evaluación capaz de impulsar políticas públicas: Los resultados de cada uno de los indicadores empleados, así como los resultados del índice, podrían impulsar la revisión de políticas públicas que apoyen la sustentabilidad.

Una iniciativa para lograr convenios de colaboración: La difusión de esta herramienta podría promover la creación de convenios de colaboración intersectoriales como apoyo a los proyectos de sustentabilidad que impulsen los municipios.

Una iniciativa para promover futuras investigaciones sobre la base de las lecciones aprendidas: Este trabajo brinda la oportunidad de que en futuras investigaciones se mejoren los indicadores cuyos datos ahora no son suficientemente precisos o consistentes. También brinda la oportunidad de expandir el Modelo a nivel regional, ya sea para que abarque una cuenca hidrográfica o regiones territoriales de planificación municipal. Además, podría ser transferible y adaptable a iniciativas de investigación similares en islas con escenarios comparables al de Puerto Rico, lo que podría conducir a futuras oportunidades de acuerdos de investigación.

Una oportunidad para aumentar la escala del Modelo y posicionarlo como una herramienta de evaluación a nivel de toda la isla: Con el tiempo, este proyecto permitirá desarrollar un "Informe sobre el Uso del Suelo en Puerto Rico", y clasificar a los municipios cada cuatro a ocho años en función de su "ecoeficiencia".

PRINCIPALES OBSTÁCULOS O LIMITACIONES ENCONTRADOS

En Puerto Rico, la confiabilidad y disponibilidad de datos estadísticos y *metadata* para usar la herramienta del Sistema Información Geográfica (GIS, por sus siglas en inglés) constituyen un gran reto. También lo constituyen la accesibilidad y disponibilidad de los técnicos en las agencias que crean los datos para su validación. No obstante, los indicadores empleados fueron seleccionados a partir de la mejor información disponible, accesible, confiable y medible, tanto en formatos digitales como no digitales. En el futuro deben realizarse investigaciones dirigidas a mejorar la base técnica de la información, de modo que se amplíe el alcance del Modelo y se incremente su exactitud y utilidad.

Los municipios, como unidades de planificación, poseen limitaciones respecto a la aplicación y recopilación de datos estadísticos porque en muchos casos el alcance de estos datos es de naturaleza regional o de todo Puerto Rico. Esto ocasionó que muchos indicadores potenciales tuviesen que descartarse. Una línea de investigación futura basada en este modelo podría ser el desarrollo de un modelo de escala regional o insular (con consideraciones regionales). Además, la metodología podría refinarse para tomar en cuenta condiciones disímiles entre municipios. Tal como lo evidencia la documentación estudiada, pocos, si algunos de los indicadores más importantes, son de igual aplicación incluso en situaciones o sistemas similares.

SUSTAINABILITY OF LAND USE IN PUERTO RICO

Report
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This Report can also be downloaded at www.proyectosambientales.info.

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ABSTRACT

Puerto Rico faces a considerable number of challenges for sustainable land use planning. As a small Caribbean island, land is a scarce and highly valuable resource. A history of inefficiency in land use has resulted in many environmental, social and economic challenges, and if current practices continue at the same rate they have in the last five decades, the whole island of Puerto Rico will become a suburban megalopolis in less than 75 years, the life span of one generation. With a population density of almost 450 inhabitants per square kilometer, one of the highest in the world, Puerto Rico is running out space and time. The Island also faces the political reality that its surface area is divided into 78 municipalities. Currently all of these municipalities have the authority to prepare individual land use plans by virtue of the Autonomous Municipalities Act (Public Law 81 of August 30, 1991). However, they lack a larger and comprehensive sustainable land use framework to guide them. Although numerous laws and regulations regarding land use planning have been approved during the past sixty years, the sequence of their enactment and their subsequent ineffective implementation have left the island without an island-wide land use plan.

Since land use is at the heart of sustainability, this project developed and proposes the Current to Optimal Model (CUTOP Model), with an accessible, easy-to-use, and feasible set of indicators and an index, based on the best available and reliable data, to measure and monitor progress towards sustainability at a municipal level. The evaluation period is eight years since municipal land use plans have to be revised at least every eight years, as established by Public Law 81. Four municipalities are used as case studies because they represent different regions and varying socio-economic and landscape scenarios: Barceloneta, Caguas, Carolina and Ponce. An External Advisory Committee, composed of stakeholders and local experts from the public and private sectors, is an integral part of the Model for decision-making.

The Model utilizes indicators as stressors and relievers to provide information about the current situation. It also provides an optimal situation to measure progress or retrocession using specific benchmarks or agreed upon planning objectives. Twenty-two indicators are proposed. They were selected based on specific criteria for quality control, measurability and feasibility. After dividing the indicators into four different categories (Environmental, Socio-economic, Infrastructural and Institutional) and assigning an appropriate sustainability weight to each one, an index (Index of Sustainable Land Use Activity or ISLA) is provided to communicate in a condensed and simple way the sustainability status - from very low sustainability to very strong sustainability - and to measure progress.

The four case studies scored "very low" on sustainability with the ISLA. The current situation of many of the 22 indicators for each case study contributed to the low scores which mirrors the widespread unsustainable land use practices on the Island. Special attention needs to be given by the municipalities studied to the following stressors indicators: *Inaccessibility to public transportation*, *The Fiscal Fragility Index*, *Footprint of public roads*, *Inaccessibility to safe drinking wate*r. Also, to the following relievers indicators: *Total recycled solid non-hazardous waste*, *Active agricultural lands*, *Use of public transportation to reach w*ork. These indicators contributed substantially to the low scores.

Results confirms the urgent need for an island-wide land use plan with specific zoning classifications and smart land use policies as guidelines - among other related environmental, socio-economic, infrastructural and institutional actions at the municipal and central government levels to improve sustainability. This will aid municipalities in acquiring a larger framework to guide their individual activities and plans. Regionalization along with municipalization is also recommended to respond faster and more efficiently to the challenges of sustainability as it is being done in other parts of the world and suggested by the United Nations. Further efforts in Puerto Rico have to directly involve and educate local actors in order to achieve consistent and effective action towards sustainability.

SUSTAINABILITY OF LAND USE IN PUERTO RICO

With the industrialization in the 1940's and 50's the following factors contributed to the accelerated urbanization of the Puerto Rican society:

The devaluation and abandonment of agriculture as a main economic sector.
The lack of tillage as a result of the absence of policies to protect this economic activity in the industrialization process left land available for other more profitable uses, specifically housing development.

The lack of a mass transportation policy.
The government did not promote or prioritize mass transportation during the accelerated stage of urbanization.

The implicit and/or explicit subsidy of private vehicles.
The government explicitly encouraged the use of cars with tax credits, and implicitly encouraged policies of keeping fuel costs low which was exacerbated by the practice of accommodating road construction to the unplanned development of residential projects.

Inadequate valuation or appraisal of the different housing development alternatives.
The emphasis on short-term cost reduction has favored housing construction on "inexpensive" land far from the urban centers instead of encouraging reconstruction and densification of the residential spaces of urban centers.

The interaction of these factors and the increasing demand for housing from an urban upwardly mobile middle class were the basis for sprawling development.

Public policy, as well as private initiatives, followed the path of least resistance without planning guidelines for a denser, more efficient development.

Source: Universidad Metropolitana (UMET), 2001.

INTRODUCTION

Puerto Rico: A Sustainable Challenge

Puerto Rico, a commonwealth under the jurisdiction of the United States, faces a considerable number of challenges for sustainable land use planning. As a small island in the Caribbean, land is a scarce and highly valuable resource. Measuring 8,870 square kilometers with a population density of almost 450 inhabitants per square kilometer (in July, 2008, the Puerto Rico Planning Board [PRPB] estimated the island's population at approximately 4.0 million[1]), one of the highest population densities in the world and the fourth highest in America,[2] Puerto Rico is running out space and out of time.

According to the classifications of the U.S. Census in 2000, already 50% of the island is urban and 50% is rural. The majority of this population (94%) lives in urban areas. This is a significant change from 1900-1930, when almost 80% of the island's population was rural (U.S. Census Bureau, 1900-1930[3], 2000). Industrialization in Puerto Rico followed the United States model of suburban growth in the 1940's and 50's, and this paved the way for an accelerated urbanization of Puerto Rican society. Urban sprawl became one of its more evident consequences and one of the greatest threats to sustainability on the island.

Locally, land use cover in Puerto Rico has been studied using a variety of methods (Thomlinson et al., 1996; Thomlinson and Rivera, 2000; López et al., 2001; Ramos González, 2001; Helmer et al., 2002; Martinuzzi et al., 2007, Gould et al., 2007, 2008ab). The most recent studies (Martinuzzi et al., 2007, 2008 and Gould et al., 2008ab) calculated that 16% of Puerto Rico is considered urban[4] (specifically, 11% of the island is composed of urban/built-up surfaces). The compact pattern of construction of urban/built-up land (high-density) encompasses nearly 60% of developed lands within the urban centers and along their important connections, and within non-contiguous exurban agglomerations. It predominates in the coastal plains and valleys where the most productive agricultural lands are located (development is closely related to the topography, it decreases rapidly as slope increases). Thirty-six percent (36%) is densely populated rural[5] (suburban developments) and 40% of Puerto Rico is considered to be experiencing a high degree of low-density or non-contiguous sprawl development[6] which is widespread across most of the island starting just outside the urban centers,

1 PRPB, Census Office, retrieved on 1/29/09 from www.censo.gobierno.pr ("proyecciones de población/2001-2010, años sencillos").

2 United Nations, Department of Economics and Social Affairs, United Nations Statistic Division. Demographic Year Book. Retrieved on 1/29/09 from http://unstats.un.org/unsd/demographic/products/dyb/dyb2006.htm (Table #3).

3 The Census information for 1900-1930 was retrieved on 1/29/09 from http://www2.census.gov/prod2/decennial/documents/00476569ch4.pdf

4 According to the authors, urban is defined as those regions where developed areas (developed pixels) per km^2 is more than 20% of the surface.

5 According to the authors, densely populated rural lands (or what they call territory of expansion of urban centers) refers to those regions where developed areas (developed pixels) per km^2 is less than 20% and, according to the core census block groups or blocks (2000 Census Urban and Rural classifications), have a population density of at least 1,000 people per mi^2 and the surrounding census blocks with an overall density of at least 500 people per mi^2. The rest is considered sparsely populated rural area.

6 The calculation of the 40%, according to the authors, considered densely populated rural and part of the urban-use areas (including exurban agglomerations and low density developments).

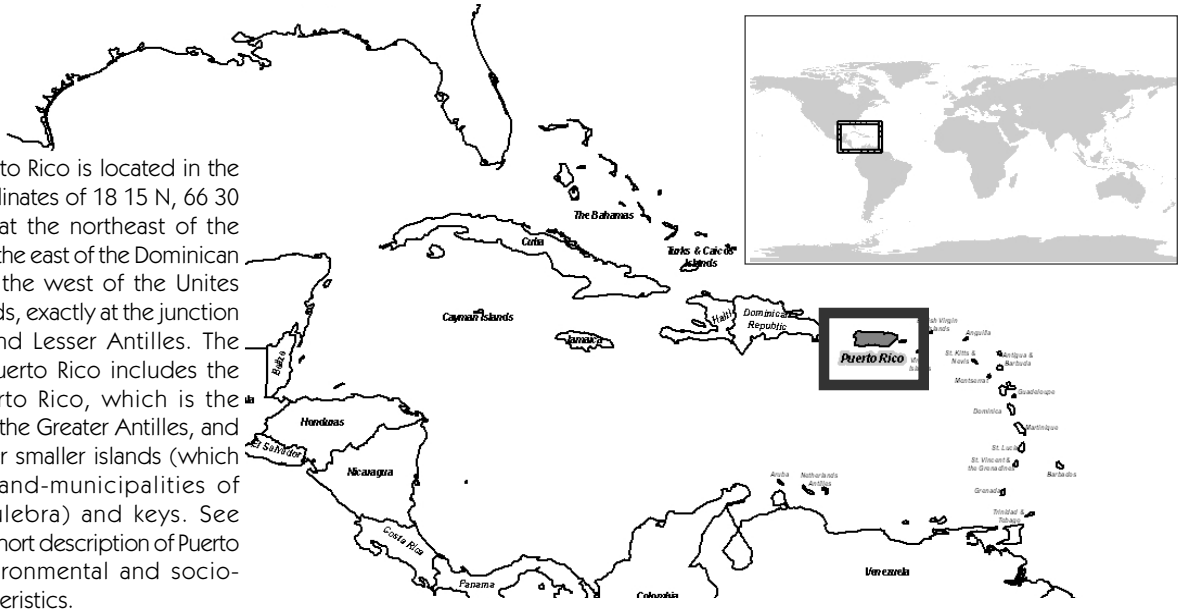
following the linear features of the roads (it predominates in the hills and mountains following the extensive rural-road network) and some of the biggest highways and routes. This sprawl has encroached in the most valuable agricultural lands, eliminating open spaces and covering watersheds with impervious surfaces. Few open regions appear with minimal human impact, mostly areas protected by the government for conservation, agriculture fields, higher elevations or rugged topography (Martinuzzi et al., 2007, 2008 and Gould et al., 2008ab).

According to López and Villanueva (2006) in the last 25 years there has been an increase of approximately 35% in this urban coverage. In spite of the fact that it is still not the biggest coverage, it is the one that has grown at a faster rate. In addition, only 7.6% of the land is protected by some form of management for biodiversity (Gould et al., 2007). Urbanization for housing and development have produced enormous pressures on the island's diverse and delicate ecosystems which range from the only tropical rainforest of the United States (El Yunque National Forest), to the Guánica Dry Forest (declared an International Biosphere Reserve by UNESCO) to the northern karst region which, according to studies, has a sustain yield of about 25 million gallons of water per day for consumption. In the description of each indicator presented in the technical section of this Report (Rationale and Methodology of the Indicators), many of the environmental, economic and social impacts of this unsustainable land use pattern are described and evidenced in the results.

Puerto Rico is also an island with topographical limitations, and a serious combination of natural hazards. Two-thirds of the land is mountainous, while the remaining one-third is composed of valleys and low-lying lands, with a coastline of 501 km, which bears the brunt of suburban development. Also, many lands are flood-prone areas, a result of hydrologic characteristics such as the island's 224 named rivers and 553 creeks, with 55 main rivers that flow into the sea, as well weather patterns characteristic of tropical areas (Puerto Rico Department of Natural and Environmental Resources [DNER] (2007).

Not a single ecological resource has escaped the impact of urban sprawl on the Island. Coupled with the infrastructure built to sustain growth and social activities, it has left an imprint on the land and the natural systems on a scale unseen until the last two decades. The real cost, however, goes far beyond strictly environmental concerns, and any economic exercise to quantify this cost faces enormous hurdles. According to the study by UMET (2001) in the case study area inside the San Juan Metropolitan Area that included the municipalities of San Juan (Capital City), Carolina, Cataño, Guaynabo, Toa Alta, Toa Baja and Trujillo Alto, the recurrent cost of urban sprawl is estimated

Figure 1. Location of Puerto Rico in the Caribbean



The Island of Puerto Rico is located in the geographic coordinates of 18 15 N, 66 30 W. It is situated at the northeast of the Caribbean Sea, at the east of the Dominican Republic and to the west of the Unites States Virgin Islands, exactly at the junction of the Greater and Lesser Antilles. The archipelago of Puerto Rico includes the main island Puerto Rico, which is the smallest island of the Greater Antilles, and a number of other smaller islands (which includes the island-municipalities of Vieques and Culebra) and keys. See Appendix B for a short description of Puerto Rico's main environmental and socio-economic characteristics.

at more than $1.6 billion. This is a conservative estimate because it does not include environmental costs due to pollution and the loss of real state value of abandoned properties in the urban centers during the suburbanization process. It includes economic savings and benefits for: less use of private vehicles, less time lost in traffic jams, less lives lost in car accidents, less maintenance cost of the network of roads and highways and the electrical power infrastructure, and more agricultural lands and scenic open spaces conserved.

