

STRATEGIC GUIDELINES FOR THE SUSTAINABLE MANAGEMENT OF FOREST RESOURCES IN PUERTO RICO: OPPORTUNITIES, CHALLENGES, AND STAKEHOLDERS IN THE PRODUCTION CHAIN OF THE FORESTRY SECTOR

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Abstract

Forest production chains grounded on applicable laws and regulations are essential for achieving sustainable forestry, circular economies, and climatic mitigation. In Puerto Rico, reactivating the forestry sector as a key player capable of providing ecosystem services, raw materials, and products can significantly contribute to these goals through the sustainable development of local wood production. However, the lack of wood processing capacity and active management for forest products became evident following the hurricanes Irma and María in 2017, which downed large quantities of trees. Most of these were removed from roads and other areas only to be discarded in landfills, undermining both the forestry production potential at the time and the conservation of Puerto Rico's natural resources. This situation highlights the urgent need for critical, forward-looking strategies.

The pattern of forest recovery since the 1950s provides Puerto Rico with favorable circumstances for developing sustainable production chains, ranging from small-scale artisanal activities to larger-scale, environmentally responsible wood production on private farms, all without compromising biodiversity conservation. To support improved strategic planning, this study analyzed Puerto Rico's forestry sector through a review of existing literature, field visits, and interviews with representatives from five sectors of the wood production chain. The objective was to identify opportunities and challenges for the sustainable production of forest products.

Key findings indicate that 70 years of forest recovery, coupled with a local artisanal forestry industry and government programs promoting both the artisan sector and sustainable forest

management on private farms, provide a strong foundation for developing sustainable production chains. However, significant constraints were identified, including challenges in forest policy, federal regulations, and intrinsic disadvantages faced by small local producers.

As a preliminary step, a stakeholder analysis identified individuals and groups with potential interest in forest resource production. Based on this analysis, we recommend establishing an advisory council to integrate the diverse perceptions and expectations of stakeholders across the forestry sector. Strategic guidelines are proposed to support the development of a robust and environmentally responsible forestry sector in Puerto Rico.

Keywords: Forestry industry, forest policy, forest resources, Puerto Rico, stakeholder analysis, sustainable forestry, wood products, wood production chains.

Resumen

Las cadenas legales de producción forestal, fundamentadas en la silvicultura sostenible, son esenciales para alcanzar los objetivos de mitigación del cambio climático y fomentar economías circulares. En Puerto Rico, la reactivación del sector forestal como un actor clave capaz de proveer servicios ecosistémicos, materias primas y productos puede contribuir significativamente a estos objetivos mediante el desarrollo de la producción sostenible de madera local. Sin embargo, la falta de capacidad de procesamiento de madera y de gestión activa de los productos forestales se hizo evidente tras los huracanes Irma y María en 2017, que derribaron árboles en gran cuantía. La mayoría de estos fueron retirados de carreteras y otras áreas, pero finalmente descartados en vertederos, lo que afectó tanto el potencial productivo del sector forestal en ese momento como la conservación de los recursos naturales de Puerto Rico. Esta situación evidencia la necesidad urgente de estrategias críticas y prospectivas.

El patrón de recuperación forestal desde la década de 1950 brinda a Puerto Rico condiciones favorables para desarrollar cadenas de producción sostenible, que abarcan desde actividades artesanales de pequeña escala hasta la producción de madera ambientalmente responsable a escala mayor en fincas privadas, todo esto sin comprometer la conservación de la biodiversidad. Para apoyar la planificación estratégica, este estudio analizó el sector forestal de Puerto Rico mediante una revisión de la literatura existente, visitas de campo y entrevistas con representantes de cinco sectores de la cadena de producción de madera. El objetivo fue identificar oportunidades y desafíos para la producción sostenible de productos forestales.

Los hallazgos clave indican que 70 años de recuperación forestal, combinados con una industria forestal artesanal local y programas gubernamentales que promueven tanto el sector artesanal como la gestión sostenible de bosques en fincas privadas, ofrecen una base sólida para desarrollar cadenas de producción sostenibles. Sin embargo, se identificaron limitaciones significativas, como desafíos en las políticas forestales, regulaciones federales y desventajas intrínsecas que enfrentan los pequeños productores locales. Como paso preliminar, un análisis de actores identificó a individuos y grupos con interés potencial en la producción de recursos forestales. Basándonos en este análisis, recomendamos establecer un consejo asesor que integre las diversas percepciones y expectativas de las partes interesadas en el sector forestal. Además, se proponen directrices estratégicas para apoyar el desarrollo de un sector forestal robusto y ambientalmente responsable en Puerto Rico.

Palabras clave: cadena de producción maderera, industria forestal, política forestal, productos madereros, Puerto Rico, recursos forestales, sostenibilidad forestal, *stakeholder analysis*.

ABBREVIATIONS AND ACRONYMS USED IN THE TEXT, FIGURE, TABLE, APPENDICES, AND REFERENCES

CADA	<i>Comité Asesor para el Desarrollo Agroforestal</i>	NOAA	National Oceanic and Atmospheric Administration
CCH	Caribbean Climate Hub	NRCS	Natural Resources Conservation Service
CCP	<i>Centro para la Conservación del Paisaje</i>	NTFPs	Non-Timber Forest Products
CEDES	<i>Centro de Estudios para el Desarrollo Sustentable</i>	OGPe	<i>Oficina de Gerencia de Permisos para la Naturaleza</i>
CNF	Caribbean National Forest	PLA	<i>para la Naturaleza</i>
COFALC	<i>Comisión Forestal para América Latina y el Caribe</i>	PR	Puerto Rico
CRCO	Caribbean Regenerative Community Development	PRDA	Department of Agriculture of the Commonwealth of Puerto Rico
dbh	diameter at breast height	PRIDCO	Industrial Development Company of the Commonwealth of Puerto Rico
DNER	Department of Natural and Environmental Resources of the Commonwealth of Puerto Rico	PRPB	Planning Board of the Commonwealth of Puerto Rico
DTOP	Department of Transportation and Public Works of the Commonwealth of Puerto Rico	PRRA	Puerto Rico Reconstruction Administration
EYNF	El Yunque National Forest	PRTC	Puerto Rico Tourism Company
FAO	Food and Agriculture Organization	RIL	Reduced Impact Logging
FEMA	Federal Emergency Management Agency	SPTF	State, Private, and Tribal Forestry
FIA	Forest Inventory and Analysis	TFF	Tropical Forest Foundation
FSC	Forest Stewardship Council	U-TREE-PR	Urban Trees for Resilience, Equity & Empowerment in Puerto Rico
GIS	Geographic Information Systems	UPR	University of Puerto Rico
IPRC	Institute of Puerto Rican Culture	U.S.	United States of America
ISA	International Society of Arboriculture	USACE	United States Army Corps of Engineers
IITF	International Institute of Tropical Forestry	USDA FS	United States Department of Agriculture-Forest Service
ITTO	International Tropical Timber Organization	USFWS	United States Fish and Wildlife Service
NGOs	Non-Governmental Organizations		
NIFA	National Institute of Food and Agriculture		

INTRODUCTION

Effective public policies for the sustainable management and use of forest resources are essential to develop a holistic approach to climatic mitigation and adaptation to the projected changes in climate (FAO 2017). The need for such policies became evident in Puerto Rico after hurricanes Irma and María, in 2017, brought down millions of trees. The United States Army Corps

of Engineers (USACE) collected more than 4.4 million cubic yards of plant material, about 70% of which was wood (Brinton et al. 2022). This material included fine hardwood species such as mahogany (*Swietenia* spp.), teak (*Tectona grandis*), white acacia (*Albizia procera*), yellow acacia (*Albizia lebbek*), mahoe (*Talipariti elatum*), black olive (*Bucida buceras*), pterocarpus (*Pterocarpus* spp.), white cedar (*Tabebuia heterophylla*), and Spanish cedar (*Cedrela odorata*). However, because of

the absence of an organized wood-production chain, the management of this plant material presented an overwhelming challenge to government authorities, including the U.S. Federal Emergency Management Agency (FEMA), the USACE, the Department of Natural and Environmental Resources of the Commonwealth of Puerto Rico (DNER), the Department of Transportation and Public Works of the Commonwealth of Puerto Rico (DTOP), and the Planning Board of the Commonwealth of Puerto Rico (PRPB) (Brinton et al. 2022). Federal policies focused on cost-efficiency for the disposal of plant material after a natural disaster prevented the participation of local actors in the decision-making process regarding the use and disposal of wood. These actors could have contributed to developing a circular economy to manage this material. Nonetheless, as a result of this lack of sound economic structure and by ignoring the recommendations of forestry professionals in the private and federal government sectors, the authorities made decisions contrary to the sustainable use of forest resources, which in some cases consisted of giving priority to certain private groups over other groups in the handling and disposition of woody debris, resulting in that most of the wood ended up being crushed and deposited in landfills without considering its quality.

If adequately managed, tropical woods with high commercial and cultural value can provide vital economic and ecological benefits that promote the sustainability of forests (COFALC 2023). In Puerto Rico, however, during the last 40 years, forest policy has primarily focused on protection, conservation, and reforestation, mostly excluding forest management for the commercial production of timber and non-timber forest products or NTFPs (Wadsworth 2012, 2014). Nonetheless, a sustainable and well-organized forestry production chain is required to create value from large volumes of wood to locally transform possibilities for income, jobs, technology transfer, and capacity development (van Hensbergen and Cedergren 2020). Moreover, sustainable managed tropical forests integrated

with legal production chains can help to develop a circular economy (ITTO 2023b). For example, current stands can be converted to more suitable stand structures and compositions using appropriate silvicultural practices and systems that integrate several spatial and temporal scales: the growth of future crop trees can be favored by liana cutting and girdling of competing trees, enhancing the regeneration of commercial species after selective timber extraction carried out with Reduced Impact Logging (RIL) techniques (Peña-Claros et al. 2008a,b; Wadsworth and Zweede 2006), which results in recovering a large portion of the initial volume harvested over the next cutting cycle (Villegas et al. 2009).

Forest management based on suitable silviculture and RIL techniques can also help to increase forest resilience and productivity, conserve biodiversity, and maintain soil and water quality (Sasaki et al. 2016). For example, well-managed forest lands can buff against floods, coastal surges, and droughts (ITTO 2023b). On the other hand, biomass energy can substitute fossil fuel energy, while harvested wood products can replace non-renewable materials with a high carbon footprint, such as plastics and concrete for construction (ITTO 2023a; FAO 2021). For example, long-lived wood products can mitigate climatic change by storing carbon for several years (FAO 2021; Kazulis et al. 2017). As a result, these practices may increase the carbon sequestration and storage capacity of forest stands, helping to adapt forest ecosystems to mitigate the influence of projected changes in climate (Ameray et al. 2021).