The island also faces the reality that it's 8,870 square kilometers of surface area are divided politically into 78 municipalities[7]. Most of their urban centers appear surrounded by sprawling development (Martinuzzi et al., 2007). Currently, all these municipalities have the authority to prepare individual land use plans without a larger sustainable land use framework to guide them. Although numerous laws and regulations regarding land use planning have been approved during the past sixty years, the sequence of their enactment and their subsequent ineffective implementation have left the island to date without an island-wide land use plan. (See Appendix A for more details.) As a result, urban sprawl and unsustainable land use patterns are both evident and alarming. Single-use land zoning implemented during the past decades has been followed by an ever expanding public infrastructure, abandonment of urban centers, and lack of proper maintenance of the existing facilities, which signifies the inability of the government to meet the challenges of growth.

The unsustainable land use can be distinguished by its loosely connected networks of highways within and between municipalities, surrounded by a "spreading sea" of single-family "cookie cutter" houses. Puerto Rican families that live in these suburban houses are completely dependent on private commute even for their daily errands. Studies made for the construction of the Urban Train estimated that about 40% of the typical family income is spent on the ownership of private vehicles, which includes the acquisition, operation and maintenance costs (UMET, 2001).

In 1999, UMET obtained a Sustainable Community Challenge Grant from USEPA for the groundbreaking project *Puerto Rico's Road to Smart Growth*. This project facilitated the analysis and dissemination of crucial information to advance the state of knowledge about the environmental, economic and social impact of urban sprawl using as a case study part of the San Juan Metropolitan Area (SJMA). The most staggering result of the study was the revelation that if urban sprawl continues at the same rate it had in the last five decades, the whole island of Puerto Rico would become a suburban megalopolis in less than 75 years, the life span of one generation.

[7] Territorial and political planning unit within the island, the equivalent of townships in the Unites States. Each municipality has a Mayor and a Municipal Assembly.

Figure 2. The Island of Puerto Rico with its 78 Municipalities

AIM OF THE PROJECT

The aim of the project is to provide an accessible, easy-to-use and, at the same time, reliable and feasible set of indicators and index model to guarantee its practical use and applicability for the municipalities in Puerto Rico. It also intends to measure and monitor the impacts of land use changes for long term sustainability.

Sustainability cannot be achieved without addressing the issue of land use. Land use is at the heart of many of the environmental, social and economic issues in any part of the world. Learning to recognize the linkages between the economic, social and environmental impacts of land use decisions is the essence of sustainability.

Sustainability of Land Use in Puerto Rico focuses on a preventive approach to help reduce the impact of unsustainable land use, and to strengthen and continue *Puerto Rico's Road to Smart Growth* project initiative, which was designed to diagnose the problem and create awareness.

ACHIEVEMENTS AND CONTRIBUTIONS

Achievements

This is a groundbreaking project for Puerto Rico. It is envisioned as a first step in the process of assessing Puerto Rico's progress towards (or away from) sustainability using the municipalities as reference. It's the first time that relevant data are compiled and studied for the development and completion of sustainable land use indicators and an index. Further areas of research will be recommended to enhance the model, its scientific base and increase its scope for public policy.

The model developed is accessible, easy-to-use- and, at the same time reliable and feasible. In general terms, it complies with the project's definition of success since it meets all of the selected criteria for the development of the indicators and index – including transferability. The model developed allows two levels for communicating the results to stakeholders: it provides uncondensed and detailed information of data sources and methodologies for technical revision and for the analysis of further areas of research to improve data and the model (technical language). It also provides condensed information to begin analyzing trends for informed decision-making and public policy in an easy to comprehend language. The use of the project's results for decision-making and public policy is considered in the original proposal as mid-term definition of success.

The project also achieved a highly satisfactory participation of key stakeholders through a representative group, the External Advisory Committee. The members of the Committee had a 70% participation rate throughout the duration of the project (specifically, 78% for the representatives of the government agencies, and 56% for the representatives of the municipalities).

The project also provided effective team work for technical and decision-making personnel of the same programmatic areas and different governmental levels (federal, state or local-central and municipal), as well as different expert groups (academia and professional organizations) in their task to develop and apply the proposed model with its indicators and index.

Specific Contributions

- A DECISION-MAKING TOOL

  Stakeholders can begin examining municipal land use choices and actions in terms of how they contribute in favor or against sustainability. Specifically, municipalities can begin evaluating themselves using their own data and historical trends, and begin comparing themselves with other municipalities. Our project provides a groundbreaking initiative and a contribution in this direction.

- AN ASSESMENT TOOL THAT COULD SPEARHEAD PUBLIC POLICY

  The results of each individual indicator used in the model, as well as the result of the index, can trigger revisions of existing and the creation of new public policies towards sustainability. (Example: The results of the previous USEPA sponsored project at UMET - *Puerto Rico's Road to Smart Growth* – helped to enact three Smart Growth and environmental related policies: Urban Center Revitalization Act, San Juan Ecological Corridor Act, and Puerto Rico Land Use Plan Act.)

- A COLLABORATIVE AGREEMENT INCENTIVE

  The disemination of this tool can promote intersectorial collaborative agreements to support municipalities in specific sustainability projects (educational, research and public policy).

- AN INITIATIVE TO PROMOTE FURTHER RESEARCH BASED ON LESSONS LEARNED

  The work provides opportunities for improvement to some indicators that at present lack more dependable and current data. It also provides research opportunities to expand the indicators to a regional scale using watersheds or other regional municipal initiatives as territorial planning units.

- AN OPPORTUNITY TO SCALE-UP AS AN ISLAND-WIDE MUNICIPAL MONITORING TOOL

  The plan for this project is to eventually develop a Puerto Rico "state of land use for sustainability report" in which municipalities would be ranked every four to eight years according to their land use "eco-efficiency".

- AN EXAMPLE FOR OTHER ISLANDS

  The proposed model could be transferable to similar research initiatives in islands with comparable scenarios.

CHALLENGES AND LESSONS LEARNED

These were the main challenges encountered during the research process and the lessons learned.

- In Puerto Rico, reliability and availability of the metadata, especially for the use of Geographic Information System (GIS), is a major challenge. Because of this specific challenge, the use of GIS as the main technical and scientific tool for the model was ruled out. Consequently, the aim of the project was reoriented to "provide an accessible, easy-to-use and, at the same time, reliable and feasible set of indicators and index model to guarantee its practical use and applicability for the municipalities in Puerto Rico, and to help measure and monitor the impacts of land use changes for long term sustainability."
- Many indicators have no clear or agreed upon benchmarks to measure progress towards sustainability. These indicators had to be evaluated separately with the stakeholders to determine local planning goals. Objectivity was a major challenge which was kept in check when selecting these goals.
- The municipality as a territorial unit poses difficulties in data collection and analysis when the scope and origin of many of the land use activities have a regional or island-wide nature. Because of this, many potential indicators had to be eliminated.
- The modeling method had to consider dissimilar conditions across municipalities.
- Stakeholders' participation from the beginning resulted in a successful collaboration and encouraged interest in the results of the project which was important for decision-making.

THEORETICAL BACKGROUND

Sustainable Development

The dictionary defines "Sustainability" as "constant renewal, perpetuity and an inexhaustible system". It also defines "Development" as "progress, change and expansion for the better". The sustainable development concept has evolved since the 1972 when the United Nations Conference on the Human Environment in Stockholm stated the goal of jointly addressing economic development, ecological health and social equity concerns due to the reality of the reduction of the Earth's capacity to sustain life in the face of the overwhelming growth of the world population, it's consumption rate and, it's depletion of the natural systems. The Conference urged the international community to prepare international, regional an sub-regional reports on the state and outlook of the environment. As a result, during the 1970's and early 1980's, a number of scientists, activists and policy makers began researching to respond to environmental, social and economic issues. The first reports described the current situation and trends in the state-of-the environment and were aimed at raising awareness (United Nations Environmental Programme [UNEP], 1972[8]; 2006; Porter, 2000; Rogers et al. 2008).

However, the terms "sustainability" and "sustainable development" were not officially defined until 1987, when the United Nations' World Commission on Environment and Development released its report *Our Common Future*. This Report brought these terms into widespread use. *Our Common Future* (also known as the Brundtland Report, after the Commisssion's Chairman, Norwegian Primer Minister Grö Harlem Brundtland) defined sustainable development as a "*development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs.*" This definition is still the one mostly used around the world to establish the link between decision-making – usually related to the political will of governments – and balancing the economic and social needs of the human population with consideration for the regenerative capacity of the natural systems (United Nations Organization [ONU], 1987[9]; Krizek and Power, 1996; Porter, 2000; Rogers et al., 2008).

The dimensions of sustainable development (economic, environmental and social) can be summarized as follows (ONU, 1987; Krizek and Power, 1996; Bell and Morse, 2003; Sustainable Measures, 1998-2006; Rogers et al., 2008; International Institute for Sustainable Development [IISD], 2009):

- THE ECONOMIC DIMENSION

  The economic future of humanity depends on the integrity of natural systems. Income cannot be maximized without maintaining constant or increasing stock of capital. In other words, there is a need for a long term view of "living off the dividens" of our natural resources by not exceeding their generation-rate capacity.

- THE ENVIRONMENTAL DIMENSION

  The need to mantain the resilience and health of natural systems and ecological processes.

- THE SOCIO-CULTURAL DIMENSION

  The need to achieve social equity and fairness, especially meeting the needs of the poor, and the stability of cultural systems.

- MULTIDIMENSIONAL SYSTEM THINKING

  The need to understand the interconnection and integration of the above three dimensions.

- INTERGENERATION JUSTICE

  The need to preserve as many economic, social and environmental resources and options as possible for future generations because they have the right, as previous generations did, to determine their needs.

So a system with "strong sustainability" is a system where the existing stock of natural capital is mantained and enhanced because it is understood that the functions it performs to sustain life is not duplicated by manufactured capital. And a system with "weak sustainability" is the system that assumes that the natural capital can be replaced or duplicated by manufactured goods and services. In other words, that it can be used indefinitely and converted into manufactured capital of equal value (Hart, 1999).

[8] For more information about this initiative also see http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97.

[9] For more information about this initiative also see http://www.un-documents.net/wced-ocf.htm.

In the June, 1992, the United Nations' Conference on Environment and Development in Río de Janeiro, Brazil (commonly referred to as the Río de Janeiro Earth Summit), representatives from almost every nation adopted a broad action strategy with a set of principles, programs and activites in the form of international treaties and agreements to achieve sustainable development under what was called Agenda 21 (or agenda for the 21st century). One of the activities called for the first time on governments and non-government organizations at the national and international levels for the development of sustainable development indicators for decision-making (Chapter 40 of Agenda 21[10]). As a result, the United Nations' Commission on Sustainable Development (CSD)[11], under the Division of Sustainable Development[12], adopted a work programme for the development and disemination of a core list of indicators for sustainable development. During 1996 and 1999 the first draft set of indicators was developed with their methodological sheets for discussion jointly with the Statisctics Division[13], both within the United Nations Department of Economics and Social Affairs. From 1996 to 1999, 22 countries pilot-tested this set of indicators and, since then, a large number of government and non-government organizations around the world have developed their own particular set of indicators using CDS guidelines. In other words, sustainable development indicators are deeply rooted in the Agenda 21 initiative. Unfortunately, progress towards using indicators for the implementation of sustainable development plans has been very slow (United Nations Department and Economic and Social Affairs [UNDESA], 2007; Bell and Morse, 2008; IISD, 2009).

Indicators

There are a number of tools and methodologies to help determine progress towards sustainability. One example is the "carrying capacity" of an ecosystem that is mostly used by ecologists: The size of the population that can be supported indefinitely upon the available resources and services (or living within the limits of an ecosystem). Another is the ecological footprint which is mostly expressed quantitatively as the amount of land area required to maintain the unit that is being analyzed. For example, if the unit being analyzed is a country, the amount of land area needed, in terms of natural resources, to mantain the actual economic and social activities of that country. The greater the land area to maintain that unit, the greater the resources needed to sustain the existence of that unit and, as a result, the larger it's ecological footprint. Even though the ecological footprint has gained popularity in recent years, the most common approach to measure sustainability is still the use of indicators and indices (Hart, 1999; Bell and Morse, 2003).

Indicators help translate complex data into comprehensive information and can show progress towards a goal. Indicators can be understood as "signs that point out, or stand for, something. They provide clues about the condition or viability of a system or the state of its health" (UNEP, 2006). "They are symbolic representations designed to communicate a property or trend in a complex system or entity. They are a communication tool. Failure to communicate makes the indicator worthless" (Moldan and Dahl, 2007). They are "variables that summarize or otherwise simplify relevant information, make visible or perceptible phenomena of interest, and quantify, measure, and communicate relevant information" (Gallopin, 1997).

[10] For more details about Agenda 21 and its Chapter 40 see http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm or http://www.un.org/esa/dsd/dsd_aofw_ind/ind_index.shtml.

[11] For more details about CSD see http://www.un.org/esa/dsd/csd/csd_aboucsd.shtml

[12] For more details about this Division see http://www.un.org/esa/dsd/index.shtml.

[13] For more information about this Division and its contribution in the implementation of Agenda 21 see http://unstats.un.org/unsd/aboutus.htm.

There are many examples of indicators. It depends on "why, where, when and how much" when developing a set of indicators for a specific country, region, city or even community. According to Meadows (1998) and Bell and Morse (2003), most of the reported sustainability indicators are place, cultural and time specific, and there are very few, if any, key indicators that could apply the same way across similar systems. "Given that sustainable development typically envisaged as having environmental, social and economic dimensions, then the usual approach is to develop a framework of indicators that cover all of these, perhaps in conjunction with a single index that tries to bring them all together into a numerical value" (Mitchell, 1996 as quoted in Bell and Morse, 2003).

The quality of an indicator depends on a number of factors. In general terms (Guy and Kibert, 1998; Meadows, 1998; Hart, 1999; United Nations Education Scientific and Cultural Organization [UNESCO], 2003b; UNEP, 2006; Sustainable Measures, 1998-2006; Moldan and Dahl, 2007; Bell and Morse, 2003, 2008; UNDESA, 2007; IISD, 2009), an indicator should have:

- PURPOSE AND APPROPRIATENESS (represent the phenomenon concerned)
- SPECIFICITY AND ACCURATENESS (clearly define the objective and relate to outcomes)
- USABILITY (practicality)
- RESPONSIVENESS (respond quickly and measurably to changes)
- MEASURABILITY OR POTENTIALITY TO REVEAL TRENDS OVER TIME (implies quantitative value)
- RELIABILITY AND FEASIBILITY (well-founded basis in quality data based on the best available and usable information or in scientific methodologies)
- AVAILABILITY (with data that is relatively easy to collect, and available on a regular basis and in the future)
- SIMPLICITY AND COMMUNICABILITY TO THE TARGET AUDIENCE (understood by the lay person, kept to the necessary minimum number of indicators and translated into some type of visual form for presentation to the audience [graphs, tables, maps, etc.])
- HIERARCHY (a user will be able to understand the technical details or can also get the general message quickly)
- COST EFFECTIVENESS (affordability to access, manage and reproduce)
- TRANSPARENCY THROUGH A PARTICIPATORY PROCESS IN ITS DEVELOPMENT, ENGAGING STAKEHOLDERS AND DECISION-MAKERS
- RELEVANCE FOR PUBLIC POLICY (can trigger and facilitate action for decision-makers)

In order to develop indicators, data availability is one of the most important selection criteria. They can be quantitative and/or qualitative in value, however the best available data needs to be feasible and reliable following agreed upon quality standards. Although it is always possible to improve data quality and to develop new data sets, this can be costly for stakeholders. If the aim of developing indicators is to promote their action towards sustainability, costs must be kept low. So simplicity and practicality are key in their development (UNEP, 2006; Molan and Dahl, 2007). "Indicators are merely assesment tools, for which the cost of improvements should not limit the capacity to implement policy. The two must be matched in cost-effective ways" (Molan and Dahl, 2007).