The most recent Forest Action Plan of Puerto Rico recognizes the production of forest products and the management of wood as an opportunity for local economic benefit (DNER 2021). For these reasons, it is essential to reactivate the forestry sector as a key actor that can provide ecosystem services, raw materials, and products (Gould et al. 2017). This reactivation, for it to be successful, requires that government environmental agencies and all the interested stakeholders promote, manage, and implement a forest policy congruent with

the sustainable use of forest resources. Stakeholders include all the people, organizations, institutions, and companies that depend on or obtain benefits from forests or those who decide, control, or regulate access to those resources (Table 1). The project “Wood Innovations: Developing the Framework for a Puerto Rico Wood Products Team,” implemented by the University of Puerto Rico (UPR) and sponsored by the U.S. Department of Agriculture Forest Service (USDA FS), was undertaken to evaluate and promote the sustainable management of forests and the development of the forestry industry in Puerto Rico. This grant required the establishment of a Wood Products Council to channel innovations in wood-products manufacturing into the forestry production chain. The group has proposed that this council have a more formal role as an advisory council, leading to participatory processes to unite all the people interested in promoting the sustainable use of forest resources in Puerto Rico. We understand that such a council will be instrumental in channeling the forestry sector’s needs into public policies enacted by the local governance system.

In this study, we analyzed the current context of the forestry sector in Puerto Rico to address the following goals:

- Identify opportunities and limitations for the sustainable use of wood.
- Understand the factors that influence the development of the forestry sector.
- Carry out an analysis of the wood production chain to identify key stakeholders and understand how they may influence or be affected by changes in the forest policy of Puerto Rico.
- Address the need for an advisory council to develop public policies to support the forestry sector.
- Propose strategic guidelines for a national dialogue on the use of wood and forest products.

We reviewed the available literature to address these goals further. Also, we carried out field visits, interviews, and conversations with subjects from five sectors

of the wood production chain, adopting and modifying the classification proposed by the Landscape Conservation Center (or *Centro para la Conservación del Paisaje* in Spanish; CCP 2022). This classification is based on the nature of the activities carried out by the different parties in the production chain of the forestry sector, ranging from forest management oriented at obtaining raw materials to marketing processed products. In addition to wood, NTFPs with commercial potential have been identified, such as seedlings, spikes, poles, charcoal, vanilla, fibers, medicines, and resins (among others). However, the market for these NTFPs is smaller than that of wood, and their production chains have not been described in Puerto Rico (CCP 2022). Therefore, we mainly focused on the following components of the wood production chain as described next.

Forest management for the production of forest products

We refer here to planning and implementing stand-scale strategies for wood production. The activities within this sector include land tenure, promotion and regulation of reforestation, planting, and forest management. The stakeholders include landowners, government agencies, non-governmental organizations (NGOs), and other institutions or organizations that manage forest and plantation areas.

Wood extraction and collection

Includes felling, collection, and extraction of wood, monitoring of harvest areas, and planning roads and storage areas. The stakeholders in this sector include arborists, sawyers, artisans, municipal collection centers, and tree contractors.

Wood processing and production of forest products

Includes drying, board production, and woodworking. The stakeholders include sawmills, artisans, and furniture makers.

Marketing

Includes the sale of wood and products made from wood (handicrafts, furniture). The stakeholders in this sector are sawmills, artisan associations, hardware stores, carpenters, architects, designers, craft and souvenir shops, galleries, and government agencies that promote the artisan sector, such as the Industrial Development Company of the Commonwealth of Puerto Rico (PRIDCO) and the Institute of Puerto Rican Culture of the Commonwealth of Puerto Rico (IPRC).

Research and education

Finally, we refer here to the production and dissemination of knowledge related to the ecology and management of trees and forests, the processing of forest products and their marketing, the quantification of carbon sequestration in managing forest products, and other aspects of the forestry sector. The stakeholders in this sector include universities, government agencies, NGOs, vocational schools, artisan associations, and design workshops that offer training opportunities to those interested in learning to work with wood and setting up artisan businesses.

CONTEXT OF THE FORESTRY SECTOR

Forest management for the production of forest products

Currently, forests cover more than 52% of the area of Puerto Rico, or 467,320 ha (1,189,110 *cuerdas*; traditional Spanish unit of measurement still used in Puerto Rico) (Brandeis and Marcano-Vega 2022), of which the majority (85.2%) is private property (Brandeis and Turner 2013; Gould et al. 2017). In contrast, only 11.1% of the forests are managed by the government of the Commonwealth of Puerto Rico and 3.7% by the federal government (Brandeis and Turner 2013). The area with potential for the commercial production of wood is known as “timberland,” as defined by the Forest Inventory and Analysis (FIA) program of the USDA FS, in its

first forest inventory of 1980 for Puerto Rico (Birdsey and Weaver 1982). This timberland is exclusively on private land and excludes public forests where wood harvesting is prohibited. Also, this timberland classification excludes areas of high environmental value or at risk but deemed necessary to conserve biodiversity and secure essential ecosystem services, for example, those provided by mangroves, dry forests, lands suitable for agriculture, or lands with very steep slopes (inclination equal to or greater than 60%), especially in critical catchment areas as reservoirs of potable water (Gould et al. 2017; Brandeis et al. 2007; Birdsey and Weaver 1982). The area with potential for commercial timber production represents 43% of the forests and 23% of the total area of the archipelago of Puerto Rico. This area corresponds to 204,265 ha (~519,706 *cuerdas* or ~504,750 acres), of which 63% are located in the Moist Subtropical Forest type and 37% in the Wet Subtropical Forest type (Forero-Montaña et al. 2019).

Studies using FIA data to assess the potential of Puerto Rico’s forests for commercial production of timber and NTFPs have shown that promising stands are developing, characterized by high richness of useful species and high densities of timber and NTFPs trees (CCP 2022; Forero-Montaña et al. 2019); many of these species correspond to high-quality woods with well-known properties (Chudnoff 1980; Longwood 1961). Live trees ≥ 12.7 cm in diameter at breast height (dbh) in the timberland were estimated at more than 536 million individuals in 2014, with a total volume of more than 17,300,000 m³. Growing stock trees, however, defined as trees ≥ 22.5 cm dbh that are free of defects and meet minimum marketability criteria, represented less than 1% of living trees and barely 10% of the total net volume (1,874,965 m³) (Forero-Montaña et al. 2019). These results show that the forests are still relatively young, with extensive coverage of species like the American muskwood (*Guarea guidonea*; known to have desirable qualities for wood production) and the African tulip tree (*Spathodea campanulata*), but sometimes limits sawn-wood production since these

species are seldom used by artisans and rarely processed in the local sawmills, where instead process species like mahoe, mahogany, and teak (Forero-Montaña et al. 2018). The latter three are non-native species introduced to enrich the forests of Puerto Rico and are considered “fine woods.” However, their plantations are mainly located in public forests, and, in many cases, the conditions and exact locations of these plantations within the forests are unknown due to a lack of inventories and historical data (Francis 1995). Although there are some plantations on private lands, they are usually not managed for production due to poor technical knowledge and a lack of consistent demand and markets for local timber. Moreover, current reforestation efforts for wildlife habitat restoration and conservation mainly focus on native and endemic species with little or no incentives to plant species for timber, which may cause a future scarcity of these resources also valued for wood production (CCP 2022).

Forests with potential for wood production are mainly on private land (Gould et al. 2017). Consequently, we must identify the needs and expectations of landowners to understand their attitudes toward planting, maintaining, and harvesting trees for wood production on their properties and develop a wood-production economic model that promotes the sustainable use of forest resources in Puerto Rico. Moreover, we also need to bridge the communication gap among stakeholders and overcome several difficulties related to policy and regulations to achieve effective and coordinated efforts for the desired goals as intended (see next paragraph).

On the federal side, 24 federally-funded government programs provide financial incentives and technical assistance to help private farm owners adopt sustainable agroforestry practices (CEDES 2019). These programs focus on the restoration of forests and the conservation of biodiversity as their primary objectives. However, they do not prioritize the for-profit management of forest products, although timber from shade trees (e.g., in coffee plantations) is recognized as an agricultural benefit for landowners (CCP 2022; Forero-Montaña et

al. 2019; Trejo Ricaño et al. 2022). Implementing these programs involves multiple state and federal agencies, educational institutions, and private non-profit organizations, each operating under different laws, objectives, and missions. This lack of alignment poses a significant challenge to achieving common goals. Additionally, local offices often lack interdisciplinary work teams and qualified personnel in forest management or forestry-based enterprise support. As a result, technical assistance for landowners interested in wood and NTFPs production is extremely limited or entirely unavailable.

At present, only 2,939 ha or 1.7% (7,478 *cuerdas* or 7,262 acres) of the ~171,207 ha of private lands with potential for the commercial production of wood (timberland; see first paragraph of this section) have management plans certified by the Forest Stewardship Program of the USDA FS (Forero-Montaña et al. 2019); very few of these landowners report having produced any forest product (CCP 2022).

On the state side, the Auxiliary State Forest Program or *Programa de Bosques Auxiliares Estatales* (in Spanish) offers property tax exemption to owners of at least 1.97 ha (5 *cuerdas* or 4.86 acres) of continuous forest not used for agriculture and committed to the conservation and sustainable management of their forests (Law 133 of July 1, 1975; Appendix 1). Even though the program provides income tax exemption for forest products produced under a management plan approved by the DNER, the absence of markets for timber and NTFPs, coupled with inadequate technical assistance to support forest owners interested in for-profit forestry, hinders the development of profitable forestry operations for landowners (Forero-Montaña et al. 2019).

A key element in developing a sustainable forest production chain is having people trust local authorities. However, several stakeholders in the forestry sector have doubts about the capacity of the DNER to effectively promote the sustainable use of forests (Santiago et al. 2022). In large part, the potential capacity of the DNER to achieve the desired goals of wood production

is primarily halted by bureaucracy and a limited operational budget, which results in low efficiency and limited implementation of comprehensive forest management programs (e.g., *Centro para la Conservación del Paisaje*, in Wood Innovations Forum, May 27, 2022, San Juan, Puerto Rico). Also, there is a perception that the management of forests for timber production and the conservation of biodiversity always is antagonistic. For example, timber production in plantations in the Río Abajo State Forest (Utua-Arecibo municipalities, north-central Puerto Rico) was suspended in the 1990s to prioritize the reintroduction of the Critically Endangered Puerto Rican parrot (*Amazona vittata*), which uses tree holes as breeding sites (*Centro para la Conservación del Paisaje*, in Wood Innovations Forum, May 27, 2022, San Juan, Puerto Rico). Nonetheless, timber production may occur in other areas throughout Puerto Rico where its objective and the conservation of biodiversity are still compatible (see Brockerhoff et al. 2008 and Gould et al. 2017), but we need better strategies with all stakeholders in consideration to achieve the intended goals “to conserve Puerto Rico’s natural resources most effectively, as well as to develop and use them more fully for the general benefit of the community” (excerpt translated freely from the Constitution of the Commonwealth of Puerto Rico, Article VI, Section 19, available at <https://bvirtualogp.pr.gov/ogp/Bvirtual/leyesreferencia/PDF/Derechos%20Civiles/CONST/CONST.pdf>; Appendix 1).

Extraction and collection of wood

As mentioned in the previous section, public and private forests are not currently the primary source of wood used in Puerto Rico. Several factors contribute to this situation. For one, harvesting is restricted by law in protected areas. Additionally, trees on private lands can only be harvested under a management plan approved by the Forest Stewardship Program or through a special permit from the DNER, which involves a lengthy bureaucratic process (see Article No. 9 Forest Law No.

133 of July 1, 1975, and Appendix 1). This regulatory framework may push the forestry sector towards informality.