Indicators are also used to show historical trends and / or show performance by calculating their progress towards a benchmark (a scientifically determined threshold) or a target (endpoints based on human values or policy-oriented goals). The aim is to have the indicator reach the desired optimal goal, such as a best practice for the indicator. This helps decision-makers and managers evaluate and understand the gap between the current and the optimal state of the environmental, social and/or economic progress. In the environmental dimension, for example, there are legal targets for levels of pollutants emissions or concentrations in the air and water, and beyond that level scientists agree that the system is no longer sustainable. There are also historical (for example, using a specific year as baseline against which to plan the future), geographical (percentage of land area, for example), and theoretical references, as well as experts' opinions (what are the "worst" and "best" conditions) to base decisions for an optimal state which represents sustainability. When the opinion of experts and stakeholders are used there may be some unalienable subjectivity and value judgment in the process, but in most cases it is still the best available reference. Also, when developing indicators, all of these approaches for optimal conditions to calculate deviations can be combined. Different ones can be used for each indicator, depending on the available information and framework (Bell and Morse, 2003; UNEP, 2006).

A number of approaches can be used for structuring the development of a set of indicators to help systematized the selection process, analysis and interpretation, and to easily communicate the methods to the target audience. The most simple and basic one, and the most commonly used framework is the Pressure or Driving Force-State-Response (PRS) Model. The linear visualization of this framework is as follows:

"It is tempting, given all the caveats and challenges in every report on sustainable development indicators, to be daunted, to postpone the task, to wait for more thinking, more modeling, more agreement – to wait for perfection. While we are waiting for perfection, fisheries are collapsing, greenhouse gases are accumulating, species are disappearing, soils are eroding, forests are overcut, people are suffering.

Response
What are we doing or supposed to be doing about it?

Pressure or Driving Force → **Existing Stage** → **New State**
Why and what is happening? *What is the actual state as a result?*

So it is important to get some preliminary indicators out there and into use, the best we can do at the moment. That way, as long as we are willing to evaluate and make corrections, we can start to learn, which is the only way we can ever achieve sustainable development. We need to learn, but we need to waste no time with our learning."

Donella Meadows, 1998

This approach assumes a target (the desired or new state) which could be reached if changes are made to improve the existing stage. It is very useful in understanding the relationship between a problem and the forces that are causing the existing state. It also helps to understand the responses needed to prevent it or to fix it, providing a level of analysis to be used by decision-makers (Hart, 1999; Bell and Morse, 2003; Esty et al. 2005; UNEP, 2006; Sustainable Measures, 1998-2006; UNDESA, 2007).

The PRS Model was first used by the Organization for the Economic Cooperation and Development (www.oecd.org) in 1994. After the PRS Model was introduced, other cause-and-effect variations and approaches has been developed by numerous entities using the PRS Model as a framework. For example, the Driving Force-Pressure-Sate-Impact Response (DPSIR); the Driving Force-Sate-Response (DSR); the Pressure-State-Impact-Response (PSIR) and the Driving Force-Pressure-State-Exposure-Effects-Action (DPSEEA) (for more information about these approaches see UNESCO, 2003b; Bell and Morse, 2003; UNEP, 2006; Moldan and Dahl, 2007). Although the PRS Model has been criticized for being simplistic in its linear cause-and-effect approach to consider all the complexities and subjectivity involved in understanding the pressure, state and responses, and their enclosement in a larger system with human - environment interactions, it is still the most applied approach. The important thing to keep in mind is its use as a framework tool to structure the development of indicators but not to assume underlying functional causalities (Galloping, 1997; UNEP, 2006). As mentioned earlier, simplicity and communicability to the target audience and the lay person is a desirable must.

The same applies to individual indicators. "Indicators cannot replace scientific studies of cause and effect. They are presentations of associations and links between variables. When we choose to present variables together as part of an indicator, we make an explicit assumption of their connection. Indicators, therefore, can never replace statistical analyses of data or the development and testing of sound hypotheses." The PRS Model, as well as the individual indicators, are just one of the "necessary parts of the flow of information to help us understand the world, make decisions, and plan actions". There will always be a degree of incompleteness, imperfection and uncertainity in the use of models and in the selection of a set of indicators. "When a system is extremely complex, it takes trial-and-error, and learning to produce a serviceable set of indicators." The important factor is to continue reducing these pitfalls and difficulties (Meadows, 1998; EAA, 2002 as quoted in Moldan and Dahl, 2007). Also, there is not an "ideal" best framework model. The important thing is that it works well for the intended purpose (Sustainable Measure, 1998-2006).

Literature indicates that another major challenge is the lack of commitment from stakeholders to implement sustainability indicators. This could be in part due to the reluctantness of the scientific community to get involved in the socio-political arena. Usually the emphasis in the development of indicators has been on the technical excellence and not helping manage change for decision-makers. This is probably the reason why sustainable indicators are not being as widely used as desired by decision-makers and end up as another research initiative in a data collection division of an agency. There are two important steps to addressing this problem. First, is engaging the stakeholders from the outset in a participatory process for the selection and construction of the indicators, and second is to circumscribe a set of performance indicators to which decision-makers can be held responsible.

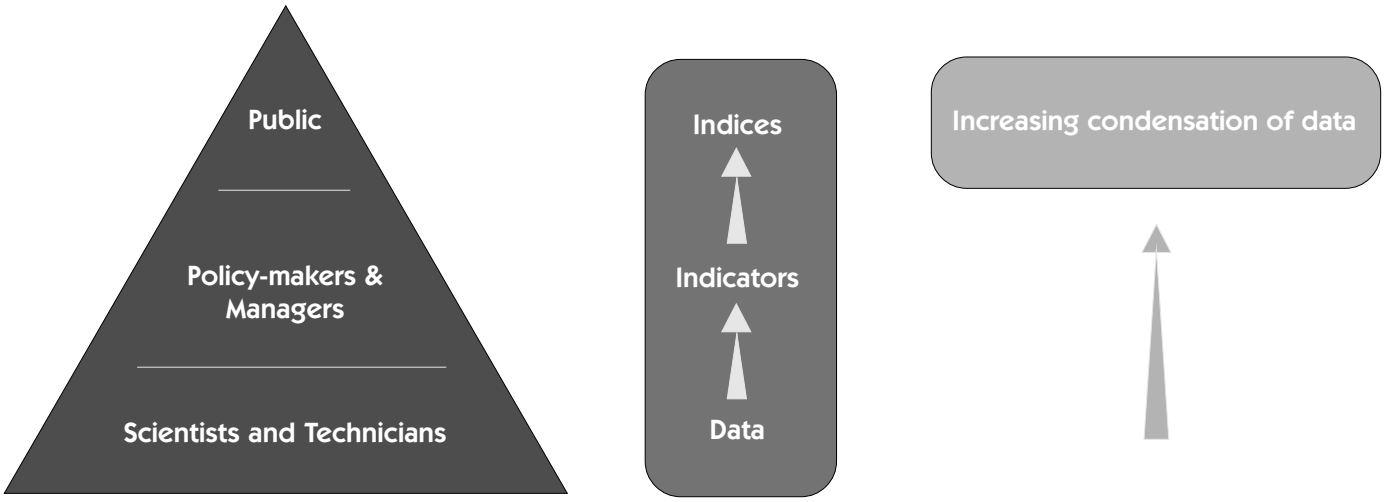
The development of sustainability indicators should not become focused on methodological and technical issues. They need to also have practical use to bring about change. Policy effective indicators are the ones that can link changes in variables to policy efforts. If decision-makers and other stakeholders are involved in the process of selecting and constructing the indicators, they also end up having some resposibility in their use to attain positive changes. This is important and should be taken into consideration in the models used to structure the development of indicators. Decision-makers are always looking for tools that can help them identify problems, track trends and set priorities for policies, investments and actions (Bell and Morse, 2003; Esty et al., 2005; Moldan and Dahl, 2007).

Indices

Condensing complex information for analysis and easy interpretation by decision-makers and other stakeholders (usually non-specialists) is highly desirable. The use of indices is a way to condense and simplify so as not to overwhelm the target audience with detailed information and technical data. Specifically, "an index is a mathematical aggregation of variables or indicators, often across different measurement units so that the result is condensed and dimensionless" (UNESCO, 2003b). The advantage of an index is that it provides an overall picture of a system being evaluated in a simple but compelling way for stakeholders and the general public (Esty et al. 2005). Scientists and technicians are more interested in the details of the methodology and they usually prefer raw uncondensed data. On the other hand, decision-makers and the general public prefer condensation and more visual interpretation of the data in a way that is manageable on how it relates to benchmarks and targets. So, a hybrid approach is generally recommended in the presentation with the unwrapped detailed information to reveal the underlying data and methods and the wrapped result in an index (Meadows, 1998; Bell and Morse, 2003).

In addition, an index should include a weighing scheme to balance out the relationships among the disparate indicators and their dependence on subjective interpretation. The aggregation and weighing methods need to be transparent and based on a clearly defined mathematical model. This is important since the main limitations of indices are that they can become too abstract or/and that they can hide defects in the condensing of many variables into a single measure (Bell and Morse, 2003; UNESCO, 2003b; Esty et al., 2005; UNEP, 2006). Also, the risk of oversimplifying the complexities of the relationship and interaction processes between the social, economic and environmental dimensions is always an issue when developing indicators and indices. This is the reason why correlative conclusions should be drawn from indicators and indices rather than a scientifically causal relationship between trends and stressors, or between implemented policies and positive or negative changes in the state towards sustainable development (UNEP, 2006).

Figure 3: Pyramid of Indicators Sets



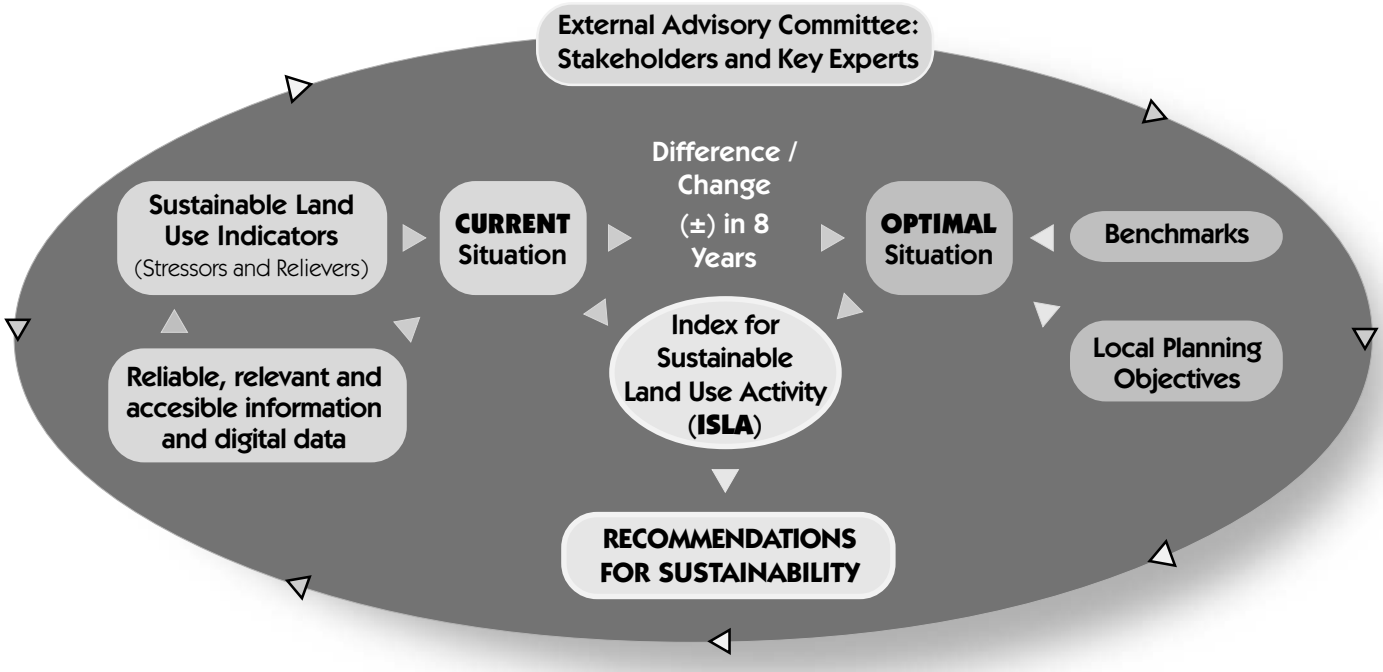
Source: Braat (1991) and OECD (1998) as published in Bell and Morse (2003).

METHODOLOGY

The Conceptual Model: Current to Optimal (CUTOP Model)

The main objective of the Current to Optimal Model (CUTOP Model) used for this project is to *identify what activities should be modified at a municipal level to help drive land use towards sustainability*. In other words, the product desired is an evaluation of how close or far the municipality is from sustainability based on the best available and reliable information. As a result, a series of recommendations will be provided to guide the municipality towards sustainability.

Figure 4: Schematic Overview of the CUTOP Model



The CUTOP Model, which uses the basic PRS Model framework explained in the Theoretical Background section, has three primary components:

1. TWO SCENARIOS

- CURRENT SITUATION. It describes the present situation using indicators related to key stressors (reduce sustainability) or relievers (improve sustainability) - which are the driving force - that help evaluate how close or far the municipality is from sustainability based on the best available and reliable data.
- OPTIMAL SITUATION. Establishes an optimal (or desired) scenario. This is based on benchmarks (locally accepted public policies' goals, internationally agreed goals or scientifically accepted thresholds) or planning objectives (when there is no benchmark, planning goals for Puerto Rico are determined on local stakeholders and experts' opinions) for the selected indicators that will help measure positive or negative change through time.

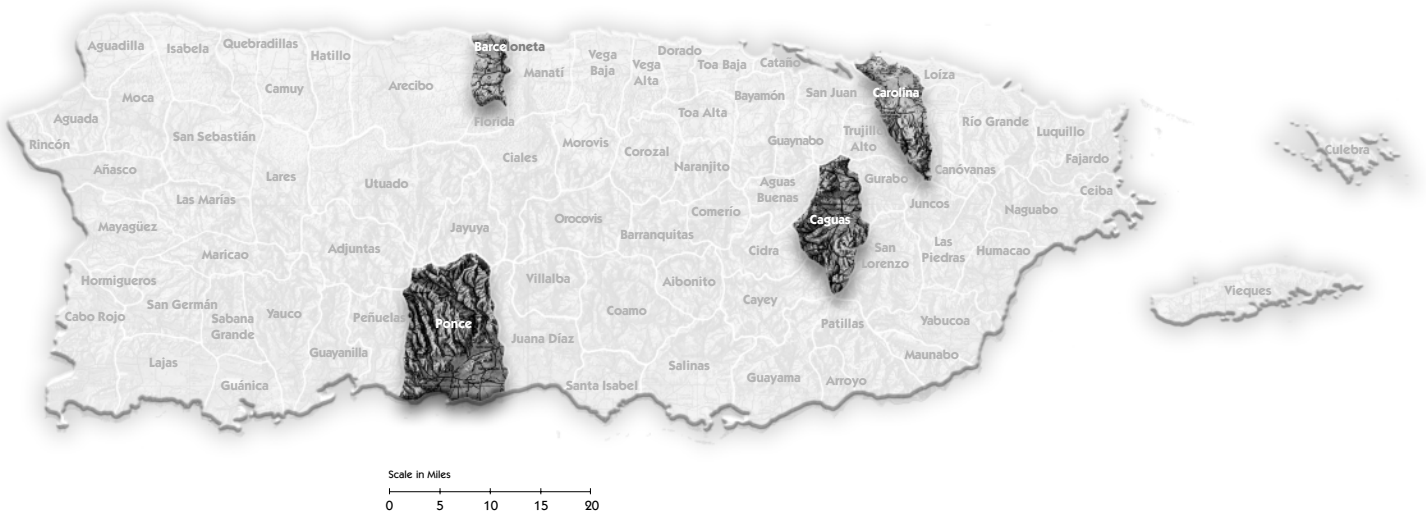
2. PROVIDE AN INDEX to communicate in a simple way status (Current Situation) and measure progress.
3. RECEIVE CONSTANT FEEDBACK AND COLLABORATION for the decision-making process and for recommendations by stakeholders, experts and partners (External Advisory Committee and key experts).