Meanwhile, the maintenance of streets, parks, and highways generates large amounts of woody material to the extent that local sawmills primarily source their wood by salvaging fine hardwoods from urban and public areas (CCP 2022; Forero-Montaña et al. 2018). However, there is no formal policy for the efficient use of wood obtained from these sources. For instance, the strategic plan for solid waste management mandates that wood, regardless of its quality, must be shredded before being deposited in landfills or compost facilities (Nazario Muñoz 2006). In response to this gap, sawmills have developed informal networks to locate cut trees and recover logs before they are shredded and discarded. Despite these efforts, two critical issues remain: 1) salvaging wood is not a priority for municipal and state entities, and 2) there is no coordinated policy for information sharing among municipalities, collection centers, and sawmills. As a result, wood resources are managed inefficiently, and significant amounts of fine hardwoods from urban and public areas are wasted.

Rescuing wood, especially after storms and hurricanes, could help Puerto Rico reduce environmental and economic infrastructure problems more effectively (Brinton et al. 2022). For instance, after hurricanes Irma and María, the DNER halted an initiative by FEMA and the USDA FS for salvaging fine wood. This decision led to the transfer of recovered woody material to the USACE, whose policy prioritizes the disposal of plant debris in the most cost-effective and time-efficient manner. As a result, large quantities of economically valuable material were shredded and disposed of in landfills across Puerto Rico (Brinton et al. 2022).

To address this issue, we must focus on developing the capacity to salvage woody debris and creating effective public policies that prioritize the sustainable use of downed wood. Additionally, coordination among federal agencies, state institutions, and other interested parties is essential to effectively manage debris

and maximize the adequate utilization of woody plant material after extreme weather events. Achieving these goals, while complex, requires several key strategies like 1) building local capacity to manage plant material outside landfills, 2) ensuring the participation of local stakeholder groups in decision-making processes based on circular economy principles, and 3) promoting education on the proper care and use of trees for both biodiversity conservation and economic contexts (Brinton et al. 2022; Pitti et al. 2020) (see the following paragraphs).

Tree harvesting requires robust public policies, planning, and effective regulation of forestry practices in appropriate areas designated for wood production. These areas should exclude lands with steep slopes or highly erodible soils and maintain a sufficient distance from adjacent rivers and streams to prevent sediment input into watersheds (see Gould et al. 2017). Additionally, forest policies should promote RIL techniques and the management of rehabilitation areas for species requiring high-light exposure for reforestation.

To maximize sustainable forest management, Puerto Rican agencies could adopt the technical criteria developed by the Tropical Forest Foundation (TFF) promoted by ITTO and implemented by the Forest Stewardship Council (FSC) in other regions (Klassen 2006[2005]; Klassen 2011; Klassen and Hasbillah 2007; TFF 2006). These criteria include 1) conducting prior inventories of the area to select suitable commercial trees for harvesting, 2) planning roads, skid strips, and landing stages before harvesting, 3) determining appropriate directional felling, 4) establishing pre-harvest procedures for log removal and hauling, and 5) performing post-harvest operations and assessing the achievement of management goals (TFF 2006).

Implementing these criteria require comprehensive training of all forest operations personnel, strong political will to support sustainable forest management, and public commitment to responsible forest practices. These elements are essential to achieve the intended goals (TFF 2006). Furthermore, certifying

wood products as sustainable is critical for ensuring the proper care of Puerto Rico's lands, aligning with the conservation mandate in the Puerto Rican Constitution, and maximizing income for producers. The Forest Stewardship Council in the United States offers a "Family Forests" program that could incentivize forest owners to adopt sustainable forest management. Through efficient and low-cost group certification programs, family forest owners could access the economic benefits of sustainable practices and enter markets for certified wood products (FSC 2011).

Previous experiences in Puerto Rico have revealed strong public opposition to timber harvesting in public forests (McGinley 2017). This highlights the paramount importance of education and effective communication about forest management and sustainable use of forest products to reactivate the forestry sector without compromising biodiversity conservation. For example, in 1986, the public and environmental organizations strongly opposed the logging and infrastructure proposals included in the management plan of the Caribbean National Forest (CNF, currently named El Yunque National Forest [EYNF]; available as read-only at <https://babel.hathitrust.org/cgi/pt?id=mdp.39015022275187&seq=5&view=1up>). In response to this opposition, the CNF management plan was revised to incorporate public concerns and visions, prioritizing forest protection and cultural activities. Logging was limited to a small demonstration and education plot (McGinley 2017; USDA FS 1997). Today, public resistance to timber production remains strong. Citizens who prioritize biodiversity conservation view the development of a forestry economy as undesirable unless proposed methods for timber extraction can demonstrate that they safeguard current recreational activities and conservation goals (Santiago et al. 2024). Therefore, establishing effective communication networks grounded in mutual trust and driven by education is essential. Such networks can help develop a sustainable timber industry in Puerto Rico that aligns with the public's conservation

priorities while addressing the potential for a forestry economy.

Wood processing

Locally produced wood in Puerto Rico is primarily processed by small artisan sawmills. These establishments are small-scale private businesses, typically operated by their owners with no more than two permanent employees. Most sawmills work independently and have operated for over 20 years, often lacking modern equipment and kilns to dry the wood. As a result, their production is relatively low and of variable quality (CCP 2022; Forero-Montaña et al. 2018). Additionally, the forestry sector in Puerto Rico faces several challenges, including difficulties in securing funding, the absence of established markets for local forest products, and higher operating costs compared to other countries. These factors have led to limited participation from individuals interested in forestry activities (Santiago et al. 2022). However, following hurricanes Irma and María, there was a notable increase in interest in using local wood as a source of income, which led to the proliferation of sawmills across Puerto Rico. Many of these new sawmills, however, are perceived as opportunistic, presumably operating without the proper tax and business structure. This situation raises concerns about unfair competition, as these sawmills often offer wood products at lower prices than registered businesses. Such practices threaten the viability of the private forestry sector, potentially pushing established sawmills toward bankruptcy (CCP 2022).

Marketing

During the industrialization of Puerto Rico in the mid-20th century, the forestry sector was relegated to producing handicrafts and souvenirs for tourists (Wadsworth 2012). Most of the wood products consumed in the archipelago today are imported, while locally produced wood is primarily used by artisans

to create furniture, musical instruments, and a wide variety of handicrafts (CCP 2022; Forero-Montaña et al. 2018; Kicliter 1997). Due to the low production and unreliable supply from local sawmills, key sectors of the wood market, such as construction and cabinet manufacturing, rely heavily on imported wood (CCP 2022; Forero-Montaña et al. 2018). However, since approximately 2022, there has been a growing interest in locally produced wood. Some sawmills have started establishing business relationships with new customers, including cabinetmakers, architects, designers, contractors, and hobbyists, as well as buyers from the U.S. Virgin Islands and some Lesser Antilles countries. Despite these developments, state agencies remain largely unaware of the commercial opportunities offered by timber products for export or the associated economic benefits that could help generate wealth and employment in Puerto Rico.

Moreover, no comprehensive economic or financial data is currently collected on the local market for wood and wood-based handicraft products. This lack of information makes it challenging to develop business strategies for these products. The market size, growth rate, trends, and profitability remain uncertain, leading to two major issues: 1) a limited understanding of consumer needs and preferences, hindering the design of new products and their potential success in the market, and 2) an absence of well-developed business strategies tailored to the local and export markets.

Since 1977, the government of Puerto Rico has implemented the Craft Development Program (today under the Department of Economic Development and Commerce) to support certified artisans in developing micro-enterprises. The program provides technical support, sponsorships, non-contributory incentives, and marketing services (Kicliter 1997). However, its current scope is largely limited to organizing festivals where artisans can sell their products tax-free. The program also lacks the institutional capacity, as well as sufficient human and financial resources, to offer comprehensive financial and technical assistance. This

limits its ability to help artisans increase their competitiveness, effectively market their products, and preserve cultural values and artisan traditions. As a result, most artisans are restricted from marketing their products at public festivals, facing challenges such as low demand for local crafts and strong competition from low-cost imported crafts and souvenirs (Forero-Montaña et al. 2018).

Small-scale producers become stronger when they work together within a mutual-trust system. By collaborating, they can buy and sell collectively, advocate for their common interests and rights, and strengthen their position in the market. Well-structured and functional producer associations, for example, can effectively lobby for the interests and needs of the group, facilitate access to technology and financial resources, and support the development of small-scale but successful enterprises. These associations are also better positioned to negotiate more sustainable, accessible, and reliable prices. Additionally, formalized and sustainable associations can offer secure employment opportunities and access to credit, which are essential for further enterprise development (FAO 2016).

Despite the existence of several associations aimed at representing the interests of the artisanal sector, artisans and sawmills in Puerto Rico generally work individually. This lack of collaboration hinders their ability to achieve larger production scales, making it difficult to compete effectively in globalized markets. Without teamwork, the artisanal sector struggles to establish quality standards, secure training opportunities, and attract financing to enhance the production and quality of its goods (Forero-Montaña et al. 2018). To help artisans develop profitable and competitive micro-enterprises, it is essential to strengthen cooperation among institutions, including government agencies, NGOs, and artisan associations. This collaboration should focus on facilitating the exchange of information, reinforcing skills, and providing the necessary support to help artisans thrive in the market (Forero-Montaña et al. 2018).

Research and education

The disconnection between different forestry sector stakeholders is one of the biggest obstacles to developing a sustainable forestry industry in Puerto Rico due to the lack of formal feedback channels between relevant agencies and institutions (CCP 2022). For example, sawmills and hardware stores that trade local wood do not have an influence on the planning and implementation of strategies for forest management. Likewise, the owners of farms with timber species and the government environmental agencies that regulate and promote sustainable forest management rarely interact with timber processors (i.e., sawyers and artisans). The result is the lack of a functional path linking the production and processing of forest products to their commercialization and use (CCP 2022). Therefore, institutions devoted to education, research, and dissemination of information related to forest management, forest product processing, and marketing could play a larger role as facilitators for the forestry industry in Puerto Rico (CCP 2022).

The research and education group is represented by universities, federal and state government agencies that regulate and promote sustainable forest management, and NGOs that focus on conservation, sustainable management, and reforestation of forests. Also represented are architecture, vocational carpentry, and art schools that train and promote the use of wood. For example, after hurricanes Irma and María in 2017 and as a strategy for mitigation and adaptation to the projected changes in climate, the UPR and the USDA Caribbean Climate Hub (CCH), in collaboration with other organizations like the CCP, worked to strengthen research and disseminate information on reforestation practices, wood supply and demand, wood harvesting and processing, and other topics related to forest management and forest products (Fain et al. 2020). Their work included conferences, seminars, meetings, forums, reports, and publications that exposed students, professors, academics, and citizens interested in forest

management and conservation to the sustainable production chain of timber and NTFPs for the benefit of the forestry sector in Puerto Rico (for more information on these efforts, consult <https://www.climatehubs.usda.gov/hubs/caribbean> and <https://www.conpaisaje.org/recursos-1>.)

In the past decades in Puerto Rico, declining interest in the forestry sector has been accompanied by a scarcity of education programs on forest management. However, sustainable forest management focused on timber production and environmental services provision requires research and knowledge based on transdisciplinary and geographic contexts. For example, a broader understanding of forestry requires knowledge of forest ecology, soils and biodiversity conservation, hydrology, forest inventory, geography and geographic information systems (GIS), forest harvesting, state and federal public policy, urban planning, business administration, marketing, communication, and ethics (among others). Also, forestry students are expected to apply sustainability practices incorporating the influence of projected climatic change on circular economic principles (i.e., valorization of wood co-products and by-products) with stronger critical thinking skills in organizing and planning for intended goals and benefits to all (Mayor et al. 2022).