Steps in the Methodological Approach of the CUTOP Model

Sixteen steps were taken in this methodological approach:

1. Definition of the information needed and literature review on the topic (understand the context for sustainability indicators and indices).
2. Construction of the Conceptual Model based on the aim of the project (clarify the methodology).
3. Site selection and characterization (selection of the case studies to establish the parameters which will eventually be used for other municipalities).
4. Selection and gathering of external stakeholders in an advisory committee for collaboration in the research and the decision-making processes, and for the endorsement of the project.
5. Selection of a preliminary list of possible indicators.
6. Collection and analysis of available information and digital data for the preliminary indicators.
7. Analysis of GIS maps, aerial photographs and satellite data for the preliminary indicators that needed to be developed with this technical tool.
8. Validation of indicators with sufficient and reliable data and elimination of indicators with insufficient or unreliable data.
9. Selection of the final list of indicators based on specific criteria.
10. Development of the mathematical model for the index.
11. Development of the selected indicators with their results (Current Situation, how things are) after steps 5, 6, 7, 8 and 9, and dividing them into categories.
12. Selection of benchmarks or planning objectives for each indicator (Optimal Situation, how things should be); and dividing them into stressors or relievers.
13. Assignment of appropriate sustainability weight to the indicators under each category.
14. Final reevaluation and validation all the information and digital data, the methodologies used for the development of each indicator and its result by the Project Team (one-to-one interviews with key technical personnel from Commonwealth and federal agencies and other experts), the External Advisory Committee and an external evaluator.
15. Data integration for the sustainability index (composite index model).
16. Analysis and evaluation of the outcomes for each indicator and the index for conclusion and recommendations.

Figure 5: Case Studies: Barceloneta, Caguas, Carolina and Ponce



Territorial Unit

The territorial unit used is the municipality. There are 78 municipalities (equivalent to townships or counties) in Puerto Rico and the local Autonomous Municipalities Act (Public Law 81 of August 30, 1991, as amended) allows each of them to develop and implement a land use plan.

Target Audience

Decision-makers at the municipal level are the key audience, although the model has been developed for the understanding of the general public.

Progress Evaluation Period

The evaluation period selected is eight years because municipalities are required to revise their land use plans at least every eight years, by virtue of Public Law 81 of 1991.

Case Studies

Four municipalities were used as case studies: Caguas, Barceloneta, Carolina and Ponce. These municipalities have land use planning offices. Ponce, Caguas and Carolina have GIS divisions with documented historical and digital data. The case studies also represent different regions with varying socio-economic and landscapes scenarios.

Table 1: Highlights of the Case Studies[14]

Variable	Barceloneta	Caguas	Carolina	Ponce
1. Year founded	1881	1775	1857	1692
2. Km²	48.43	152.03	117.33	297.07
3. Wards ("barrios")	4	11	13	31
5. Population	22,322	140,502	186,076	186,475
6. Population density by km²	461	924	1,586	628
7. Median age	31.1	33.3	33.5	33.5
8. Housing units	8,375	50,568	71,347	66,471
9. Employment rate	76.2	83.8	92.9	74.9
10. Major employment sector(s)	Industrial (mostly pharmaceutical)	Educational, Health and Social Services	Retail Trade	Retail Trade and Construction (Considered the economic pole of the southern part of the island)
11. Location, ecological life zones and substrate (geoclimatic information)	Costal / north-central. Subtropical moist forest. The northern portion consists of wetlands (moist saline and non-saline) and alluvial plain, and the southern part is limestone (tropical karst).	Interior / central. Mostly subtropical moist forest with some subtropical wet forest to the south. Dominated by mountains from the central volcanic region of the island and alluvial plain (Caguas Valley).	Coastal / north-east. Subtropical moist forest. The northern portion is dominated by wetlands (moist saline), alluvial plain and the south is part of the central volcanic region.	Coastal / south-central. Mostly subtropical dry forest (coastal south), where the weather is relatively dry and hot, and to the north mountainous with subtropical moist and west forest. The coastal south has dry saline wetlands and alluvial plain, and the mountainous north is part of the central volcanic region.

[14] Most of the information is from the 2000 U.S. Census and Gould et al.,2008.

Indicators' Selection Criteria

Based on the reviewed literature, the following eight criteria were used to select the indicators for this project:

1. RELIABILITY AND VALIDITY of the all the data based on the best available technical and scientific information in government agencies and other sources (complete, most recent information, and with a methodology).
2. SIMPLICITY AND LIMITED IN NUMBER for easy comprehension to the target audience and the general public.
3. RELEVANCE, FUNCTIONALITY AND PRACTICALITY for planning and for assessing progress at the municipal level to help improve outcome of decision-making, preferably through the implementation of public policy.
4. AVAILABILITY AND EASY ACCESSIBILITY AND MANAGEMENT of the information for the municipalities to be able to obtain, verify and reproduce.
5. ADAPTABILITY TO DIFFERENT SCENARIOS because there are 78 municipalities with varying environmental, social and economic characteristics.
6. ABILITY TO EVALUATE CURRENT SITUATION AND FUTURE TRENDS for continuity in their use (the data can be collected and updated with some frequency or can be used to forecast tendencies).
7. HAVE QUANTITATIVE AND QUALITATIVE VALUE for the target audience and the general public.
8. AFFORDABILITY in the process of obtaining the data, its validation, the reproduction of the indicators and the feasibility of initiating a monitoring process that will help measure progress in the future.

Mathematical Model for the Index

Required Actions to Develop the Index

To develop the index, the Project Team and the External Advisory Committee carried out the following tasks:

- Selected the final indicators;
- defined benchmarks or planning objectives for each of the indicators;
- classified the indicators into relievers and stressors;
- and assigned weights for each of the indicators.

The Component Series: Indicators

The indicators to be used in the index fell into two major and mutually exclusive categories:

- Stressors – Factors that reduce the sustainability of land use activities.
- Relievers – Factors that improve the sustainability of land use activities.

The Stressors Index (STI)

Each stressor indicator is designated a lower case letter x. There are n stressors identified as:

$$x_1, x_2, x_3, \ldots\ldots, x_n$$

For example, x_1 could be the amount of *solid non-hazardous waste generation per resident* in a given municipality.

For each of the stressors, the Project Team and the External Advisory Committee defined a benchmark or planning objective representing a value for that particular indicator.

Each stressor is divided by its benchmark or planning objective and multiplied by 100 to produce an indexed value for the stressor that is designated with an upper case letter X. The indexed value ranges between 1 and 100. There are then a list of n indexed stressors identified as:

$$X_1, X_2, X_3, \ldots\ldots, X_n$$

The n indexed stressors are combined into the Stressors Index, as follows:

$$STI = X_1^{\alpha} X_2^{\beta} X_3^{\gamma} \ldots X_n^{\zeta}$$

The exponents α, β, γ,... ζ are weights assigned by the Project Team and the External Advisory Committee to each of the indicators. If all were to be equally weighed, the exponent in each case would be 1/n. However, the Project Team and the Advisory Committee assigned different weights to the various stressors.

The STI can take on values in the range 1 to 100. A value of 100 means that each of the n stressors has reached the worst possible state for the municipality in question. A value of one means that each of the individual stressors is entirely absent; which is an unattainable ideal state.

The Relievers Index (RI)

Each reliever indicator is designated a lower case letter y. There are m relievers identified as:

$$y_1, y_2, y_3, \ldots\ldots, y_m$$

For example, y_1 could be the percentage of *land officially protected* in a given municipality.

For each of the relievers, the Project Team and the External Advisory Committee defined a benchmark or planning objective representing an optimal value for that particular indicator.

Each reliever is divided by its benchmark and multiplied by 100 to produce an indexed value for the reliever that will be designated with an upper case letter Y. The indexed value ranges between 1 and 100. There are a list of m indexed relievers identified as:

$$Y_1, Y_2, Y_3, \ldots\ldots., Y_m$$

The m indexed relievers are then combined into the Relievers Index, as follows:

$$RI = Y_1^{\alpha} Y_2^{\beta} Y_3^{\gamma} \ldots Y_m^{\zeta}$$

The exponents $\alpha, \beta, \gamma, \ldots \zeta$ are weights assigned by the Project Team and the External Advisory Committee to each of the indicators. If all were to be equally weighed, the exponent in each case would be 1/m. However, the Project Team and the Advisory Committee assigned different weights to the various relievers.

The RI can take on values in the range 1 to 100. A value of 100 means that each of the m relievers have reached the best possible state for the municipality in question. A value of one means that each of the individual relievers is entirely absent; which is the worst possible state.

The Index of Sustainable Land Use Activity (ISLA)

The Relievers Index and the Stressors Index are then combined into a single index to measure sustainability, as shown below:

$$ISLA = \sqrt{\frac{RI}{STI} \times 100}$$

Multiplication by 100 and the taking of the square root are mathematical transformations designed to generate an easy-to-read scale for the index. As designed, the index can take on values between 1 and 100. A value of 100 is the best-case state, while a value of 1 is the worst-case state.

Figure 6: ISLA Values from Very Low Sustainability to Very Strong Sustainability

A value of 10 happens when the STI and RI have the same value, in which case they cancel each other out. For readings below 10, the STI is larger than the RI and ISLA is stressor-dominated (or very low in sustainability). For values higher than 10, ISLA is reliever-dominated (or starting to improve in sustainability). A reading of 10 is a stalemate marking the threshold in sustainability. The figure above presents the proposed interpretation of the ISLA values.

OUTREACH AND EXTERNAL COLLABORATION

The systematization of the link between stakeholders and the project was achieved through:

- An External Advisory Committee that met regularly.
- The Project Team participation in public activities.
- One-to-one meetings and interviews with informed representatives of key government agencies.
- The collaboration of the University with government agencies in related public policy initiatives.

External Advisory Committee

The Committee met regularly once every two to three months during the first two years of the project. The last year, the Committee met once for the presentation of the final results and to discuss conclusions and recommendations. Its members were assigned representatives from the following federal and local government entities (see Appendix C for the participants):

- U.S. Department of Agriculture (USDA), Forest Service, International Institute of Tropical Forestry
- USDA, Natural Resources Conservation Services (NRCS)
- P.R Department of Agriculture (PRDA)
- P.R. Department of Natural and Environmental Resources (PRDNER)
- PR Environmental Quality Board (PREQB)
- PR Planning Board (PRPB)
- 13 municipalities (as a sample of the 78 municipalities in Puerto Rico), including the 4 case studies.
- A representative from the Puerto Rico Planning Society's Board of Directors.
- Estudios Técnicos, Inc. and Advantage Busines Consulting, two local planning and economic consulting firms from the private sector.

Public Meeting

An important opportunity for stakeholders' participation, in addition to the External Advisory Committee, was the Puerto Rico Social Forum held the week of November 13, 2006 at the University of Puerto Rico, Río Piedras Campus. The activity, which had more than 1,500 attendees, presented a wide range of topics, including our project: *Sustainability of Land Use in Puerto Rico.* During our presentation on November 19, several important recommendations for the indicators were provided by the attendees. Some of these were incorporated into the final list of indicators.

OUTREACH AND EXTERNAL COLLABORATION

Government Outreach

An important task was obtaining the collaboration of key federal and local government agencies in order to obtain and validate information. The Project Team met and interviewed key technical personnel from the following agencies:

- USEPA's Caribbean Office
- USDA, NRCS
- USDA, Forest Service, International Institute of Tropical Forestry
- PRDA
- P.R. Department of Health (PRDOH)
- PRDNER
- P.R. Electric Power Authority (PREPA)
- PREQB
- PRPB
- P.R. Solid Waste Management Authority (PRSWMA)
- P.R. Aqueduct & Sewer Authority (PRASA)

Others

The Project Team interviewed Aurelio Mercado, Ph.D., Director of the Coastal Hazards Center, Sea Grant Program, Department of Marine Science of the University of Puerto Rico, Mayaguez Campus for two of the indicators: *Coastal flood hazard* and *Residents living in floodways*.

Also, the University was invited to be part of the Sustainable Committee for the PRPB's Land Use Plan (required by the Puerto Rico Land Use Plan Act, Public Law 550 of October 3, 2004) and to collaborate with the PREQB on the development of island-wide environmental indicators for Puerto Rico (required by the Sustainable Development Public Policy Act, Public Law 267 of September 10, 2004, as part of the Puerto Rico Annual Environmental Quality Report for the Legislature and the Governor as required by the new amendment of the Environmental Public Policy Act, Public Law 416 of September 22, 2004).

In addition, this project enhances key ongoing initiatives at UMET. First, the Puerto Rico Spanish version of the International City / County Management Association (ICMA) and Smart Growth Network's educational publication *Getting to Smart Growth: 100 Policies for Implementation* (available to download in PDF in the Internet at www.proyectosambientales.info). Second, the two-day seminar on *Urban Redevelopment: Incorporating Communities* held on January 18 and 19, 2007 with the participation of the Office of Policy, Economics and Innovation of the Development, Community and Environmental Division of the USEPA in Washington, D.C., the University of Maryland and Smart Growth Network.

SCIENTIFIC SOUNDNESS AND RELEVANCE

The analysis involved selecting, evaluating and validating the indicators through published research studies, best available and accessible quantifiable data sources in different government agencies, and interviews with local scientists and informed stakeholders for the quality control and relevance of the indicators to the aim of the project and the realities of Puerto Rico.

The following environmental assessment approach was used for the overall research process:

- The collection, organization and analysis of available and best reliable data in Puerto Rico to evaluate the likelihood of the impact of different stressors or relievers that could measure progress towards sustainability. See page 18 for the indicators' selection criteria list and Appendix D: Rational and Methodology of Each Indicator.

  In addition, the use of GIS as a technical and analytical tool for geoprocessing to generate derived data sets. This includes, among other things, line distance, spatial and cluster analysis for building some of the indicators. See Appendix D. The digital data used are official and updated (most reliable and recent) from various federal and Commonwealth agencies, and from case studies (municipal governments): PRPB; PRDNER; Municipal Revenue Collection Center (MRCC); municipal planning and land use offices from the four case studies; 2000 U.S. Census Bureau data sets (Housing units shapefile [block centroids]-Summary File 3 [SF-3], Population shapefile [block centroids]-Summary File 1 [SF-1] and TIGER/Line files for roads); USDA, NRCS' GIS soils database; and Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Maps (FIRM). These digital data were provided via disks, e-mail or downloaded from the agencies' electronic bulletin boards or as hard copy. They were also received in different formats: ArcView shapefiles, ArcInfo coverages, and Arc export files.

- The proposal of a conceptual model to develop a sustainability index was based on: (a) two basic scenarios – the current situation and a desired or optimal situation for sustainability – (b) and measurement endpoints using indicators with benchmarks or planning objectives for the optimal level for each indicator. See page 14 for the CUTOP Model.

- An index that summarizes and integrates the quantities and qualitative expressions of unsustainability risk (from weak or low in sustainability to strong or high in sustainability). These expressions are accompanied by an explanatory text interpreting the results and recommendations for actions or public policies for sustainability purposes. See page 18 for the ISLA (index) and the Results and Recommendations sections.

- The use of case studies to establish the parameters that will be used later for other municipalities on the island. See page 16 for the case studies.

Quality Control

The Project Team assessed quality in the research process through:

- One-to-one interviews with executives and key technical personnel in government agencies which provided most of the information and digital data for the indicators and with other local experts on the related topics.
- Revision of the rationale, methodology and the results of each indicator by an external evaluator (Estudios Técnicos, Inc.).
- Presentation of the methodologies and the results of each indicator to the External Advisory Committee composed of key stakeholders for their feedback and final validation.
- For the indicators that use the GIS tool, the analyses were performed several times with two GIS Analysts to corroborate the results. This, in turn, helped reevaluate and refine the methodologies of these indicators.