One strategy for the development of such students would be a bachelor's and master's degree in forest management, which could be implemented as a cooperative program between the campuses of the UPR in Río Piedras and Mayagüez, along with private institutions, with a commitment to reviewing the requirement of related curricula. Also, the development and approval of minor concentrations and certifications within existing programs addressing particular areas of need for the forestry sector. For example, the USDA National Institute of Food and Agriculture (NIFA) funded the initiative “*A Wood Products Laboratory and Outreach Facility to Support Sustainable Community Forestry in Puerto Rico*”. This project, based at the UPR-Mayagüez, focuses on capacity building and

curriculum development in wood production, treatment, and processing.

Additionally, experts in planting, pruning, and reforestation do not necessarily require a degree in forestry but can practice with a certification. In Puerto Rico, for instance, the planting, care, and management of urban trees, especially those generating significant woody material after extreme weather events, are primarily handled by certified arborists. A formal degree is not required to work in this field, but certifications, such as those offered by the International Society of Arboriculture (ISA), are highly recommended (see the U.S. Bureau of Labor Statistics at <https://www.bls.gov/ooh/building-and-grounds-cleaning/grounds-maintenance-workers.htm#tab-4>; ISA 2023; Zippia Team 2003). While the ISA certification is available in Puerto Rico, local arborist certification programs are not widely offered (C. Torres, personal communication), underscoring the need to provide this training opportunity regularly.

Furthermore, in an unprecedented funding allocation through the Infrastructure Reduction Act of 2023 to the NGO Caribbean Regenerative Community Development, The Urban Trees for Resilience, Equity & Empowerment in Puerto Rico (U-TREE-PR) Program with the support from the USDA FS, aims at promoting workforce development and helping communities in Puerto Rico in achieving certified Tree Cities status. Overall, strategic research and education initiatives are essential to support professional development and effective communication among stakeholders in the forestry sector and the public (Pynnönen et al. 2019).

Stakeholder analysis

Promoting the sustainable use of the forest resources of Puerto Rico requires a policy reform that adapts to the changing needs of different stakeholder groups and new challenges and opportunities (e.g., FAO 2010; Clark 2011). Achieving this requires understanding and integrating the different perceptions and expectations

Table 1. Key stakeholders of the forestry sector and their main role in the local-wood production chain) in Puerto Rico. Under Stakeholder, acronyms follow the main text.

Role	Stakeholder						
Those who have land tenure and rights to natural resources.	Landowners	PR Commonwealth government	U.S. federal government	para la Naturaleza			
Resource managers with jurisdiction over forests.	Landowners	DNER	USDA FS EYNF	U.S. FWS	para la Naturaleza		
Local-wood users.	Farmers	Sawyers	Artisans				
Traders and consumers of local wood and artisanal products.	Sawyers	Artisans	Wood Retailers	Souvenir shops	Tourists	Citizens	
Institutions devoted to education and research.	UPR (Río Piedras, Mayagüez, Utuado campuses)	USDA FS IITF	USDA CCH	USDA FS SPTF	USDA FS EYNF	USDA NRCS	U.S. FWS
Institutions supporting the artisan sector.	PRIDCO	IPRC	PRTC				
Non-governmental organizations.	ENVIROSURVEY INC.	CAFI CULTURA PUERTORRIQUEÑA INC.	TROPIC VENTURE RESEARCH AND EDUCATION FOUNDATION INC.	PARA LA NATURALEZA INC.			

of various stakeholders. In this study, we conducted a preliminary analysis to identify key stakeholders who could be affected by and/or directly influence a forest policy reform to reactivate the forestry sector in Puerto Rico. Our aim is to help devise strategies to convene and promote their participation in this reform process. The stakeholder analysis herein conducted follows recommendations of the European Commission (2022) with modifications: the analysis was structured in three stages, 1) identification of stakeholders, 2) classification of stakeholders, and 3) assessment of their particular interests in the potential success of a forest policy reform, and their perceived power and influence to support this process. This analysis was based on qualitative methods that included expert interviews, observations, and examination of available and relevant documents.

The key stakeholders of Puerto Rico’s forestry sector include various actors with different interests and power of influence (Table 1). For example, herein included are: 1) private landowners who have tenure rights to most of the Puerto Rico’s forests; 2) sawmills and artisans who are the main collectors, processors, and traders of local timber and NTFPs; 3) state and federal environmental agencies that manage the resources and have jurisdiction over the state (DNER) and federal (USDA FS EYNF) forests; 4) institutions dedicated to education and research including universities (UPR Río Piedras, Mayagüez, and Utuado campuses);

5) federal environmental agencies such as the USDA FS with all its components and programs (i.e., the USDA FS IITF, USDA FS EYNF, and USDA FS State, Private and Tribal Forestry [SPTF]), the USDA CCH, the USDA NRCS, and the USFWS, which do research and provide professional, technical, and financial assistance to promote wildlife conservation and sustainable management of natural resources; and 6) various environmental NGOs (e.g., *para la Naturaleza*, CCP, Envirosurvey, Tropic Venture Research and Education Foundation, *Cafi Cultura Puertorriqueña*) that focus on conservation, sustainable management, and reforestation of forests; and vocational schools of carpentry and arts that train and promote the use of wood.

We identified key stakeholders and generated a list describing their main activities and their levels of attitude and influence regarding a forest policy reform process aimed at reactivating the forestry sector in Puerto Rico. Stakeholders were classified based on their role in the forestry sector and their main characteristics to determine their specific interests (Appendix 2).

Appendix 2 presents a comprehensive list of stakeholders, detailing their main activities and their levels of attitude and influence concerning the policy reform process. Attitude refers to the position that a stakeholder is likely to take regarding the reform, while influence denotes their weight or power in the decision-making process, which could significantly impact the success

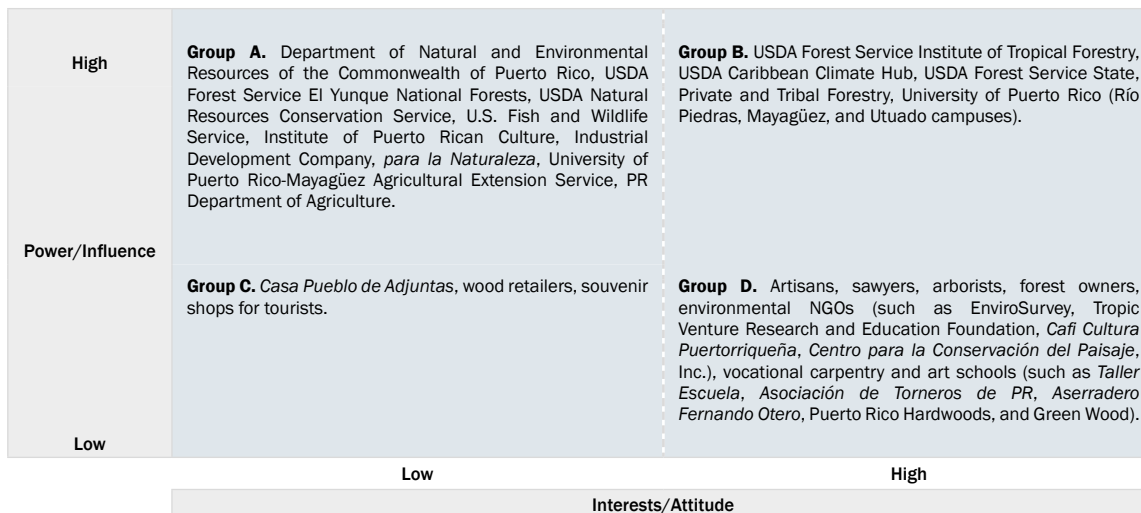


Figure 1. Matrix of Stakeholder Analysis.

or failure of the policy reform. The activities of each organization were described based on the mission and vision statements presented on their websites. To ensure the accuracy of the information provided, we created a measure of control to evaluate the quality of the data included in the other columns. This measure reflects our degree of certainty about each organization's involvement in the forestry sector, as some organizations' roles might have been exaggerated or underestimated. A low score in this variable indicates that further research is necessary to better elucidate its interests and power of influence in a forest policy reform process.

Additionally, we constructed a stakeholder matrix to characterize the different actors based on their levels of attitude/interest and power/influence (Figure 1). This analysis facilitates prioritizing strategies for managing stakeholder participation, identifying key stakeholders for inclusion in the advisory council, defining their potential roles, and determining the conditions necessary for their involvement. It also acknowledges the possibility that not all stakeholders will express interest in participating in forestry-related initiatives (FAO 2010).

Given their position in the stakeholder matrix (Figure 1), Group A and Group D require more careful attention to encourage their engagement for the

following reasons (Brugha and Varvasovszky 2009). Group A comprises key stakeholders with high power but low interest or attitude. These stakeholders can significantly influence changes in forest policy, either positively or negatively. Therefore, it is essential to carefully approach and monitor this group, keeping them informed, and recognizing their unique perspectives and interests. Members of Group A include the DNER, federal environmental agencies (such as USDA FS EYNE, USDA NRCS, and USFWS), the *para la Naturaleza* (PLN; an environmental NGO focused on protecting strategic natural areas and promoting reforestation with native species). Other members include the Agricultural Extension Service of the UPR-Mayagüez Campus, which promotes sun-grow coffee cultivation, and Puerto Rico government agencies that promote artisan products, such as PRIDCO and IPRC, which support artisan products but have had minimal involvement in forestry affairs thus far. In contrast, Group D comprises stakeholders with high interest or attitude but low power and influence. This group requires focused efforts to build their capacity for meaningful participation in the forest policy reform process. These stakeholders are often directly affected by changes in forest policy and must be empowered

to ensure they are heard. Group D includes forest owners, artisans, sawyers, arborists, environmental NGOs, and vocational carpentry and art schools. By addressing the specific needs of Groups A and D, the reform process can be more inclusive and equitable, maximizing the chances of its success.

Group B includes key stakeholders with high interest and significant influence in the stakeholder matrix design. This group does not require much attention beyond regular follow-ups and documentation of their efforts, as these actors already possess the capacity and willingness to actively participate in developing policies to promote the forestry sector. Key collaborators in this group include the UPR and federal agencies such as the USDA FS IITF, USDA FS SPTF, and USDA CCH. In contrast, Group C comprises stakeholders with low interest in wood production and limited power or influence within the production chain. This group does not require a dedicated participation strategy; instead, keeping them well-informed about forestry initiatives and maintaining open communication seems sufficient. This ensures the communication network remains functional and allows for feedback when necessary. Group C includes organizations such as *Casa Pueblo de Adjuntas*, wood retailers, and souvenir shops for tourists (Figure 1).

Mission and structure of the advisory board

Framing new public forestry policies also requires leadership and support from the highest levels of government (FAO 2010; Clark 2011). Specifically, the participation of government entities that decide, control, and regulate forests, as well as access to their resources and benefits or have the authority to change land use, is fundamental to the success of such reforms (FAO 2010). It is, therefore, essential to involve high-ranking political authorities from the outset, ensuring they are willing to endorse the reforms and are committed to implementing new policies. In Puerto Rico, however, the political will of the DNER to lead forest policy changes has been limited. To date, the involvement of

DNER leaders in efforts to strengthen the forestry sector has been minimal, largely due to political interference from whichever political party is in power. This interference often results in public policies that do not necessarily align with the long-term interests outlined in the constitutional framework. Furthermore, as mentioned, government agencies, NGOs, and artisan associations in Puerto Rico often work independently, without a shared vision or collaborative efforts to promote the sustainable use of forest resources.