RESULTS

Results of the Indicators

Over 50 indicators were identified for the first group of indicators. After analysis and evaluation of this preliminary group based on the criteria explained in the Methodology Section, the amount was reduced to 22 indicators.

The final 22 indicators were divided in four categories following the External Advisory Committee's recommendations: Environmental, Socio-economic, Infrastructural and Institutional. Some of the indicators could have been in more than one category (for example, *Land officially protected* could have been under the Environmental category but it is under Institutional). The decision for the name and the category of each selected indicator was based on:

- The substantive nature and the main purpose of each one.
- Its benchmark or planning objective to show progress towards sustainability based on local idiosyncrasies, challenges and needs, and the people responsible for its achievement.
- Its communication strategy, when it was written and categorized to bring attention and incite action from the target audience and for public policy.

Table 2: Indicators and Categories for Sustainability of Land Use

ENVIRONMENTAL

1. Water pollution risk due to lack of sewer connection
2. Development pressure on rural land
3. Accessibility to public natural open spaces in urban areas
4. Solid non-hazardous waste generation per resident
5. Total recycled solid non-hazardous waste
6. Coastal flood hazard
7. CO^2 emissions per household
8. Release of toxic substances to the environment by industries
9. Water consumption per household

SOCIO-ECONOMIC

10. Highly valuable agricultural lands
11. Active agricultural lands
12. Residents who work where they live
13. Re-population of urban areas
14. Residents living in floodways
15. Socio-Economic Index

INFRASTRUCTURAL

16. Inaccessibility to public transportation
17. Use of public transportation to reach work
18. Footprint of public roads
19. Inaccessibility to safe drinking water

INSTITUTIONAL

20. Approved Municipal Land Use Plan
21. Fiscal Fragility Index
22. Officially protected land

RESULTS

After the final list of indicators was selected and categorized, the following steps were followed, as explained in the Methodology Section, to calculate the ISLA (index). This was done with the continuous counsel of the External Advisory Committee:

1. Development of each selected indicator with their results (Current Situation).
2. Selection of a benchmark or planning objective for each indicator (Optimal Situation).
3. Classification of the indicators into stressors and relievers.
4. Assignment of sustainability weights under each category.

Table 3 in the next pages (pages 28 and 29) illustrates the results of the above four steps. For details by indicator see Appendix D (Rationale and Methodology of Each Indicator).

Table 3: Results by Indicator per Case Study

ENVIRONMENTAL

1 **Water pollution risk due to lack of sewer connection** Measurement: Houses without a sewer connection to PRASA as a percentage of the total number of housing units.

2 **Development pressure on rural land** Measurement: Housing density on the Common Rural Land (houses per km2).

3 **Accessibility to public natural open spaces in urban areas** Measurement: Residents living in the urban area within a 15-minute walk (500 meters) from parks and other public natural open spaces as a percentage of the total urban population.

4 **Solid non-hazardous waste generation per resident** Measurement: Solid non-hazardous waste generation in pounds per resident per day from total municipal waste generation.

5 **Total recycled solid non-hazardous waste** Measurement: Total recycled solid non-hazardous waste as a percentage of total annual municipal waste.

6 **Coastal flood hazard** Measurement: Total housing units in coastal flood hazard areas (Zone VE) to be potentially affected by storm surges.

7 **CO2 emissions per household** Measurement: Annual release in pounds of CO2 per kWh of electric energy consumption per household.

8 **Release of toxic substances to the environment by industries** Measurement: Annual on-site disposal of toxic substances in pounds, per km2, by industries regulated by EPCRA.

9 **Water consumption per household** Measurement: Water consumption in gallons per household (PRASA's residential clients) per day.

SOCIO-ECONOMIC

10 **Highly valuable agricultural lands** Measurement: Highly valuable agricultural lands as a percentage of total Rural Land.

11 **Active agricultural lands** Measurement: Active agricultural lands as a percentage of total Rural Land.

12 **Residents who work where they live** Measurement: Total number of residents who work in the municipality as a percentage of the total number of workers-residents.

13 **Re-population of urban areas** Measurement: Population density in urban areas or Urban Land (persons per km2).

14 **Residents living in floodways** Measurement: Total number of residents living in floodways (AE floodways).

15 **The Socio-Economic Index** Measurement: Index of municipal socio-economic activity.

INFRASTRUCTURAL

16 **Inaccessibility to public transportation** Measurement: Wards that are not served by at least one public transportation route that connects to the urban center as a percentage of total wards.

17 **Use of public transportation to reach work** Measurement: Change in percentage points in the use of public transportation to reach work by workers-residents 16 years and over.

18 **Footprint of public roads** Measurement: Kilometers of public roads per square kilometers of municipal land.

19 **Inaccessibility to safe drinking water** Measurement: Total number of residents served by PRASA and the Non-PRASA public water systems that are "significant non-compliers" (SNC).

INSTITUTIONAL

20 **Approved Municipal Land Use Plan** Measurement: Municipal Land Use Plan approved by the PRPB.

21 **The Fiscal Fragility Index** Measurement: Index to measure the municipal fiscal situation.

22 **Officially protected land** Measurement: Land officially and actively protected through management or ownership by federal, state and municipal governments, and NGOs, classified as Specially Protected Rural Land, as a percentage of total municipal land.

34.0%	30.0%	46.0%	25.0%	5.5% reduction	S	0.5
89.0%	73.0%	72.0%	89.0%	All the urban residents	R	1.5
2.3%	3.2%	0.8%	6.8%	35%	R	3.9
8,327	11,416	8,326	10,522	16% reduction	S	0.4
142	164	182	143	27% decrease	S	0.6 / **10**
5.8%	19.9%	61.0%	32.6%	No change	R	1.6
86.4%	56.1%	56.2%	41.8%	60%	R	1.9
3,236	3,839	669	1,410	No residents (0)	S	0.9
55.0%	9.0%	0%	23.0%	100% - all wards	S	5.8
4.36	5.18	4.6	6.11	No increase	S	1.5
1	1	1	1	1 Approved	R	3.8
33.1%	4.5%	52.6%	22.5%	No reduction	R	1.8 / **10**

Results of the ISLA

After applying the benchmarks or planning objectives and weights, the following results were obtained:

Table 4: Results of the Relievers and Stressors Indices and ISLA

Index	Ponce	Caguas	Barceloneta	Carolina
Relievers Index	15.0416	14.9922	14.6850	15.2824
Stressors Index	19.4268	19.4044	18.1049	18.9020
Summary Index (ISLA)	8.7993	8.7899	9.0061	8.9917

As shown in the above table, none of the four municipalities used as case studies passed the 10-point threshold between sustainability and unsustainability. The table also shows that stressors have a dominant influence on the summary value of the index: the stressors index is on average about four points higher than the relievers index.

Looking at the individual indicators, seven were identified as critical action areas for the municipalities to improve land use sustainability: four of these are stressors and three are relievers.

As shown in the next table, four of the 12 stressors indicators contributed half of the total value of the stressors index. Two of these, *Inaccesibility to public transportation* and the *Fiscal Fragility Index*, have relatively high weights and demanding benchmarks. Improvements in public transportation would go a long way to increase land use sustainability, and may be achieved in a relatively short period of time. Thus, it is strongly recommended to the four municipalities in the study. Fiscal fragility is not easy to overcome in a short period of time, but evidently it should also get more attention from municipal governments.

On the relievers' side, three made particularly low contributions to the total value of the relievers index, which suggests they should be addressed in policy. Barceloneta stood out as doing very poorly in recycling, although the four municipalities have substantial room to improve. It is also important to encourage the cultivation of existing agricultural lands and to foster greater use of public transportation to travel to and from the workplace.

Table 5: Key Indicators to Improve Sustainability

#	Description	Benchmark	Weight	Contribution %
	STRESSORS			
16	Inaccessibility to public transportation	0 inaccessibility (100% of all wards)	5.8	20.75
21	The Fiscal Fragility Index	0	4.4	14.32
18	Footprint of public roads	No increase	1.5	7.62
19	Inaccessibility to safe drinking water	0 residents	1.6	7.58
	RELIEVERS			
5	Total recycled solid non-hazardous waste	35% minimum	3.9	7.93
11	Active agricultural lands	No negative change	1.0	8.28
17	Use of public transportation to reach work	6% points increase	1.1	8.34

FINAL REMARKS

According to the results of the CUTOP Model, Ponce, Caguas, Barceloneta and Carolina are not sustainable. Although these municipalities have taken specific measures to become more sustainable, the Model indicates that they are making slow progress. The four case studies reflect the situation in Puerto Rico, and if trends are not reversed, it appears that the Island will continue on an unsustainable path. So the results of most of the indicators (Current Situation) and the ISLA confirm that Puerto Rico and its municipalities are not sustainable. The Model proposed allows the municipalities to establish policies and actions that will move them towards becoming more sustainable.

Some of the most important challenges for sustainability in Puerto Rico have already been mentioned in the introduction of this Report and in the rationale of each indicator in Appendix D. To summarize, some of the most fundamentals challenges are:

1. INEFFICIENCY IN LAND USE

Forty percent (40%) of Puerto Rico is experiencing a high degree of urban sprawl encroaching rural and valuable agricultural lands according to a recent study. Most of the urban centers in the municipalities appear surrounded by sprawling development. In addition, the increase in constructed area does not correspond with the increase in population. For example, while constructed area increased by 1,286% between 1936 and 2000 in the SJMA, population increased 303%, showing a high degree of inefficiency in land use. Land use is at the heart of achieving sustainability, and this is critical for Puerto Rico due to its size, overpopulation and the political reality of being divided into 78 municipalities with individual influence over land use decisions by virtue of the Autonomous Municipalities Act of 1991.

2. MUNICIPAL FISCAL FRAGILITY

In spite of the fact that the Autonomous Municipalities Act of 1991 allows decentralization for land use decisions and regulations (subject to a series of procedural and substantive conditions), according to statements made by the executive directors of the two groups that represent the mayors of the 78 municipalities (the Association of Mayors and the Federation of Mayors), 49 of the 78 municipalities (63%) do not generate enough income to pay 50% of their regular expenses. And of those 49 municipalities, 18 (23%) depend a total of 75% on the Central Government to cover their expenses and 5 (6%) depend a total of 90% (Santana-Ortíz, 2007ab). This means that half of the municipalities do not have or have very few economic and fiscal resources to invest in programs, projects and activities that might be needed to move towards sustainability.

3. ABSENCE OF AN EFFICIENT, RELIABLE AND INTEGRATED PUBLIC TRANSPORTATION SYSTEM AND A HIGH PROPORTION OF KILOMETERS OF ROAD BY KM^2 OF TERRITORY

Puerto Rico ranks third in the world in density of vehicles per inhabitant (in 2005 it had 2.8 million vehicles, almost one car per inhabitant). This gives an idea of the amount of CO_2 the island is emitting to the atmosphere if an average passenger car emits about one pound of CO_2 for every mile traveled. Approximately 89% of the workers use private vehicles to reach their work place and about half of these works in municipalities

different from the one where they live. Daily commuting is most common among municipalities. The increase in the number of automobiles registered can be correlated with the increase of kilometers of roads. The island has one of the highest proportions of kilometers of road by km^2 of territory when compared to other countries (1.50 kilometers of road per km^2 of territory).

4. SOLID WASTE GENERATION AND MANAGEMENT

Puerto Rico generates more solid waste per person per day (5.56 lbs.) as compared to countries in Latin America (1.7 lbs.), Europe (2.2 lbs.) and the United States (4.5 lbs.), according to published data. Generation of solid waste continues to increase. Between 2003 and 2007, solid waste generation increased by 16% even though population rate decreased. In addition, recycling rate is low compared to other countries and compared to our own recycling goal of a 35% recycling rate, according to Act 70 of 1992 as amended in 1996 and 2000. In 2008, this goal had not yet been reached. Our traditional recycling rate island-wide at the present moment is approximately 15% (the amount of recyclable materials per person per day is around .49 pounds and this contrasts with our disposal rate of 5.56 lbs.). This situation worsen when considering that there are 32 landfills on the island with a useful life of only 12 years and of these, five will start to close in the next five years due to non-compliance with environmental laws.

5. FOOD SECURITY / AGRICULTURAL ACTIVITY

Approximately 85% to 90% of all the food consumed in Puerto Rico is imported. At the present moment only .75% of the island's GNP and .49% of the GDP comes from agriculture, as a result of the devaluation and abandonment of agriculture in favor of industrialization in the 1940's and 50's. In addition, the past 30 years have represented a loss of approximately 30% of agricultural lands to other non-agricultural uses.

6. ACCESSIBILITY TO SAFE DRINKING WATER

Even though the great majority of Puerto Ricans have access to safe drinking water; in 2008, 49% of all the reported PRASA and Non-PRASA public water systems were in some sort of violation. Of these, 9% of PRASA systems and 55% of Non-PRASA systems were persistent violators.

7. POLLUTION OF WATER BODIES

Approximately 30.3% of all monitored river and stream miles are impaired and do not support their designated uses. All the lakes are considered to be impaired for aquatic life. Sixty six percent (66%) of the monitored estuarine acres and 53.3% of stream miles that form part of the estuaries are also impaired. In addition, 45% of the population in Puerto Rico, almost two million people, lacks sanitary sewer service. Most use septic tanks which do not work adequately due to lack of proper monitoring and maintenance. This might be one of the principal sources of water pollution.

8. WATER AVAILABILITY FOR CONSUMPTION

Published data have shown that Puerto Rico is included in the 30% of the countries that have less water available per capita. According to PRASA, consumption of water is still growing and the island currently does not have sufficient space to construct more damns.

9. LAND CONSERVATION FOR FUTURE GENERATIONS AND FOR BIODIVERSITY

Only 7.6% of the land is officially protected by some form of management for biodiversity according to the recent Puerto Rico Gap Analysis Project. The Government of Puerto Rico has established a goal to increase the amount of protected lands by 100,000 acres in the next 5 years. If the goal is met, the land officially protected will represent around 12% of the territory. The Gap Analysis Project recommends a minimum of 15% for the protection of biodiversity. The Nature Conservancy recommends 30%.

10. CO_2 EMISSIONS AND CONTRIBUTION TO GLOBAL WARMING

Ninety nine percent (99.5%) of the energy produced in Puerto Rico comes from burning fossil fuels. Puerto Rico has the highest consumption of electric power by square kilometer and it is the third in the world in consumption of megawatts per inhabitant. The Director of the Caribbean Division of the EPA calculates that Puerto Rico contributes to global warming 230% more than the average inhabitant worldwide and 333% more than the average inhabitant of Latin America and the Caribbean.

11. COASTAL FLOOD HAZARD

Puerto Rico is not taking measures to counteract erosion in coastal areas nor to protect life and properties due to the expected increases in the frequency and intensity of storm surges and the average sea level as a result of climate change. Construction in the coastal maritime zone boundaries continues even though there are laws that limit construction in this zone and, as a result, the population living in coastal areas exposed to storm surges keeps increasing (studies show that in the last decade the population increased by 12.1%).

When using the CUTOP Model stakeholders should also take into account the following points for its implementation:

SHARED JURISDICTION BEYOND THE INDIVIDUAL MUNICIPAL BOUNDARY

As mentioned before, a challenge encountered in this Report was the use of the municipality as a unit of analysis. Considering that the average size of the 78 municipalities is only 113.7 km^2, a considerable amount of the information gathered for the indicators overlapped in scope and origin since the impacts of most land use related activities are at the regional scale. Natural systems, such as watersheds, do not correspond to political boundaries and this is a challenge that should also be considered when preparing or updating municipal land use plans. So to intervene in these systems, there must be cooperation in shared jurisdictions between adjacent municipalities that could seek out opportunities to work as a region with the support of several central government agencies or public corporations.