Despite these challenges, since 2013, the “Wood Innovations Grant Program” of the USDA FS has financed six projects in the continental U.S. to establish groups known as Statewide Wood Utilization Teams. These teams unite federal and state agencies, private for-profit and non-profit organizations, and research and educational institutions to support and strengthen wood product markets. The structure and mission of these groups vary based on the specific context of each state. Inspired by this model, Puerto Rico’s socio-political context led to the creation of “The Wood Innovations Project: Developing the Infrastructure for a Puerto Rico Wood Products Team.” This initiative aims to establish an advisory council to unite key stakeholders most affected by forestry sector reforms. The council seeks to address the lack of organization and capacity of stakeholders, enabling more effective collaboration and significant intervention in the reform (see next paragraph).

Establishing an advisory council in Puerto Rico to strengthen the forestry sector requires ensuring the participation of key stakeholders and selecting representatives who reflect the interests of forest owners, farmers, artisans, sawyers, arborists, NGOs, and vocational carpentry and art schools, among others. Our stakeholder analysis led us to recommend that the proposed council be structured to engage actors that are currently hesitant or less inclined to participate (i.e., those scoring low in interest and attitude, such as the DNER and federal environmental agencies like USDA NRCS and the USFWS). Encouraging their active

involvement in the development of forest policies is crucial for revitalizing the forestry sector.

We also suggest holding community forums and meetings to foster the engagement of stakeholders with low attitudes and interests. Cross-sector committees and study groups could also be established to promote collaboration and ensure broader participation in the policy-making process. Public surveys and hearings must be conducted to increase participation across all sectors. To further promote stakeholder engagement, we propose that the advisory council comprise institutions, organizations, and individuals with high expertise in research, education (formal and informal), local knowledge, and communication. This inclusive approach requires more active involvement from UPR's Agricultural Extension Service, which is instrumental in securing the engagement of local communities in forestry and agriculture. Therefore, it will be necessary to convene professors and researchers from universities, members of artisan associations and farmers' associations, state and federal environmental agencies, and NGOs to identify individuals interested in assembling this group (see next paragraph).

In 2014, a facilitator group known as the Advisory Committee for Agroforestry Development (*Comité Asesor para el Desarrollo Agroforestal*, CADA in Spanish) was created in Puerto Rico to promote the sustainable use of the archipelago's forest resources. Sponsored by the DNER and the USDA FS IITF, CADA was supported by key personnel from state and federal government agencies, universities, private companies, and organizations. Prior to its formal establishment, the group held several meetings between 2012 and 2016 to discuss topics, including education, economy, plantation inventories, legislation, infrastructure, and forest management. It also organized two symposia on forest products, with participants from the academia, the USDA FS IITF, DNER, PRDA, and DTOP. However, the group disintegrated after the 2016 governmental elections, which led to undesirable administrative changes within the DNER.

This experience highlights that, for the new advisory council to succeed, it must have political and economic independence from the government and continuity beyond general elections. It should work in coordination with the executive and legislative branches, irrespective of the political party in power, to reform forestry laws effectively for the benefit of the people of Puerto Rico and the biodiversity that supports them. Moreover, the council will benefit from the participation of scientists and science-based organizations capable of synthesizing the best available scientific information and communicating it to decision-makers in an accessible format (Hetemäki 2019).

Currently, there is an increasing amount of scientific information available to support policymaking. However, as in other societies, a lack of synthesis studies written in an understandable format remains a significant limitation for effective science-policy support (Hetemäki 2019). Advancing a holistic, transdisciplinary, and transparent science-policy advocacy effort will require input from diverse disciplines. Scientists and organizations facilitating such efforts must avoid imposing their agendas or interests. Instead, co-creation, dialogue, and deliberation with key stakeholders will be essential to generate valuable policy-relevant information (Hetemäki 2019). The proposed Forest Products Council must embrace a transdisciplinary perspective to be truly effective. Its role should go beyond identifying problems to include isolating their causes, analyzing available evidence, and conducting research to develop viable policy options (Appendix 3). These options should adhere to the criteria of feasibility: being technically sound, practically achievable, economically beneficial, environmentally sustainable, politically advantageous, and socially acceptable, as outlined in Bomford's (1988) framework.

Policy advocacy must also involve citizens' active and continued participation to ensure that local communities play a central role in shaping and implementing changes in prevailing policies. As a first step in forming the new advisory Forest Products Council, former

members of CADA should be contacted to gauge their interest in reactivating the group or forming a new entity to foster a national dialogue on timber and NTFPs. The new council should prioritize openness to differing opinions, interests, and objectives, promoting discussions and negotiations that lead to agreements and resolving discrepancies.

CONCLUDING REMARK

The proposed Forest Products Council could serve as a unified platform for local forest businesses, forest landowners, and NGOs to present their ideas for forest policy reforms. Its primary goals would include facilitating legal access to forest resources, creating incentives to promote sustainable forest management on private lands, and encouraging the association of small forest enterprises to enhance their ability to add value and remain competitive in both local and international markets (Forero-Montaña et al. 2018).

Additionally, the council would play a key role in guiding the decision-making process for timber management within Puerto Rico's institutional framework and developing a comprehensive policy advocacy strategy for timber-related activities. This strategy would encompass lobbying decision-makers, mobilizing citizen groups, conducting community outreach and grassroots organizing, assessing the political environment, and building coalitions.

In this study, we have summarized some of the key issues limiting timber-related activities and proposed solutions for the challenges faced by Puerto Rico's forestry sector. This summary serves as a valuable initial working document to guide the efforts of the proposed council and establish a path toward feasible policy reforms.

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APPENDIX 1

A) A brief legal background to state forest management in Puerto Rico since 1824 and B) a discussion of the recent history of state and federal forest management in the wood-production context from the 1970s to the present.

A) Legal background to state forest management in Puerto Rico since 1824

In August 1824, Governor Miguel De La Torre introduced the first conservation law in Puerto Rico, Circular No. 493, during the Spanish Colonial Period. The Circular called attention to the amount of forested land being cleared on the archipelago due to agriculture and the adverse effects of deforestation on the water supply. It suggested various measures to remedy the problem, including prohibiting cutting trees around the island's watersheds and reforestation of bare watersheds using fast-growing tree species (DNER 2006).

In 1917, under the colonial rule of the United States of America, the Legislature of Puerto Rico enacted the first Forest Act, Law Num. 22, 1917. The Forest Act provided for the proclamation of State Forests, timber production, and watersheds and wildlife protection. It also established the Puerto Rico Forest Service under the direction of the U.S. Department of Agriculture at the Luquillo National Forest. In the years following the Forest Act enactment, the governor proclaimed Guánica, Maricao, Piñones, Ceiba, Aguirre, Boquerón, and Mona Island as State Forests (Robinson et al. 2014).

In 1930 the lands comprising Toro Negro Forest were purchased by the Puerto Rico Reconstruction Administration (PRRA), and they were added to the Luquillo National Forest, which became the Caribbean National Forest (Robinson et al. 2014). On 1935 PRRA added Río Abajo, Carite, Guajataca, Guilarte, and Susúa Forests to the Caribbean National Forest (DNER 2006). Between 1934 and 1946, more than 29 million trees of 53 species (including 24 native species) were planted in the forests of Puerto Rico. In 1943, most areas designated as forests outside of Luquillo were transferred to the Puerto Rico Forest Service. By 1949, all public forests had been reforested: 8,790

acres were naturally regenerated, and 3,600 acres were reforested by planting (Robinson et al. 2014). In 1953, the PR Forest Service was separated from the USDA Forest Service and became an independent bureau in the Puerto Rico Department of Agriculture named the Forest, Fisheries, and Wildlife Section.

In 1972, the Department of Natural and Environmental Resources of the Commonwealth of Puerto Rico (DNER) was created through Law Num. 23, 1972 (12 L.P.R.A. §§ 151-165). The DNER received the mandate to implement the environmental public policy of the government of Puerto Rico as established in Section 19 Article VI of the Constitution of the Commonwealth to implement any program and measures necessary for the utilization and conservation of the natural resources of the archipelago. The DNER Enabling Act transferred to the DNER all the functions and power bestowed by the Forest Act of 1917 to the U. S. Department of Agriculture and all the functions concerning forest lands and greenhouses contained in other laws (Robinson et al. 2014).

By 1975, the Legislature enacted a new Puerto Rico Forest Act, Law Num. 133, 1975 (12 L.P.R.A. §§ 191–204). This legislation established as the public forest policy of the Commonwealth of Puerto Rico the maintenance, conservation, protection, and expansion of forests to secure their full benefit and enjoyment for this generation, as well as a legacy for future generations; the efficient use of forest products and benefits; the designation and management of estate owned forest land as Commonwealth Forests for their rational development and management to obtain the maximum and continuous yield of the forest products, services, and utilities; the development and establishment of measures for forests

conservation; and the stimulus of private initiatives for the same purposes (12 L.P.R.A. § 192 [a]).

The Puerto Rico Forest Act of 1975 created a new State Forest Service and empowered it with the immediate direction and control of all matters related to forestry (12 L.P.R.A. § 194). This included supervision of funds and personnel, production of trees for forestation, conducting studies, investigation on suitable techniques for reforestation, management of Commonwealth Forests, and use of forest products. Consequently, the DNER is authorized to dispose, by sale, license, permit, or any other appropriate means, any timber or derived or processed products thereof, including wood, resin, forage, or any other forestry product produced on Commonwealth Forests, except minerals. Any sale, license, permit, or any other disposition of any wood product whose value exceeds ten thousand dollars (\$10,000) shall be made through an auction previously advertised to the public in a newspaper of general circulation (12 L.P.R.A. § 196 [d] [2] [A]). The Secretary of the DNER was directed to establish the norms and criteria for fixing the price of disposition of forest products through regulations. No such regulation exists.

The Puerto Rico Forest Act also provides for the lease or grant, under limited permits, for the use or exploitation of structures, facilities or lands, water, or other commodities or resources within the forests, except for minerals, if consistent with the purposes for which the forests were established (12 L.P.R.A. § 196 [d] [2] [B]). The DNER could lease or allow the exploitation of a plantation to extract wood within an area of any Commonwealth Forest under the terms and conditions it may prescribe for any interval not to exceed fifteen (15) years. It can also execute any agreement and contract, including but not limited to the purchase and sale of timber, be it in the form of trees, logs, processed or in any other form, with natural or juridical, private or public persons and with federal, Commonwealth, or municipal agencies and bodies, under the terms and conditions it deems necessary or convenient (12 L.P.R.A. § 196 [f]). However, no such agreement has ever been used by the

DNER to extract or produce wood products. A similar system is used for the installation, maintenance, and operation of electronic communication equipment within the forests (12 L.P.R.A. § 196 [d] [2] [C]).