SPECIFIC CONSIDERATIONS FOR EACH MUNICIPALITY

Even though the CUTOP Model has been designed to help jurisdictions evaluate themselves across time and against each other, it is important to point out that the use of the Model should also consider dissimilar conditions between municipalities when doing individual historical trends evaluations or when doing comparisons with other jurisdictions. The use of the Model should incorporate the geographic, environmental and socio-economic context of each municipality to better define the application of each of the indicators and their assigned sustainability weight. This is important since some of the indicators (either stressors or relievers) can vary somewhat based on the specific local realities and this should be taken into account. This is something that will always come across when selecting indicators and when calculating an index to compare performance among countries, regions, cities or communities since, as evidenced in the literature review, there are few, if any, key indicators that could apply the same way across even similar systems.

IMPLEMENTATION OF LAWS AND REGULATIONS

As mentioned in Appendix A, from a legal standpoint Puerto Rico has enough laws and regulations, as well as plans and programs, in place that aknowledge the importance of sustainable development and land management. The Island does not need more normatives in this area. Normatives just need to be effectively implemented and, when necessary, ammended or tempered to meet the realities and challenges of the 21st century.

GENERAL RECOMMENDATIONS

An Island-wide Land Use Plan

This report highlights the pressing need for Puerto Rico to have in place a functional island-wide-land use plan. The PRPB would use this island-wide land use plan as a framework to guide the integral development of the Island and to provide direction and coherence to the municipalities on their local land use plans.

In 2004 the Puerto Rico Legislative Assembly ordered the PRPB, by virtue of Public Law 550, to develop the Puerto Rico Land Use Plan. In February of 2006, the PRPB developed a draft version of the Plan with information presented in public hearings during that same year. However, at the present time there is no island-wide land use plan or timetable to finish it.

The sustainable development of the scarcest resource in Puerto Rico (land) depends heavily on the making of this Plan. With the inclusion of clear smart land use policies and a common agreed vision into the plan, Puerto Rico could be on the path to a sustainable future.

Responsible entities: PR Legislative Assembly and PRPB

Municipalization and Regionalization

Because of the serious limitations imposed by the excessive centralization of functions in the central government, which has led to inefficiency, as well as jurisdictional and fiscal limitations of the municipalities, it is recommended the decentralization of the central in regional governments. Such regional governments should be composed of several municipalities that would represent equally the total population of the Island, and with the economic capacity to carry out activities that are now executed by the State. This regionalization, by virtue of public policy, should emphasize cooperation and shared responsibilities for those social, economic and environmental activities that are more regional in scope and impact.

By grouping municipalities in regions and facilitating them with key administrative decision-making powers, this would allow them to respond faster and more effectively to the challenges of sustainability. As the international known phrase goes "Think Globally, Act Locally".

Already the United Nations Institute for Training and Research (UNITAR) has recognized the importance of local and regional players in the achievement of sustainability through its Decentralization Cooperation Programme (DCP)[15] which provides training to local actors (authorities, public and private companies, civil society and academia) to enhance their capacity to implement international agreements and the United Nations' Millennium Development Goals[16]. The training sessions focus on four major areas: environment and sustainable development, urban services, economic development and local governance, and human security. The seminars are implemented through a network of regional associated training centers known as CIFAL ("Centre International de Formation des Autorités/Acteurs Locaux" or International Training Centre for Local Authorities/Actors).

Regionalization policies all over the world have been used as a smart development strategy. For example, since the 1980's, the European Union promotes an integral strategy of the territories of its Members-States based on (Council of Europe, 1983):

- A balanced socio-economic development of the regions,
- the improvement of the quality of daily life,
- the responsible management of the natural resources and the protection of the environment,
- and the rational use of the land.

Responsible entities: PR Legislative Assembly and the municipal governments.

Incorporate the use of the indictors and the ISLA (Index) in the decision-making process

Municipalities can incorporate the indicators, with their benchmarks or recommended planning objectives, and the ISLA in their core processes of decision-making through a municipal ordinance. Appendix E provides an example of such an ordinance.

Responsible entities: The Mayor and the Municipal Assembly

Adoption of Smart Growth Principles

According to the Smart Growth Network[17] "what, where and how we build have major impacts on our personal lives, our communities and our nation. And in communities where development has improved daily life, the economy, and the environment, Smart Growth principles have been a key to that success." The term "smart growth" refers to the concept that integrates the best planning and urban development practices which consider the well being of communities and the environment. The concept has international acceptance and recognition because of its universal character and the common sense of its principles which are framed within the sustainable development context of justice for generations to come.

15 For more information about UNITAR and DCP see http://dcp.unitar.org.

16 The Millennium Development Goals (MDGs) are eight goals to be achieved by 2015 that respond to the main development challenges for the 21st century. They are drawn from the actions and targets contained in the Millennium Declaration which was adopted by 189 nations during the UN Millenium Summit in September 2000. The eight MDGs break down into 21 specific and quantifiable targets that are measured by 60 indicators. The eight goals are:

(1) Eradicate extreme poverty and hunger
(2) Achieve universal primary education
(3) Promote gender equality and empower women
(4) Reduce child mortality
(5) Improve maternal health
(6) Combat HIV/AIDS, malaria and other diseases
(7) Ensure environmental sustainability
(8) Develop a Global Partnership for Development

17 As quoted in the Smart Growth Network web page: http://www.smartgrowth.org

Smart Growth is fundamentally based on the following 10 principles:

1. Mix land uses. (Zoning for multiple uses.)
2. Compact building design. (Densification and more efficient use of the land. Well planned mixed land uses and compact building design create safe and healthy communities for all ages where homes, offices, schools and shops are at walkable distances and the surrounding infrastructure promotes public health and welfare.)
3. Increase of the range of housing opportunities and choices. (Convenient neighborhoods with affordable homes for everyone, including residents with lower incomes and retirees.)
4. Walkable cities and neighborhoods. (Wide sidewalks, with adequate trees properly maintained to provide a pleasant urban landscape and cooler environment so as to promote walking to different destinations within the city.)
5. Distinctive, attractive communities with a strong sense of place. (Places designed for people, at a human scale dimension, which foster social interaction and a sense of community and belonging.)
6. Preservation of open space, farmland, natural beauty and critical environmental areas. (Active protection and preservation of our natural heritage and agricultural lands.)
7. Development towards existing communities. (Wise investment of taxpayers' money, where time, attention, and resources are invested in maintaining and restoring community living with the revitalization of urban centers and the development of compact, mixed use neighborhoods, all of which reduce the costs of providing government related services and infrastructure [health care, public safety, education, new roads and sewage, etc.].)
8. Variety of transportation choices. (Freedom for people to choose their mode of transport, either walking, biking, by public transportation or automobile.)
9. Predictable, fair and cost effective development decisions. (Development decisions that are transparent and fair to everyone which balance the needs of residents and developers.)
10. Community and stakeholders collaboration in all the processes. (Different sectors working together for the common good.)

All the ten principles are viable in the municipalities through the adoption of clear Smart Growth public policies and through the implementation of plans, incentives, and regulations. They could positively impact – directly or indirectly- most of the indicators. But specifically they would directly impact the following: *Development pressure in rural land*, *Residents who work were they live*, *Re-population or urban areas*, *Inaccessibility to public transportation*, *Use of public transportation to reach work*, *Footprint of public roads* and *Officially protected land*.

An adaptation of the Smart Growth principles and strategies to Puerto Rico by UMET's Center for Sustainable Development Studies is now available to the public through the publication "*Hacia el desarrollo inteligente: 10 principios y 100 estrategias para Puerto Rico"*, a Puerto Rican version of the educational publication *Getting to Smart Growth: 100 Policies for Implementation* of the Smart Growth Network and the International City/County Management Association. It can be downloaded from www.proyectosambientales.info. The adaptation provides local examples of Smart Growth in our municipalities and relates strategies to local norms.

Responsible entities: PR Legislative Assembly, PRPB, PREQB, PRDNER and the municipal governments.

Endorsing the "Earth Charter"

Municipalities can go a further step in their support for sustainable development by endorsing the document of the Earth Charter. At stated in their web page, the Earth Charter is a widely recognized, global consensus statement on ethics and values for a sustainable future, developed over a period of ten years through an extensive global consultation process. This initiative, also known as the "Earth Charter Initiative" is a broad-based, voluntary, civil society effort that includes renowned international organizations (UNESCO and the World Conservation Union), national and city governments, non-government organizations and community-based groups, among others. It has already been endorsed by over 2,500 different organizations.[18] The Municipality of Caguas, one of our case studies, signed the Earth Charter on March 30, 2007 as part of the inauguration of the Caguas Botanical and Cultural Garden.

The mission of the Earth Chapter is *to promote the transition to sustainable ways of living and a global society founded on a shared ethical framework that includes respect and care for the community of life, ecological integrity, universal human rights, respect for diversity, economic justice, democracy, and a culture of peace*.

The endorsement of the Earth Charter means that the entity, in this case a city government or a municipality, has accepted the following mission to demonstrate the relevance of the Earth Charter's values and principles to global governance:

"We, the undersigned, endorse the Earth Charter. We embrace the spirit and aims of the document. We pledge to join the global partnership for a just, sustainable, and peaceful world and to work for the realization of the values and principles of the Earth Charter."[19]

Responsible entities: The Mayor and the Municipal Assembly.

18 For more information see web page http: //www.earthcharterinaction.org/content/.

19 For more information about the Earth Charter's endorsement document go to http://www.earthcharterinaction.org/content/pages/Read-the-Charter.html.

Future Research Opportunities

1. This work provides the opportunity to expand the CUTOP Model to all the other municipalities. As a next step, the University can develop a "state of land use for sustainability report" for Puerto Rico in which municipalities could be ranked every four to eight years according to their land use "eco-efficiency". Special recognition would be given to those with the greatest progress made in the implementation of the sustainability indicators. Possible partners in the selection of these municipalities could include the USEPA-Caribbean Division, the Association and Federation of Mayors, and local professional organizations such as the Puerto Rico College of Architects and Landscape Architects and the Puerto Rico Planning Society.

2. Many indicators encountered some limitations in their development due to the challenge of the reliability, measurability and availability of local data. Future work can be oriented towards addressing these limitations. This could include the development of specific data collection parameters and protocols for better quality control.

3. In the first and original list of indicators, there were several good indicators that were discarded because there were no reliable and measurable data. Future work can include the development of the data needed for some of these indicators.

4. Studies have shown that there is a correlation between public health and land use. Diseases like obesity and asthma, among others, are also related to urban sprawl and how we develop our urban areas. Future work can include health related indicators.

5. Another potential area of research is the development of a regional model based on the CUTOP Model for municipalities. As previously mentioned in this Report, the municipality as a territorial unit poses difficulties in data collection and analysis because many land use activities are regional in scope and impact. Another alternative is the development of an island-wide model based on this Model which can include regional considerations.

6. The proposed Model and its results can be presented as an education tool in appropriate forums in the Caribbean and in the United Sates to explore its transferability and adaptability to similar scenarios. This could lead to future collaborative research opportunities.

RECOMMENDATIONS BY INDICATOR

ENVIRONMENTAL INDICATORS

1. WATER POLLUTION RISK DUE TO LACK OF SEWER CONNECTION

To help achieve the planning objective of reducing by 5.5% the number of housing units without sewer connection:

- An adequate and a consistent monitoring program of septic tanks should be established by the PRDOH in collaboration with ARPE (for strict compliance with the design and construction norms of septic tanks for single family housing units), USEPA (due to the requirements of the Clean Water Act) and the municipalities. This includes the assignment of additional funds to the Auxiliary Secretariat for Environmental Health of the PRDOH to hire regional inspectors that can specialize in this area (at present, regional inspectors are overwhelmed with other inspections, including restaurants, animal farms, etc.). Municipalities can help develop and keep an inventory and maintanance schedule of single family units' septic tanks within their jurisdiction for the best monitoring.

- PRASA's annual Capital Improvements Program should integrate, as a priority and as a strategic objective, a significant reduction in the number of housing units that have septic tanks.

- PRDOH's educational efforts for health and water quality protection should also include information of the proper design, construction and maintenance of septic tanks to their owners with the collaboration of ARPE and USEPA. Educational materials could be available, free of charge, at the municipalities' planning, permits and endorsements and/o environmental offices.

- As soon as the USEPA's *Stormwater NPDES Program* is well established in Puerto Rico and this federal agency starts granting the *Stormwater NPDES Permit*, this permit should also be included as a water quality indicator for highly urbanized jurisdictions as explained in the indicator's methodological sheet.

Responsible entities: PRDOH, PRASA, ARPE, the municipal governments and USEPA.

2. DEVELOPMENT PRESSURE ON RURAL LAND

To help achieve the planning objective of not increasing housing units density in the municipality's Common Rural Land:

- Municipalities' planning and/or land use offices should prepare an assessment of the problem of individual segregations of private parcels of lands in rural areas for additional housing units (known locally as "lotificaciones simples" or simple segregations) to monitor its impact on land use changes on an annual basis and reduce it as much as possible with different Smart Growth strategies and incentives (see recommendations for the *Re-population of urban areas* indicator). An example of a strategy is the Transferable Development Rights (TDR), as provided by the Autonomous Municipalities Act (Public Law 81 of 1991) in its Article13.024. TDR can be used for protected rural land by transferring development rights to urban areas[20]. Even though the Act allows for the use of this tool by the municipalities for land use planning, as of this project it has not been properly implemented by any municipality. The approval of land use plans by the PRPB and/or the delegation of powers to the municipalities, as allowed by Public Law 81 of 1991, should be contingent on municipalities making it a priority.

  Responsible entities: PRPB and municipal governments.

3. ACCESSIBILITY TO PUBLIC NATURAL OPEN SPACES IN URBAN AREAS

To help achieve the benchmark that all urban population in the municipality should live within a 500 meters (approximately 15-minute walking distance) from a park or other public natural open space:

- As explained in the Limitations section of this indicator, municipalities need to define better the land use zoning category of parks and public natural open spaces for a more accurate analysis of the indicator and comparison with other municipalities.
- With the help of the central government, the municipalities can adopt a program of acquisition or de-appropriation of parcels of lands that have the potential of being converted into parks or other natural open spaces within urban areas to improve social, environmental and economic conditions (.i.e., increase of property values) within these developed areas.
- Prepare an inventory of the land in and around urban areas that are easements of PRASA, PREPA, PRDTPW (to protect public infrastructure) or PRDNER (around waters bodies to protect the resource) in order to determine the possibility of conditioning theses easements as natural open public spaces for passive recreation.
- Implement the recommendations provided in the State Comprehensive Outdoor Recreational Plan (SCORP) for 2008-2013. One of these recommendations is the need to provide pedestrian accessibility by creating a system of trails through linear parks that could connect different municipal or national parks, urban forests, botanical gardens and other outdoor passive recreational spaces as natural hubs in urban areas.

  Responsible entities: PRPB, PRDNER, PR National Parks Company, the PR Department of Recreation and Sports and the municipal governments.

4. SOLID NON-HAZARDOUS WASTE GENERATION PER RESIDENT

To help achieve the benchmark of reducing the amount of solid waste generated by residents to a maximum of 3.6 lbs.:

- The Reduction and Recycling Act (Public Law 70 of 1992, as amended into Public Law 411 in 2000) and the Regulation for the Reduction, Reuse and Recycling of Solid Waste (Regulation 6825) that provide norms, incentives and mechanism for the municipalities[21] and for the private sector in order to reduce waste disposal and reach the 35% recycling rate goal for the Island, both need to be consistently and appropriately implemented. So far, this has not been the case.[22] More funds should be provided to implement the reduction and recycling norms and, if necessary, amend the Act and the Regulation to be more stringent in their implementation.
- Establish a "pay-as-you-throw program" (PAYT) after recycling in each municipality as part of a municipal tax. In a PAYT program, residents are charge based on the amount of weighed waste the municipality collects from their homes after recycling. This provides a direct economic incentive to generate less waste and to recycle more. Collecting waste is then considered like any other consumption related public service or utility (electricity and water). According to the USEPA, in the United Sates communities with PAYT programs in place have reported significant increases in recycling and reductions in waste.[23]
- The PRSWMA shall update the actual data for solid waste generation since the only data available is from 2003 (Wehran-Puerto Rico Study). The update of this study should include a characterization analysis of the solid waste generated by the local population and by municipality or region (adjacent group of municipalities) to better plan.
- Any action plan should include the design and implementation of an effective educational campaign to create awareness about the reasons and the need to reduce solid waste generation (this should go hand-in-hand with educating about our consumption patterns that cause the excessive generation of waste). The municipalities can help in this educational campaign by distributing educational material among its residents and offering educational presentations in its different neighborhoods and/or wards.
- All the landfills should have a weighing systems in place to keep accurate data of the historical trends of solid waste disposition. As explained in the Limitation section of this indicator, the lack of these weighing systems compels PRSWMA to work exclusively with projections.