A Special Forest Development fund was created for all incomes accruing from any activities on Commonwealth Forests within the scope of the Puerto Rico Forest Act, including the sale of wood and wood products (12 L.P.R.A. § 197). The funds deposited in that account should be used for the improvement and development of forests, including the acquisition of forest lands, reforestation, and the establishment, extension, and improvement of facilities and any other activities necessary or convenient for the performance of the objectives of the Forest Act (12 L.P.R.A. § 197). Also, within Commonwealth Forests, it is expressly forbidden, except by express authorization in writing by the Secretary of the DNER, to burn or cause the burning of any structure, timber, shrubbery, or grass; pasturing of cattle; removal or destruction of fences, notices, signs, landmark or marks set by the PR-DNER along the borders of the forest; hunting; and depositing of wastes (12 L.P.R.A. § 198 [b]–[g]). It is also forbidden either on public or private lands to fell, prune, strip the bark or otherwise affect the trees whose characteristics are indispensable or necessary for forest development, including the protection of watersheds, erosion control, and the ecological balance of the environment; rare endangered tree species; tree species protected for any reason whatever which is duly justified through regulations; trees located in public parks and town squares; and those that are indispensable for any essential public utility purpose (12 L.P.R.A. § 199 [b]).

Additionally, laws stipulate that no person shall cut, remove the bark from, kill, destroy, tear, ruin, or otherwise damage or cause deterioration of any tree on private or public property without a permit from the DNER (12 L.P.R.A. §198 [a] and § 199 [a]; Planting, Felling and Forestry Regulations for Puerto Rico, DNER, and Planning Board Regulation 5922, 1998). When the proposed action is not associated with a construction project, a

permit petition should be presented to the DNER (See *Solicitud de Permiso para Corte, Poda, Transplante y Siembra de Árboles No Asociados a Proyectos de Construcción o Enmienda a Permiso Incidental*, Petition MA-01, DNER. 2016. Available at <https://www.drna.pr.gov/documentos/formularios/ma-01-permiso-de-actividad-no-incidental-a-obra/>). A forest technician should evaluate the petition within 30 days of presentation and proceed with the necessary recommendation for the permit approval and the applicable conditions to the permit (Regulation 5922, Art. 3.03).

Government agencies and municipalities must comply with the disposition of the Forest Act and the regulations regarding cutting trees except for agencies exempted explicitly by law like the Power Authority (Regulation 5922, Art. 3.05–3.06). Other government agencies who wish to be exempt from the permit requirement should submit a plan for the management of trees in general to the DNER for its evaluation and comments. If a final decision from the DNER about the management plan is not taken within thirty (30) days after its presentation, the plan should be assumed to be endorsed by the DNER (Regulation 5922, Art. 3.06).

Any construction project in which trees are planned to be cut or removed needs a permit from the Office for the Management of Permits (“Oficina de Gerencia de Permisos,” OGP_e in Spanish) or Autonomous Municipalities, depending on jurisdiction, and shall comply with the dispositions contained in the Regulation 5922, regarding planting and forestation (Regulation 5922, Art. 4.00). The Regulation 5922 specifies the requirements for each type of construction project type considered. Personnel from DNER assigned to the OGP_e environmental unit evaluate the proposed projects and their possible effect on fauna and flora, including the trees to be removed, and shall emit its recommendations. All petitions shall include identifying the trees affected, any protection measures needed for existing trees, and a certified planting plan detailing the proposed trees to replace those cut and the areas where they will be planted (Regulation 5922, Art. 4.02). The

planting plan should adhere to the guidelines established in Regulation 5922 regarding distances between trees and between trees and existing and proposed structures and power lines. When planted on buffer zones of green barriers, trees shall have a minimum height of six (6) feet or four (4) feet. Any bush being planted should have a minimum height of twenty-four (24) inches (Regulation 5922, Art. 4.05).

In 2010, the Puerto Rico Forest Act was amended to exclude farmers from the permit requirement in the performance of activities related to agriculture focused on the production of food, fiber, fuel, or others by using natural resources consistently with the environment (12 L.P.R.A. § 199 [c]). Farmers are allowed to cut, trim, fell, or otherwise cause damage to native or endemic tree species that have eight (8) inches or less either in trunk diameter at breast height (dbh), provided an agronomist certifies the agricultural practices as being part of integral plan for agricultural development and resource conservation and the agricultural activity is endorsed by the Department of Agriculture of the Commonwealth of Puerto Rico (12 L.P.R.A. § 199 [c] [1]). Trees with more than eight (8) inches dbh or more than four (4) feet high could be cut down with a permit from DNER (see *Solicitud de Permiso de Actividad Incidental para Práctica Agrícolas del DRNA*. MOI. Available at <https://www.drna.pr.gov/documentos/permiso-de-actividad-incidental-para-practicas-agricolas-del-drna/>). Adequate mitigation measures imposed by the PR-DNER in those cases cannot exceed the planting of more than one tree for each one eliminated (12 L.P.R.A. § 199 [c] [2]). No permits shall be necessary, irrespective of trunk’s diameter, in the case of tree species recognized as invasive or as plagues (12 L.P.R.A. § 199 [c] [3]). In addition, no mitigation measures shall be necessary when the trees to be cut, trimmed, stripped the bark of, or damaged are dedicated to the production of an agricultural product and the action is taken as part of farming activities (12 L.P.R.A. § 199 [c] [4]).

Owners of Auxiliary forests are also exempt from the permit requisite to cut trees, although they need to

submit a plan for forest protection and management to be considered by the DNER (12 L.P.R.A. § 200 [a]). Auxiliary Forests are private lands with a continuous area exceeding five (5) cuerdas (1.965 ha) devoted exclusively to the production and development of forests for purposes other than the production of coffee, fruits, or other edible products designated as such by the Secretary of DNER at the petition of the owner (12 L.P.R.A. § 200 [a]). Owners may at any time remove or cut down trees or parts of trees exposed to fire or which have fallen or are broken or injured by any natural cause and may, in a rational manner, do the necessary cleaning of the property and remove those varieties of undesirable trees and they may use whenever necessary, the timber which may be needed for use on the property for general purposes (12 L.P.R.A. § 200 [b] [2]).

Auxiliary forest lands are also exempt from property taxes, and the income proceeding from the sale of forestry products from those forests is exempt from the payment of income taxes (12 L.P.R.A. § 200 [a]). The tax exemptions last while the Auxiliary Forest is preserved as such. The property shall be inspected at least once a year by the DNER to determine if the landowner is complying with the agreed-upon management plan and any conditions set forth by the agency.

As amended, the Puerto Rico Forest Act recognized all present and future Commonwealth Forests as refuges for any wildlife species, including birds, whether native or migratory, and game animals (12 L.P.R.A. § 202). It also recognizes forests as an essential source of employment to mitigate rural poverty, educate unruly

children, and rehabilitate convicts and, for that purpose, authorizes the DNER to enter into agreements with other governmental agencies mainly responsible for dealing with these problems to develop projects and to use commonwealth forest lands as a place to employ personnel or otherwise implement these objectives (12 L.P.R.A. § 201).

Finally, the DNER could impose administrative fines for violations of the amended Puerto Rico Forest Act, including cutting a tree without a permit, after holding a quasi-judicial public hearing, in which basic procedural due process needs to be followed. The administrative fines shall not exceed fifty thousand dollars (\$50,000), nor shall they be less than fifty dollars (\$50) or greater than five hundred dollars (\$500) for each affected tree. In the case of repeated offenses, the DNER could impose an administrative fine of not less than five thousand dollars (\$5,000) nor greater than fifty thousand dollars (\$50,000) after holding an administrative hearing. In addition to any fine, the DNER could order the reforestation, restoration, or mitigation of an affected area, considering the ecological and scientific factors convenient to the forest and the public interest (12 L.P.R.A. § 203). Any violation of any provision of the Act or its regulation shall constitute a misdemeanor, and upon conviction, the accused shall be punished by a fine of not less than five hundred dollars (\$500) nor greater than five thousand dollars (\$5,000), or imprisonment for a term of not less than five (5) days nor more than ninety (90) days, or both penalties at the discretion of the court (12 L.P.R.A. § 204).

B) Discussion of the recent history of state and federal forest management in the wood-production context from the 1970s to the present.

When the DNER was created in 1972, it inherited a legacy of land proclamation linked to active reforestation and natural forest regeneration as central accomplishments of governmental agencies in charge of forest resources since the first Forest Act of 1917. This was especially critical given that Puerto Rico's

forest area had dropped to only 6 percent of its total land by the late 1940s (Birdsey and Weaver 1982). The passage of a new Puerto Rico Forest Act in 1975 emphasizing the maintenance, conservation, protection, and expansion of forests was illustrative of this archetype. The USDA FS IITF, under the direction of

Frank Wadsworth (1956-1974), played an active role in informing and influencing policymaking, contributing significant advances in the forestry sector by direct science advocacy in policymaking (A. E. Lugo, personal communication). The research work carried out in the forests of Puerto Rico by the USDA FS IITF during these days was fundamental to generating and disseminating knowledge about the sustainable management of tropical forests and paved the way for silviculture elsewhere in Central and South America (Wadsworth 2014). Those efforts showed that the productivity of tropical forests can recover after being cleared for agriculture as long as soils are preserved.

Comparative tests on the regeneration of more than 450 species were carried out, successful reforestation techniques were developed, and wood was sustainably produced by the mid-twentieth century. However, after the 1970s, the federal government suspended wood extraction and silvicultural research aimed at this purpose in the Luquillo Experimental Forest. Subsequently, forest management shifted to a custodial approach for the protection of at-risk species, the sustainability of water production, and quality opportunities for ecological recreation (Wadsworth 2014). On the other hand, past efforts for the establishment of urban forestry projects drifted when the forestry programs that were initially under the USDA FS State, Private, and Tribal Forestry were assigned to the USDA Natural Resources Conservation Service (USDA NRCS), which does not promote forestry, slowing down the development of the forestry sector (A. E. Lugo, personal communication). As a result of this change in the federal vision of forestry production, the assignment of the DNER has been mainly focused on the propagation of trees, the implementation of reforestation techniques, and the conservation of wildlife. However, the agency has also been empowered on all matters regarding the use and sale of forest products since the Puerto Rico Forest Act of 1975. Still, managing forests for the sustained yield of forest products is not one of its policies.

The generated dichotomy between forestry and agriculture goals limited the effectiveness of forest policy development because each environmental agency has focused on its respective policy component of the system as an individual rather than a cooperative transdisciplinary system. Thus, the view of an entire system integrating the conservation and sustainable use of forest land has been missing, preventing the implementation of a comprehensive forest policy at the state and federal levels (E. González, personal communication). For instance, the Department of Agriculture of the Commonwealth of Puerto Rico (PRDA) has not promoted forest products in its programs, possibly because it considers that the production of wood and NTFPs conflicts with its mission to strengthen agriculture. Not recognizing silviculture as part of agriculture has been a significant limitation for the sustainable management of forest resources, especially after the creation of the DNER that contributed to the separation of forest management from the federal and the state departments of agriculture in Puerto Rico. In 2010, the Forest Act was amended by Puerto Rico's Legislature to exclude farmers from the permit requirement to cut trees; however, wood and NTFPs were not considered agricultural products.