Responsible entities: PRSWMA, PR Legislative Assembly and the municipal governments.

20 There are several web pages that provide information about TDR: http://www.state.nj.us/dca/osg/resources/tdr/index.shtml (Sate of New Jersey), http://ohioline.osu.edu/cd-fact/1264.html (Ohio State University), http://www.kingcounty.gov/environment/stewardship/sustainable-building/transfer-development-rights.aspx (King County in Washington), among many others.

21 This includes the obligation of hiring a Municipal Recycling Coordinator and assigning funds to the Municipal Recycling Office.

22 See http://www.ads.gobierno.pr/secciones/reciclaje/ley4112000.htm for a copy of the amendments to Public Law 70 (Public Law 411).

23 See USEPA web site about the benefits a PAYT program can provide at http://www.epa.gov/epawaste/conserve/tools/payt/index.htm.

5. TOTAL RECYCLED SOLID NON-HAZARDOUS WASTE

To help achieve the benchmark of increasing the recycling rate to a minimum of 35%, the recommendations for the previous indicator *Solid non-hazardous waste generation per resident* also apply to this indicator. In addition:

- Municipalities should comply regularly and on time with their trimester reports deadlines and with the certifications of the recycling and drop off centers for the validation of the delivered materials. The PRSWMA should implement some type of penalty to the municipalities that do not comply with these norms consistently and timely. The PRSWMA should also establish a regular monitoring or inspection program to guarantee consistency of recycling data collection among municipalities.
- Recycling is still not seen in Puerto Rico as a business venture. It is mostly seen as a voluntary good will activity. The same assistance and incentives provided to other companies for starting and conducting business in Puerto Rico, should also apply to commercial recycling initiatives. In addition, special support should be provided to existing recycling cooperatives in Puerto Rico.
- All new development, including housing, commercial and industrial projects, should include a well designed recycling and composting space as a requisite to obtain construction permits. At the present moment, Puerto Rico has the Act to Create Areas in Housing Complexes for the Recuperation of Recyclable Material (PRSWMA Public Law 61 of 2002) that makes mandatory the construction of this space in residential projects. Section 20 of the Segregation and Urbanization Regulation (PRPB Regulation 3) provides specific guidelines on how to design and build this space. So far, the Law has not been consistently and effectively implemented (ARPE oversees its implementation advised by PRSWMA).[24] In addition, the Act and the Regulation (Section 20) could be amended to extend this requirement to commercial and industrial projects. The Leadership in Energy and Environmental Design (LEED) of the Green Building Council also provides guidelines for the design and construction of this space.

  Responsible entities: PRSWMA, ARPE and the municipal governments.

6. COASTAL FLOOD HAZARD

To help achieve the proposed planning objective that no one should be living in coastal flood hazard areas (specifically, Zone VE as identified by the FEMA's FIRM):

- The costal maritime zone delimitation and definition should be tempered to the realities of the 21st century. At the present moment, the definition of this zone is base on old laws when Puerto Rico was a territory of Spain (Waters Act of 1866 and Ports Act of 1886). This old definition is based on the realities of the coasts of Spain of almost two centuries ago and does not represent the reality of a Caribbean island in the 21st century. As a result, the definition of the delimitation of the coastal maritime zone has been arbitrarily interpreted by the government and the proponents of coastal projects as only that zone that the waves cover in their constant flow (raise and fall) of tides, and avoiding the dangerous waves associated with tropical storms or hurricanes. This interpretation also does not consider the actual reality of climate change and, as a result, the rise in the intensity and frequency of climatologically extremes

24 Interview with Adalis Martínez Cruz, Environmental Analyst of the Planning Department of the PRSWMA on 3/16/09.

25 Mercado-Irizarry (2008). Also, interview with the author, Aurelio Mercado-Irizarry, Director of the Coastal Hazards Center, Sea Grant Program at the University of Puerto Rico, Mayaguez Campus on 3/09/09.

events. This is why this project recommends considering Public Law Project 3031 of the House of Representatives and Public Law Project 1703 of the Senate presented to the Legislature between 2005 and 2006, to create the new Puerto Rico Coastal Act. This proposed act presented an objective, clear and updated coastal maritime zone delimitation for the Island which was defined as starting in the line of lower tides (or inferior limit) up to the inland line that dangerously high waves can reach (waves as defined in the VE Zone by FEMA's FIRM, which can be up to 3 feet in high and that propagate over the cyclonic tide of a 100 years recurrence hurricane). This zone should be of a minimum of 50 meters starting at the line of higher tides during the year and it reaches until where the influence of the sea can be measured inland, and it extends to the margins of the rivers and their tributaries, and throughout other bodies of water until they can be navigated or until changes in tides can be measurable. This new definition also provides for the covering of the right to free access to the beaches as public spaces and guarantees public safety.

- Another important point is that FEMA's maps do not consider the erosion problem in coastal areas which increases coastal hazard. Because of this, also recommended is what is known as the "setback area" which relates the width of the area to be protected with the annual erosion rate of that particular coastal place. A good example is the "Shoreline Setback Areas" (SSA) used in Hawaii to control development along its coasts which are also considered "Special Management Areas". More information can be found at http://www.honolulu.gov/refs/roh/23.htm and http://www.hawaii-county.com/planning/rules/rule%2311.pdf.

  The "Coastal Construction Control Line" (CCCL) is another example that is being used in the State of Florida which forms part of their Coastal Zone Management Program. The CCCL considers erosion and the combined impact of erosion and cyclonic tides of a 100 years recurrence hurricane. To address this, the State of Florida, in addition of using FEMA maps, also includes the stability of the shore (fluctuations in its localization and its erosion pattern through historical studies using maps and aerial photos), the topography and how it relates to the tide (the inland line of the 3 feet waves) and the floods and cyclonic tides of 100 years recurrence through simulated computer modeling. They also use the "Erosion Line" (EL) which was established in 1985 to prohibit major constructions between the actual shore and the projected shore in 30 years due to the erosion rate. If the EL is inside the CCCL, then only the CCCL applies. More information about the CCCL and the EL in the State of Florida can be obtained at http://www.dep.state.fl.us/beaches/programs/ccclprog.htm.[25]

- Coastal municipalities, with the help of FEMA and the Central Government, can also do an assessment and prepare an inventory of the actual amount of housing units in Zone VE (so as not to depend only on the estimates of the decennial census) to prepare a plan for the gradual and eventual re-localization of people living in this Zone. Once this assessment is done, the coastal municipalities should also consider prohibiting, through a municipal ordinance, any new major construction or housing development is this Zone.

  Responsible entities: PR Legislative Assembly, PRPB, FEMA and the municipal governments.

6. CO_2 EMISSIONS PER HOUSEHOLD

To help achieve the benchmark of 16% reduction of CO_2 from current CO_2 emissions:

- Municipalities' should adopt the Sierra Club's Cool Cities ("Ciudades Cool") goal for Puerto Rico of reducing by 2% per year the total of CO_2 emission in order to achieve an 80% reduction by 2050. As mentioned in the methodological sheet of this indicator in Appendix D, six municipalities have already joined the Cools Cities campaign by signing a municipal ordinance provided by the local chapter of the Sierra Club. The adoption of this goal should be accompanied by an implementation plan and an educational initiative directed towards the municipal residents. The Club's local chapter web page (http://puertorico.sierraclub.org/ciudadescool/index.html) stores the document "*Manual para hacer tu ciudad cool en cuatro pasos*" (How to Make Your City Cool in Four Steps[26]) which has specific recommendations at the municipal level to achieve the proposed goal of CO_2 reduction and an example of the municipal ordinance. Both can be downloaded from the Club's web page. The U.S. Mayor Climate Protection Center (http://www.usmayors.org/climateprotection/) also provides information, guidance and assistance for mayors to help them lead their cities' efforts to reduce greenhouse gas emissions. There is clear evidence that mayoral leadership is fundamental to produce business and community support for policies that reduce CO_2. The Center facilitates leadership experiences by providing the necessary knowledge and tools. A manual for best practices for climate protection can also be downloaded from their web site.
- As the Sierra Club's Cool Cities campaign proposes, municipalities can achieve substantial energy efficiency improvements through policies and specific action plans to provide incentives and promote the use of efficient technologies, and integrate them into planning decisions. Specifically, adopt the LEED of the U.S. Green Building Council as a strict requirement for all new developments, including housing developments, within the municipality. LEED standards provide energy efficiency design guidelines for different types of building and developments. Also, municipalities can establish a plan to retrofit existing buildings, including residential houses, to achieve energy efficiency. The U.S. Building Council has also LEED retrofit standards for exiting buildings.
- USEPA and the U.S. Department of Energy's Energy Star program (http://www.energystar.gov/) also provide specific guidelines to achieve energy efficiency. Homes can also be certified as Energy Star homes. Municipalities can also consider using EPA's Energy Star standards as requisite for all new housing developments and to help existing homes improve their energy efficiency through a retrofit educational program with PREPA's collaboration.
- Recently, in Puerto Rico there have been several initiatives towards achieving energy efficiency through executive orders and public laws. The important thing, right know, is their full implementation. Some examples are:

26 The four steps are:
1. Take the "Cool Cities" Pledge
2. Conduct a Global Warming Emissions Inventory.
3. Create a Solutions Plan, and
4. Implement and Monitor Progress.

Public Law 229 of August 9, 2008 or the Green Building Act which main purpose is to promote efficiency in energy and water use in new and existing public buildings.

Public Law 114 of August 16, 2007, as amended, to order PRPEA the establishment of a net metering program for its client who has installed renewable energy equipment. This Law enables a connection between PREPA's transmission and distribution system and clients who has installed renewable energy systems to get credit for the energy they generate.

Public Law 248 of August 10, 2008 to amend the tax laws and provide incentives for the acquisition and installation of photovoltaic panels (including a 75% credit between the Fiscal Years 2007-2008 and 2008-2009!)

Executive Order 2007-40 to order all the agencies, instrumentalities and public corporations acquire equipment and products that are certified as Energy Star and efficient illumination systems.

Executive Order 2007-41 to promote the construction and use of sustainable buildings through the cost-effective application of the Green Building Council's LEED rating system.

Executive Order 2008-33 to establish a fund of $5 million dollars to provide a $500 voucher program for the acquisition of solar water heaters, and to establish a low interest loan program for the purchase of solar water heaters in local cooperatives.

Responsible entities: PR Legislative Assembly, PREPA, ARPE and the municipal governments.

7. RELEASE OF TOXIC SUBSTANCES TO THE ENVIRONMENT BY INDUSTRIES

To help achieve the planning objective of zero (0) increase in the TRI:

- Municipalities could provide specific local incentives, maybe through a reduction in the percentage of municipal taxes or patents that industries pay, in order to reduce the TRI per industry in its jurisdiction and, as a result, within the municipality's territorial boundaries.
- Promote the ISO 14000[27] certification and the USEPA's Environmental Management Systems[28] among all local and international industries operating in Puerto Rico. This can also become a prerequisite for industries which would like to establish their operation within local jurisdictions.
- The Zoning Regulation 4 of Puerto Rico, as amended, contains two districts of industrial zoning: the Light Industrial District and the Heavy Industrial District. The Heavy Industrial District is established *to classify areas that by its nature and intensity they require of a special location…The delimitation of the extension of lands for heavy industries is based on the potentialities of the area for the development of heavy industries, the direction of the winds, negative effects of the heavy industries on the air, water or other…. excluding in this district the commercial and residential uses, and light industries…*[29] Municipalities should use these zoning categories wisely to limit the location of new industries that might contribute to their TRI.

Responsible entities: PRPB, the municipal governments and the PR Department of Economic and Commerce.

27 For more information see ISO14000 Essentials at the ISO International Organization for Standardization at http://www.iso.org/iso/iso_14000_essentials (downloaded on 5/3/09)

28 For more information see USEPA's web site on EMS at http://www.epa.gov/ems/(downloaded on 5/3/09).

20 PRB, Zoning Regulation 4 , as amended, Section 20.01

8. WATER CONSUMPTION PER HOUSEHOLD

To help achieve the benchmark of a 27% reduction of water consumption by municipal residents:

- As global warming is making scarce the availability of freshwater, especially in small islands as explained in the indicator's methodological sheet in Appendix D, for strategic and public safety reasons, the government should adopt norms and programs to promote the reduction of per capita water consumption as well as its efficient use. This includes the effective implementation of the PRDNER's Comprehensive Plan for Water Resources in Puerto Rico (2007).
- With the collaboration of PRASA, municipalities should carry out a more aggressive educational campaign to make the public aware of the need to reduce their drinking water consumption.
- Through an agreed collaboration plan that might include the assignment of some funds to the municipalities for inspection and repair support activities, PRASA should also incorporate the municipalities in the task of identifying and repairing leakages and breakages of the PRASA's distribution system as well as identifying and penalizing illegal connections within the municipalities' territorial boundary.
- Municipalities, with the support of PRASA, should also provide incentives for families to reduce their consumption rate by providing for free retrofit equipments for showers, toilets and faucets through a well established retrofit program.

  Responsible entities: PRASA and the municipal governments.

SOCIO-ECONOMIC INDICATORS

9. HIGHLY VALUABLE AGRICULTURAL LANDS

To help achieve the proposed planning goal that the amount of highly valuable agricultural lands should not be reduced over time:

- The central government, as well as each individual municipality in their land use plans, should adopt as a public policy the conservation of the agricultural lands necessary to ensure food security. At the municipal level, this could also include a municipal ordinance to assure the future protection of those areas already assigned as Common Rural Land within their municipalities that have *valuable agricultural lands* as well as *active agricultural lands*.
- By the development of proper legislation or the amendment of existing legislation, the protection of highly valuable agricultural lands, as identified by the USDA/NRCS and the PRDA, should not be under the discretionary powers of the PRPB. At the present moment, the USDA/NRCS and the PRDA can only comment and recommend during the inter-agencies comments and endorsements phase and during the public hearings when incompatible developments are proposed inside valuable agricultural lands. Because of the importance of guaranteeing food security for sustainability in the 21st century, the PRDA should be allowed to have veto power when in comes to decisions related to land use in valuable agricultural lands.
- Since there are several municipalities – mostly in the central mountainous areas - with important agricultural activities in land classified by the USDA/NRCS as values 5-8 as well, it is recommended that the calculation of this indicator for these particular municipalities take into consideration the agricultural importance of these lands as well.
- Create easements that serve as buffer zones around highly valuable agricultural lands to protect these lands from incompatible land use changes in their surroundings.

Responsible entities: PR Legislative Assembly, PRPB, PRDA and the municipal governments.

10. ACTIVE AGRICULTURAL LANDS

To help achieve the proposed planning objective of no negative change in active agricultural lands:

- Zone all the lands – from values 1 to 8 as classified by the USDA/NRCS - that are actually being use for agricultural activities but that are still not zoned as such, as A-P ("Agrícola Productivo" or Agricultural Productive) A-G (Agricultural General), according to the PRPB Zoning Regulation 4, as amended.
- At the present moment, agricultural activities represent less than 1% of Puerto Rico's GDP and the GNP. The PRDA has over 100 regulations to protect and promote agriculture activities. The challenge that the agriculture sector has at the present moment is the lack of sufficient funds to implement these regulations effectively and consistently among local farmers. The government has to provide attention to this sector, the same way it gives attention to the construction, commercial and industrial sectors. As explained in the Introduction section of the Report, since the industrialization of Puerto Rico in the 1940's and 50's there has been a gradual devaluation and abandonment of agriculture as a viable economic activity in the Island's portfolio.