The area suitable as timberland also overlaps with the coffee-growing region of Puerto Rico (Fain et al. 2018; Monroig 1999; Birdsey and Weaver 1982), and coffee production should occur in the context of sustainable production of forest products as well. However, there are contradicting policies between state and federal governments to promote coffee farming in Puerto Rico (Villegas 2017; Borkhataria et al. 2012). For example, while the PRDA programs focus on enhancing coffee's productivity by providing aid to pay wages, acquire coffee trees, and apply agrochemicals to full-sun grown-coffee, federal environmental agencies such as USDA NRCS and the U.S. Fish and Wildlife Service (USFWS) focus their efforts on promoting agroforestry practices to encourage biodiversity conservation in shade coffee plantations

(Villegas 2017). On the one hand, many agronomists do not believe that shade-grown coffee is economically viable and think the state government should promote growing coffee under full sun to increase coffee yields, economic profits, and employment (N. A. Trejo Ricaño, personal communication). On the other hand, farmers face tough competition from cheaper imported products, and specialized markets for agroforestry products such as shade-grown coffee and cocoa are still poorly developed since there is no certification for these production systems in Puerto Rico (González Muñiz 2013). Still, farmers and forest owners currently interested in agroforestry largely depend on financial and technical assistance from the federal government, making the adoption of these practices on private farms dependent on these

incentives, which is unsustainable in the long term (Forero-Montaña et al. 2019).

In summary, the USDA NRCS provides programs promoting sustainable production on agriculture and forest lands at the federal level in the United States. Still, its programs in Puerto Rico have mainly focused on conserving and protecting natural resources on private farms instead of managing forest products. Thus, there is a great need to integrate the interests and functions of the federal environmental agencies, the PRDA, and the DNER to achieve forest conservation and agriculture in Puerto Rico—wood production included. This integration is essential to mitigate and adapt to climate change and reduce the environmental footprint of agriculture practices in Puerto Rico and other Caribbean and Latin American countries (FAO 2019).

APPENDIX 2

Complete list of stakeholders and their main activities in the wood products chain of Puerto Rico showing their level of attitude (**A**), level of influence (**I**), and our level of certainty (**C**) about this information. **Attitude**: refers to the position that the specific stakeholder would take regarding a forest policy reform process to reactivate the forestry sector in PR, where 2 = totally in favor of the process, 1 = moderately in favor of the process, 0 = indifferent towards the process, -1 = moderately against the process, -2 = totally against the process; **Influence**: refers to the specific weight of the stakeholder in the decision-making process that in some way could affect the success or failure of a policy reform, where 3 = very influential in decision making, 2 = influential, 1 = little influential; **Certainty**: is a measure of control over the information expressed in the other columns that evaluates its quality, where 3 = the planning team is confident in the values assigned to the stakeholder, which are based on clear and accurate information, 2 = the planning team is not entirely sure of the assigned values to the stakeholder, classifications are based on incomplete information, 1 = the planning team has no information about the stakeholder and the assigned values are based on a shared perception of the stakeholder. * = in the wood products chain. ** = described based on the mission/vision that each organization posted on its website.

Stakeholder	Sector*	Social Sector	Activities**	A	I	C
Landowners	Forest management	Civil society	They have legal rights over the land. Some are farmers that could be timber and NTFP producers.	0	3	1
Caribbean Soil Conservation District	Forest management	Environmental NGOs	It works in collaboration with the USDA NRCS providing services to farmers in the towns of Coamo, Juana Díaz, Santa Isabel, Villalba, Peñuelas, Ponce, and Salinas.	0	1	1
<i>para la Naturaleza, Inc.</i>	Forest Management	Environmental NGOs	It promotes the conservation of Puerto Rico's natural resources by acquiring lands to be protected, establishing conservation easements, and through restoration and education programs	-1	2	1
U.S. Farmer Services Agency	Forest Management	Public sector, federal government	It provides technical and economic assistance to agricultural and livestock producers to help them rehabilitate lands affected by natural disasters through the Emergency Conservation Program	0	1	1
Department of Agriculture (PRDA)	Forest Management	Public sector, Commonwealth government	Its mission is to strengthen agriculture in Puerto Rico to provide high quality food, create jobs, and protect natural resources.	-2	2	1
<i>Café Cultura Puertorriqueña, Inc.</i>	Forest Management; Research and Education	Environmental NGOs	It provides technical assistance to farmers and private farm owners to develop management plans with an emphasis on conservation, agriculture, tourism, and marketing strategies.	1	2	1
EnviroSurvey, Inc.	Forest Management; Research and Education	Environmental NGOs	It helps to establish conservation and natural resource management agreements on private farms by providing technical assistance to farmers and farm owners in collaboration with local and federal agencies through programs such as the Forest Stewardship, Partners for Wildlife, and Incentives for Environmental Quality	1	2	1
Landscape Conservation Center (CCP, in Spanish)	Forest Management; Research and Education	Environmental NGOs	By means of interdisciplinary projects, it promotes the protection, restoration, and sustainable management of natural resources.	2	2	3
Bosque Modelo (<i>Casa Pueblo de Adjuntas, Inc.</i>)	Forest Management; Research and Education	NGOs	It is a community organization that brings together 7,000 farms, which include 157,827 hectares (~390,000 acres) in 32 municipalities of the central region in key hydrographic basins.	0	2	1
Puerto Rico Farm Bureau, Inc.	Forest Management; Research and Education	NGOs	It promotes the growth of Puerto Rico's agriculture by defending the rights of farmers and advocating for their well-being.	0	1	1
Agricultural Extension Service, UPR-Mayagüez Campus	Forest Management; Research and Education	Public sector	It addresses the aspirations and needs of farmers by offering technical advice in all aspects of production, marketing, financing, use of pesticides, farm administration, and conservation of natural resources.	-1	2	1

Stakeholder	Sector*	Social Sector	Activities**	A	I	C
U.S. Fish and Wildlife Service (USFWS)	Forest Management; Research and Education	Public sector, federal government	It provides technical and financial assistance to landowners for implementing projects aimed at the conservation, acquisition, restoration and/or improvement of critical ecosystems for the conservation of wildlife.	-1	3	1
USDA Natural Resources Conservation Service (USDA NRCS)	Forest Management, Research and Education	Public sector, federal government	It provides economic and technical assistance to landowners for the protection, restoration, and improvement of critical areas of agricultural lands through numerous programs.	-1	3	1
National Oceanic and Atmospheric Administration (NOAA)	Forest Management; Research and Education	Public sector, federal government	It promotes the sustainable use and conservation of natural resources in the coastal area. It participates in the Coastal Management Program that provides technical assistance for land management in the coastal zone and for the identification of areas of high natural value.	0	1	1
USDA Caribbean Climate Hub (USDA CCH)	Forest Management; Research and Education	Public sector, federal government	It develops and delivers science-based information and technologies with the collaboration of other USDA agencies and partners to agricultural and natural resource managers to enable climate-informed decision-making.	2	3	3
USDA FS State, Private and Tribal Forestry (USDA FS SPTF)	Forest management, Research and education	Public sector federal government	It provides professional, technical, and financial assistance to state agencies, universities, and non-profit organizations in PR and the U.S. Virgin Islands to support sustainable management of the island's forests and production of important goods and services.	2	3	3
USDA FS El Yunque National Forests (USDA FS EYNF)	Forest Management; Research and Education	Public sector, federal government	Located in Puerto Rico's Northeast Region, with its almost 11,800 hectares, is the only tropical rainforest in the U.S. national forest system. It manages the forest with the primary purpose of protecting vital water supplies and wildlife habitat, while providing outdoor recreation and environmental education.	1	3	2
USDA FS International Institute of Tropical Forestry (USDA FS IITF)	Forest Management; Research and Education	Public sector, federal government	It focuses on scientific research and technology transfer for the development of tropical forestry in Puerto Rico, the United States, and other tropical countries, as well as the exchange of essential knowledge to maintain tropical forest services. It manages several experimental forest-sites in El Yunque National Forest and provides funds for the Forest Steward Program and the Urban Forestry and Communities Program.	2	3	3
Department of Natural and Environmental Resources of Puerto Rico (DNER)	Forest Management; Research and Education	Public sector, Commonwealth government	It administers and safeguards the state forests and has jurisdiction over the management of private forests. The Forest Law Art. 6 1975 establishes that the DNER must encourage the planting of trees and the reforestation of forests for forestry purposes. The DNER must conduct the necessary studies to develop appropriate techniques for reforestation, management, and use of forest products. Through the Forest Stewardship Program, it provides forestry technical assistance to owners of private lands by designing management plans. It grants permits for cutting trees on private properties.	-1	3	1
Tropic Venture Research and Education Foundation, Inc.	Forest Management; Wood Extraction and Collection; Wood Processing; Marketing; Research and Education	Environmental NGOs	Works in research and education to demonstrate the sustainable economic use of Puerto Rico's forests. It has plantations of mahogany, mahoe, and other tropical woods.	2	2	3
Caribbean Regenerative Community Development (CRCD)	Forest Management; Research and Education	Environmental NGOs	It focuses on agroforestry plantations of native trees; soil improvement; educational workshops; community training, environmental assessments, and management recommendations.	1	2	1
Hardware Stores	Marketing	Private with profit interests	They include megastores, for example, of American multinational home improvement retail corporations, and small retailers that exclusively sell imported wood. Their main customers are cabinet makers, constructors, and architects.	0	1	1
Souvenir shops for tourists	Marketing	Private with profit interests	They sell crafts and souvenirs for tourists, they are located in Old San Juan, airports, and other touristic places.	0	1	1

Stakeholder	Sector*	Social Sector	Activities**	A	I	C
Institute of Puerto Rican Culture (IPRC)	Marketing	Public sector Commonwealth government	It implements the Popular Arts of Puerto Rican Culture Program that focuses on the promotion and preservation of art. It helps artisans to market their products by organizing fairs and festivals and has recently created a mobile application to put artisans in contact with customers. It publishes the Popular Arts Bulletin.	0	3	1
Puerto Rico Industrial Development Company (PRIDCO)	Marketing	Public sector Commonwealth government	Through the Artisan Development Program, it provides technical assistance to certified artisans to support the creation of microbusinesses. It helps in the promotion, distribution, and marketing of artisan products. In collaboration with the IPRC it helps to organize fairs and festivals where certified artisans can exhibit and sell Puerto Rican crafts. It also promotes artistic work in and outside Puerto Rico.	-1	3	1
Puerto Rico Tourism Company	Marketing	Public sector Commonwealth government	It promotes events and festivals, and created tourist areas where artisans can exhibit and sell their products, such as <i>Paseo de la Princesa</i> in San Juan.	-1	2	1
Sea Grant Program of the UPR-Mayagüez Campus	Research and Education	Education program	It promotes the sustainable use of marine and coastal resources through applied scientific research and by providing technical assistance to farmers and landowners	0	1	1
Green Wood	Research and Education	NGOs	It implements the Artisan Ecotours Program with cooperation from the USDA CCH, which aims to strengthen connections between carpentry and forestry artisans of Puerto Rico and USA by developing tourism opportunities for carving, turning, and carpentry workshops.	2	1	3
University of Puerto Rico-Mayagüez Campus	Research and Education	Public higher education	It is currently participating in the Wood Innovations Project by developing research in forest management, as well as techniques for drying and processing wood.	2	3	3
University of Puerto Rico-Río Piedras Campus	Research and Education	Public higher education	Implements the Wood Innovations Project in collaboration with various partners such as UPR-Mayagüez Campus, USDA FS IITF, USDA CCH, CCP, and Puerto Rico Hardwoods. It has held conferences, seminars, meetings and publications to strengthen research and dissemination of information related to various topics related to forest management and the sustainable use of wood and forest products.	2	3	3
University of Puerto Rico-Utuado Campus	Research and Education	Public higher education	It offers a course on Agroforestry Systems with a theoretical and practical component as part of a Bachelor's Degree in Sustainable Agriculture.	1	3	1
Arborists	Wood Extraction and Collection	Private with profit interests	They are urban tree care specialists, which are trained in the competence of planting, caring for, and maintaining individual trees	1	2	1
Department of Transportation and Public Works of Puerto Rico.	Wood Extraction and Collection	Public sector, Commonwealth government	It manages public roads, carries out maintenance, pruning, and felling of trees on public roads.	-1	1	1
Planning Board of Puerto Rico	Wood Extraction and Collection	Public sector, Commonwealth government	It prepares the development plan outlining the policies and strategies for the comprehensive development of Puerto Rico. It plays a key role in the recovery plan of Puerto Rico after severe environmental disasters.	-2	1	1
The United States Army Corps of Engineers (USACE)	Wood Extraction and Collection	Public sector, federal government	It delivers engineering services and plays a key role in the development and implementation of the recovery plan after severe storms and natural disasters.	-1	1	1
U.S. Federal Emergency Management Agency (FEMA)	Wood Extraction and Collection	Public sector, federal government	It is ascribed to the U.S. Department of Homeland Security, which coordinates the response to natural disasters with the aim of repairing and rebuilding public facilities and infrastructure. For this reason, it has a direct influence on the management of wood material after hurricanes.	-1	2	1
Municipal Collection Centers	Wood Extraction and Collection	Commonwealth government	They play a critical role in waste management. They receive and process wood waste before being deposited in landfills.	-1	2	1
Taller Escuela	Wood Extraction and Collection; Research and Education	Private sector	Vocational school in art design and woodworking offers workshops to those interested in learning to work with wood and establishing craft companies	2	1	3