Responsible entities PR Legislative Assembly, PRPB, PRDA and the municipal governments.

11. RESIDENTS WHO WORK WHERE THEY LIVE

To help achieve the planning objective that at least 60% (Puerto Rico average for 2000) of the number of workers-residents should work in the same municipality where they live:

- Public policies, programs, and specific area plans should be established to encourage the integration of mixed land use in urban areas by both, the central government and the municipalities in their land use plans (one of the Smart Growth strategies). See also the recommendation of the next indicador *Re-population of urban areas.*
- A balance between the development levels of the different geographical regions within the Island should be established as an island-wide public policy to promote the needed mix of activities within groups of adjacent municipalities.

Responsible entities: PRPB and the municipal governments.

12. RE-POPULATION OF URBAN AREAS

To help achieve the proposed planning objective of increasing the population density in urban areas at least by 11%:

- The central government and the municipalities should adopt public policies on the densities that each municipality should observe in their urban areas based on specific criteria for the optimal use of the land.
- The Urban Centers Revitalization Act's (Public Law 212 of August 29, 2002, as amended) main purpose is the revitalization, redevelopment, densification and repopulation of urban centers through private-public partnerships for investments in specific urban areas. This Act could have been a perfect tool to promote re-population in urban areas but, in its implementation phase, municipalities and private investors confronted many challenges in order to comply with all the requirements imposed by the Treasury Department and by the Directorate of Urbanism of the PRDTPW.

Ammendments to the regulations that help implement the Act have substantially reduced the incentives needed to achieve the main goal of the Act. In order to revitalize, redevelop and re-populate the urban areas this should be reversed. Attractive and effective incentives are required to attract potential investors.

- Promote land banking in the urban areas for new mix use and mid to high density developments.
- Increase public safety in the redevelopment areas.
- Adopt Smart Growth principles (see general recommendations) through public policies, plans, programs and activities.

Responsible entities: PRPB and the municipal governments.

13. PEOPLE LIVING IN FLOODWAYS

To achieve the benchmark that no one should be living in floodways (AE Floodway):

- Municipalities need only to comply with the PRPB Planning Regulation 13 that considerably limits development in these areas.
- An eight-year gradual relocation plan could be established with the help of FEMA for those already living in floodways. After relocating people, any structure in these areas should be removed.
- In the Municipal Land Use Plan the AE Floodway areas, as identified by FEMA FIRM, should be rezoned to only allow natural open spaces (easements under the PRDNER), like lineal parks along rivers (examples are Caguas Honor al Río and Río Bayamón, both linear parks) or biological corridors, for the protection

of water bodies, passive recreation and to provide additional spaces for native fauna movement and migration. Passive linear parks in floodways could be managed in collaboration with the PR National Parks Company and/or the municipalities.

Responsible entities: PRPB, PRDNR, FEMA and the municipal governments.

14. THE SOCIO-ECONOMIC INDEX

To help achieve the benchmark of no less than 100 (numerical value for the Index):

- Municipalities, as well as the central government, should adopt this Index as part of the necessary information they need to design plans, programs and activities to eradicate poverty.

  Responsible entities: PRPB, MRCC, Office of the Commissioner of Municipal Affairs, PR Department of Education, PR Department of the Family and the municipal governments.

INFRASTRUCTURAL INDICATORS

15. INACCESSIBILITY TO PUBLIC TRANSPORTATION

To help achieve the planning objective that all wards within the municipality should have at least one public transportation route to the urban center:

- Data of public transportation by each municipal ward should be collected and maintained on a regular basis.
- Municipalities, with the support of the central government, should adopt public policies that guarantee public transportation for each of their wards.
- Public-private partnerships should also be established to supply more efficient, frequent and timely public transportation to and from the wards and the urban centers, between wards and between municipalities through buses or "carros públicos" (public taxis).
- Integrate the public transportation system in and between all the municipalities (island-wide) through buses and public taxis. Assigned transportation funds, both from the federal and local governments, should give priority to establishing an island-wide mass transportation system (see also recommendations for the indicator *Footprint of public roads*).

Responsible entities: PRDTPW, Puerto Rico Service Commission, PRPB and the municipal governments.

16. USE OF PUBLIC TRANSPORTATION TO REACH WORK

To help achieve the proposed planning objective of increasing 6% points the use of public transportation to reach work:

- Recommendations for the indicator *Inaccessibility to public transportation* will help improve this indicator as well.
- The government must encourage the use of public transportation to reach the place of work through different incentives and assertive programs. Municipalities can provide frequent and reliable public transportation within their urban center and within their wards and the urban center for residents that work in the same municipality by the use of trolleys, as some municipalities are already doing. This service can offer packages of reduced monthly or annual fares for residents. Some municipalities have already this type of trolley service but still need to improve in frequency and reliability.
- The implementation of Smart Growth principles and strategies for urban areas can also help (see general recommendations). This is paramount in the achievement of sustainability due to the population high dependence on private vehicles.

- Since the only information available for Puerto Rico is the use of public tansportation to reach work by worker-residents from the U.S. Census, as explained in the methodological sheet of the this indicator in Appendix D, Puerto Rico can become a partner of the Add-On Participants Program of the U.S. Department of Transportation's (DOT) National Household Travel Survey (NHTS), formerly the Nationwide Personal Transportation Survey (NPTS), which serves as the nation's inventory of personal travel. It is the only trusted source of national data on personal travel behavior (including purpose of the trip, means of transportation, trip length, day of the week and month of the year, number of people on the trip, and a host of other trip-making characteristics). Since it is based on a survey basis (it is not a census and Puerto Rico is not included in the survey), therefore results cannot be extrapolated to Puerto Rico. Nonetheless, the DOT, for its 2008 NHTS, has the Add-On Participants Program. This Program is designed for states, Metropolitan Planning Organizations (MPOs) and regional transportation organizations so they can purchase additional samples in the NHTS to get more accurate data for their respective areas. By becoming a partner in the Add-On Program, Pueto Rico would be able to acquire additional valuable data about local personal transportation distances, tendencies and choices for better decision-making when developing and imlpementing transportation plans.[30]

  Responsible entities: PRDTPW, PRPB and the municipal governments.

17. FOOTPRINT OF PUBLIC ROADS

To help achieve the proposed planning objective of no change or increase over time in the public road's footprint:

- The government should prioritize significantly in the maintenance and improvement (i.e., Intelligent Transportation Systems [ITS][31]) of the network of existing roads and in the development and integration of a massive public transportation system, instead of constructing new roads which brings scattered low density development along the edges. Puerto Rico already has one of the highest proportions of roads per km^2 in the world with all the resulting unsustainable environmental impacts this has brought in the world to local land use. Municipalities can influence the central government towards this direction when related to transportation decisions within their municipal boundaries.
- The central and municipal governments can coordinate within the different agencies and offices different work hours for their employees to help reduce peak transit rush hours.

  Responsible entities: PRDTPW, PRPB, and the municipal governments.

30 More information can be found on their web site: http://www.fhwa.dot.gov/policy/ohpi/nhts/aboutnhts.cfm.

31 The ITS program of the DTO was designed to facilitate deployment of technology to enhance the efficiency, safety, and convenience of surface transportation, resulting in improved access, saved lives and time, and increased productivity mostly for existing roads. For more information see: http://www.its.dot.gov/about.htm

18. INACCESSIBILITY TO SAFE DRINKING WATER

To help achieve the benchmark of eliminating all systems from USEPA's SNC list:

- Special attention should be given to Non-PRASA systems. Since 1997 the "Enforcement and Compliance Strategy for Non-PRASA Public Water Supply Systems" (known as the Non-PRASA Strategy) under the leadership of PRDOH and USEPA, has been in place and implemented with some positive progress. But there is still much to be done.

  The Non-PRASA Strategy's main objectives are to:

- "Connect Non-PRASA systems to PRASA, when possible.
- Install disinfection units in all Non-PRASA systems.
- Reduce the number of surface water systems (surface water intakes).
- Create a surveillance program to assure adequate operation and maintenance of the Non-PRASA systems.
- Reduce the number of positive bacteriological results" (PRDDOH et al., 2006).

  The PRDOH and USEPA need the full support of the municipalities to assist the Non-PRASA communities and achieve the above objectives. These Non-PRASA communities represent a challenge for land use sustainability because they are mostly informally and unplanned built communities, established in remote and/or mountainous areas. Therefore, municipalities encounter difficulties in providing these communities with appropriate utilities and public services, such as safe drinking water, especially in emergency situations (i.e. hurricanes or natural disasters). Municipalities should avoid future informal development of these communities and, as much as possible, work with those already established to improve their accessibility to adequate public services.

  An example of a municipality that has worked with Non-PRASA system communities is the Municipality of Caguas. In this case, the Municipality and a local university worked with 17 communities (organized as ASOCAGUAS, Inc. communities) to educate and empower them in order to comply with the federal Safe Drinking Water and Clean Water Act for their Non-PRASA systems. Another, example is the "Cooperativa de Acueductos de Patillas" (Patillas Aqueduct Cooperative) in the Municipality of Patillas. This Cooperative consists of five communities that, with the help of a local university, got together to learn how to properly administer and operate their Non-PRASA system in accordance with federal laws.[32]

- The "Four Year Capital Improvements Program" of the government should require the funds for the maintenance of the existing drinking water systems as a prerequisite before authorizing new projects.

  Responsible entities: PRDOH, PRASA, PRPB, USEPA and the municipal governments.

32 Interview with Cristina Maldonado, Environmental Scientist of USEPA's Caribbean Division, Municipal Water Programs Branch.

INSTITUTIONAL INDICATORS

19. APPROVED MUNICIPAL LAND USE PLAN

To help achieve the benchmark that every municipality should have an approved Land Use Plan:

- The central government should review resources and the procedures to ensure, with agreed deadlines, that all municipalities have a Land Use Plan.

  Responsible entities: PR Legislative Assembly, PRPB, municipal governments and the Association and Federation of Mayors.

20. THE FISCAL FRAGILITY INDEX

To help achieve the benchmark of above 0 (numerical value for the Index):

- The municipalities, as well as the central government, should adopt this Index as an economic analysis tool to evaluate the jurisdictions' fiscal health and for accountability with their communities.

  Responsible entities: Government Development Bank, PRPB, MRCC, Office of the Commissioner of Municipal Affairs and the municipal governments.

21. LAND OFFICIALLY PROTECTED

To help achieve the planning objective of no negative change or zero (0) decrease of Specially Protected Rural Land (SPRL):

- As previously recommended in the indicator *Development pressure in rural land* a tool that can be use by municipalities is the Transferable Development Rights (TDR), as provided by the Autonomous Municipalities Act (Public Law 81 of 1991) in its Article13.024. TDR can help to protect and increase SPRL.
- In addition, and as explained in the Limitations of this indicators' methodological sheet in Appendix D, some municipalities have established in their individual land use plans land use zoning districts in urban zones that have conservation restrictions. Since the indicator only considers land classified as SPRL - as defined by the central government- municipalities should consider adding to this indicator the amount of land of said municipal land conservation districts when evaluating this indicator for their territorial units. An example is District "BM" ("Bosque Municipal" or municipal forest) in the Municipality of Carolina.

- Important to mention is Section 2 of Act 49 of January 4, 2003, as amended, known as the Act to Set Forth the Public Policy of Puerto Rico on Flood Prevention and the Preservation of Rivers and Ravines. This Act set forth that *in any urbanization works, or any lotification adjacent to a river, ravine, lagoon, or any body of water, a section of land shall be dedicated to public use in the general interest of the preservation of the body of water, by means of inscription in the Registry of the Property, consisting of a minimum of five linear meters at both sides of the riverbed, or the bed of the stream, ravine, lagoon, or lake. Said section of land shall remain expeditious, and may only be used for preservation purpose.*[33] Municipalities should be aware of the requirement in this Act when setting aside and classifying its SPRL.
- At the central government level, and with the help of the municipalities since highly valuable ecological lands identify for conservation fall inside municipal jursidictions, a plan should be established through public policy to achieve the minimum recommended by the GAP Analysis Project (Gould et al., 2008) for the Island of 15% of SPRL for the protection of biodiversity. According to this study, special attention should be given to expanding reserves in the limestone hills and coastal plains (the matrix of wetland and upland vegetation that is found in the former Roosevelt Roads and Sabana Seca Naval Base, the Northeast Ecological Corridor, and Piñones, among other areas).

  Responsible entities: PR Legislative Assembly, PRDNER, PRPB and the municipal governments.

33 Retrieved on 12/15/08 from http://www.oslpr.org/download/en/2003/0049.pdf

LIMITATIONS

The Serious Constraints Imposed by the Absence of Statistical Data, Their Reliability and Regularity

The truth is that there is a general dissatisfaction and numerous criticism for the delays with which information is supplied by government agencies and the credibility of the indicators and reports of the results of opinion surveys, as well as of the procedures used to produce them both in the public and private level (Statement of Motives, "The Institute of Statistics of Puerto Rico Act, Public Law 209 of August 28, 2003).

As the Institute of Statistics of Puerto Rico began operations in mid-2007 (http://www.estadisticas.gobierno.pr), the situation described in the preceding paragraph prevailed throughout the period of time that took to develop this research project. As a result, the major challenge encountered was to address the reliability of many of the information and digital data available for the indicators. It was what consumed the most time in the research conducted because there are no metadata for many data sets. Information was sometimes not available in digital form but distributed in documents in several government agencies, so the gathering, analysis and validation of the data was a major challenge and took much longer than expected.

Multiple references to the quality of the statistical data produced by the Government of Puerto Rico can be found in the Limitations section of each of the 22 indicators (Appendix D). In fact, the problem of data reliability was one of the main reasons for which most of all the potential indicators considered had to be eliminated. Other indicators were carefully reevaluated and changed in scope in the validation process. Even the use of GIS as the main technical and scientific tool for the model, as originally proposed, was ruled out as explained before in Challenges and Lessons Learned. The selected indicators are based on the best reliable and readily available information and digital data. Notwithstanding, it is important to point out that in regards to reliability, the information used for the different analyses of this project is official, authorized and published by the pertinent government agencies at the time of the preparation and publication of this work. Thus, the pertinent metadata as well as the geomatics used in the project, correspond to those responsible for the original creation of each layer. [34]

Another limitation was the lack of availability and disposition of the technical experts in the agencies for interviews and validation of the information. This made the research process even a greater challenge.

34 It is important to mention that the information used in the demographic and spatial analyses through the GIS has, in general terms, the limitation that there is no particular organization or institution who takes responsibility for the quality, updating, precision and accuracy of the geospatial data available in Puerto Rico. This responds, in great measure, to the fact that the majority of the agencies (state as well as municipal and federal) that produce geospatial information in any way as part of their performance and administrative functions, still conduct work with their own protocol and quality control system for the development of information or with the criteria selected for such a task (scale, projection, format in the system of coordinates, precision). That is, digitalized geospatial information of the different agencies does not necessarily have the same precision ranges, the same level or scale, the same temporal frequency, the same method of information collection and digitalization method (automatic, manual, software, hardware, etc.) Thus, independently of the declarations of the limitations in the use of any information, there is always some degree of uncertainty in total compatibility and reliability of the data, especially when the sources of information are varied and disperse, as is the case of this project due to its magnitude and extension.

Limitations of the ISLA

The ISLA index has two major limitations, which could be overcome in a later version of the study. These are:

1. High sensitivity to benchmarks and weights. Researchers must choose benchmarks for —or planning objectives when there are no specific benchmarks— and assign weights to each of the stressors and relievers indicators. The study found that standard technical data on which to base benchmarks and weights are not as readily available as was originally expected. The resulting need to rely on experts' opinions leaves the index susceptible to subjectivity on the part of the researchers.
2. The mathematical formulation does not allow for incremental measures of stressors or relievers intensity for indicators that overshoot their benchmarks. If such incremental sensitivity is desired, the formula for the index may need to be modified in the future.