Stakeholder	Sector*	Social Sector	Activities**	A	I	C
Sawyers	Wood Extraction and Collection; Wood Processing, Marketing	Private with profit interests	They are family micro-enterprises that collect, extract, process, and market local wood mainly supplying the artisanal sector. They currently operate around 40 establishments in Puerto Rico, of which only 4 work full time, while the others belong to artisans or amateurs who operate part-time. The amateurs are new actors that after the 2017 hurricanes, bought equipment to process wood and do it mainly as a hobby.	2	3	1
<i>Aserradero Fernando Otero</i>	Wood Extraction and Collection; Wood Processing; Marketing	Private with profit interests	It rescues, saws, and sells wood	2	1	2
Puerto Rico Hardwoods, Inc.	Wood Extraction and Collection; Wood Processing; Marketing; Research and Education	Private with profit interests	It is a company dedicated to the sustainable use of Puerto Rican wood. It salvages, sells, saws wood, and makes furniture. It offers workshops to those interested in learning to handle wood.	2	1	3
Artisans	Wood Extraction and Collection; Wood Processing, Marketing	Private with profit interests	They make crafts using local wood and NTFPs, they market their crafts mainly at fairs and festivals.	2	3	1
<i>Asociación de Torneros de Madera de Puerto Rico, Inc.</i>	Wood Processing; Research and Education	Association of small producers	It promotes education about the art of woodturning and facilitates the training of its members through activities to share new techniques, ideas, and experiences	2	2	2

APPENDIX 3

Summary of main issues identified and proposed solutions for the policy needs and institutional limitations of each forestry sector in Puerto Rico. The Forestry Sector includes (justified, in **bold**) Forest Management, Wood Extraction and Collection, Wood Processing and Production of Forest Products, Marketing, and Research and Education. Under corresponding Factors and Processes, “Policy Needs” highlights the requirement for developing new programs and policies to achieve the proposed solution. In contrast, “Institutional Limitations” highlights factors and processes that hinder an organization from leading to successful policies.

Factors and Processes	Issue	Proposed solution
Forestry Sector: Forest Management		
Policy Needs	1. Lack of integration between agricultural and forestry policies.	1. Integrate forest production objectives into the agricultural and forest management and conservation programs of the federal (USDA FS, USDA NRCS, USFWS) and commonwealth agencies of Puerto Rico (PRDA, DNER), with the Agricultural Extension Service of the UPR-Mayagüez campus and the USDA NRCS as mediators. 2. Develop and support legislation to create an office devoted to coordinating goals related to silviculture and agroforestry among existing institutions (e.g., Office of Silvicultural and Agroforestry Systems). This office could be located within the PRDA.
	2. A perceived conflict between biodiversity conservation and the management of forests for timber production.	1. Unify the efforts of the different environmental agencies to promote farm forestry as an important economic activity that can deliver ecosystem services and wood products. 2. Create a national dialogue on this concern grounded on a participatory process to bring together all the interested people in promoting the sustainable use of forest resources in Puerto Rico. Fostering grassroots community-led efforts is essential to create a national dialogue scaled up to the broader commonwealth.
	3. Non-effective incentives to support forest owners interested in for-profit forestry.	1. Provide more effective incentives to forest owners. The federal environmental agencies (USDA FS, USDA NRCS), the DNER, and the Agricultural Extension Service UPR-Mayagüez campus should work together to provide suitable information, appropriate education, and accurate technical assistance. 2. Conduct a social acceptability study among forest owners to find out their interests, needs, expectations, and perceptions about forestry. As part of this study, forest owners interested in implementing pilot projects would be identified to demonstrate the feasibility of developing forest production systems on private lands. This study would also explore the willingness to form small producer associations, which would provide effective technical assistance and business and financial services.
	4. Restricted legal access to wood and other forest resources.	Make lobbying efforts at the commonwealth legislative and executive levels to: A) review and clarify the regulations for cutting trees on private properties; B) establish clear rules to regulate the rescue of fine woods in a participatory manner; C) create information networks among municipalities, collection centers, and sawmills to facilitate the rescue of fine woods.
	5. Strong contradiction between applicable state and federal policies promoting coffee farming in Puerto Rico.	Promote a national dialogue on this issue to integrate the interests and functions of the PRDA, the DNER, and the federal environmental agencies. A unified policy can link forest management and biodiversity conservation with agriculture through effective agroforestry programs.
Institutional Limitations	1. Limited silvicultural knowledge to sustainably manage forest plantations.	1. Create field schools for training forest farmers in forest management techniques. These educational spaces are important to help small producers and rural communities innovate their technical skills through participatory processes of knowledge exchange based on practical exercises in the field. 2. Develop training for growers and contractors in reduced impact logging (RIL) techniques in variegated landscapes.
	2. Limited or inaccessible information about the condition and location of forestry plantations in public and private lands.	Conduct forest plantation inventories on public and private lands to determine their precise location and condition and estimate the wood availability in the archipelago.
	3. Inefficient institutional coordination to achieve common goals regarding the sustainable management of forest resources	1. Unify the efforts of the different environmental agencies, including federal and local institutions, to promote the sustainable management of forest resources. 2. Develop and support legislation to create an office devoted to coordinating goals related to silvicultural and agroforestry systems among existing institutions (e.g., Office of Silvicultural and Agroforestry Systems). This office could be appointed to PRDA.
	4. Limited interdisciplinary working teams and qualified personnel in forest management and the support of forestry-based enterprises in the environmental agencies.	Create interdisciplinary working teams to strengthen institutional capacity to provide effective technical assistance to forest owners interested in for-profit forestry.

Factors and Processes	Issue	Proposed solution
	5. Limited capacity of the DNER related to a broader understanding of forestry goals and opportunities and to effectively coordinate and execute the agency's programs and applicable forestry policies supporting timber sustainability and forest conservation.	1. Lobbying for the political will to secure the financial and human resources needed for developing and implementing effective and comprehensive forest management programs in agreement with desired goals mandated by the Constitution of the Commonwealth of Puerto Rico. 2. Review policies in conflict that limit the production of wood and forest products in private forests.
	6. Ineffective regulation of applicable forestry practices.	Develop strong planning and regulation of tree harvesting and forestry practices with the participation of federal and local environmental agencies.
Forestry Sector: Wood Extraction and Collection		
Policy Needs	1. Lack of regulations to establish the norms and criteria for fixing the price of disposition of forest products.	Work with relevant federal and state environmental agencies to lobby for establishing effective norms and criteria by Puerto Rico's Legislature and Executive branches.
	2. Inefficient procedures for the management of wood waste.	Increase local capacity to save woody debris from reaching landfills by developing strong alliances between municipal governments and private sectors.
	3. Lack of a public policy prioritizing the use of downed wood.	1. Work with local and federal agencies (USDA FS, DNER, PRDA) and municipal governments for policy-making prioritizing the effective use of downed wood. 2. Enhance the participation of local stakeholder groups in the corresponding decision-making processes.
Forestry Sector: Wood Processing and Production of Forest Products		
Policy Needs	1. Limited capacity of sawyers and artisans to develop profitable and competitive microenterprises.	1. Work with PRIDCO to develop effective strategies to support small forest enterprises. 2. Promote the association of small forest enterprises to enhance their ability to add value and increase competitiveness in local and international markets. (NOTE: Small-scale producers benefit significantly from working collectively, as collaboration forests-trust enables collective buying and selling and strengthens their advocacy for rights. Once established and functional, producer groups can lobby for access to land and resources, connect members with the technology and financing required for enterprise growth, and negotiate better product prices. The small-scale farm forest sector can be formalized and made sustainable when organized, providing secure employment and access credit for enterprise development).
Institutional Limitations	1. Lack of institutional capacity and human and financial resources to provide effective technical assistance to help small forest enterprises increase their competitiveness, market their products, and preserve desirable artisan traditions.	Strengthen cooperation among institutions, including government agencies, NGOs, and artisan associations, to facilitate information exchange and reinforce skills throughout the entire value chain of artisanal products.
	2. Low production and reliability of supply from local sawmills.	Provide effective technical and financial assistance to small forestry enterprises to help them increase their production capacity and adapt to market demands.
Forestry Sector: Marketing		
Policy Needs	1. Lack of consistent demand and markets for local timber and NTFP. 2. Lack of specialized markets for local wood and agroforestry products such as shade-grown coffee and cacao.	Improve marketing and distribution of local timber and NTFPs extracted from sustainably managed forests. Develop a certification program for agroforestry products and sustainable produced timber. This development could be accomplished through fair trade certification, such as Fairtrade International, which sets and maintains standards for all commodities, including cocoa and coffee, and FLO-CERT, which inspects and certifies producers and traders.
Institutional Limitations	1. Lack of economic and financial data on the local market for wood and handicraft products made from wood.	Conduct a market analysis to determine the market size, growth rate, trends, and profitability of wood products.
Forestry Sector: Research and Education		
Policy Needs	1. Misconceptions from the public about the use of trees as timber.	Develop effective communication and education strategies on forestry topics that clarify the following: A) the societal and environmental benefits in promoting sustainable use and environmentally-responsible consumption of products made from local wood; B) misconceptions about forestry activities.
Institutional Limitations	1. Isolation among forestry sector stakeholders due to lack of feedback from relevant agencies and institutions. 2. Limited to non-existent professional and technical education programs on forest management.	Continue strengthening institutions devoted to education, research, and disseminating information on forest management, forest product processing, and marketing in Puerto Rico. 1. Develop and implement a transdisciplinary forestry program at the bachelor's and/or master's education levels among relevant UPB campuses and other venues. 2. Review curricula for establishing minor concentrations, certifications, or both in applicable institutions for continued education of arborists, sawyers, and tree contractors.