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# HURRICANE MARÍA, AGROECOLOGY, AND CLIMATE CHANGE RESILIENCY

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> Probably no part of the Antilles is more fertile than Porto Rico, and none so generally susceptible of cultivation and diversified farming … Porto Rico is essentially the land of the farmer … It is the only island where agriculture is so diversified that it produces sufficient food for consumption of its inhabitants, in addition to vast plantation crops of sugar and coffee for export.
>
> *Hill, 1898, 159*

Recent years have witnessed numerous extreme climate-related events. According to the Global Climate Risk Index 2019, the Caribbean island of Puerto Rico was ranked the country most affected by extreme weather events after the passage of Hurricane María in 2017, with human losses of over 3,000 persons and monetary damages of over US$82 million (Eckstein et al., 2019). Between 1998 and 2017, Puerto Rico experienced a total of twenty-five events, principally hurricanes, but also severe droughts affecting hundreds of thousands of people for weeks.

A warmer climate is coupled with heavier rainstorms, which cause flooding and increased topsoil erosion, while hotter days lead to more evaporation and diminished groundwater replenishing. Puerto Rico's average temperature has increased by more than 1.8 degrees Celsius since the mid-20th century, and the surrounding waters have warmed by nearly 3.6 degrees Celsius since 1901 (NOAA, 2019). Of the ten warmest years on record, nine have occurred in this century.

An estimated 600,000 people live in in flood-prone areas, due to river overflows of storm surges. Over 250,000 structures are at risk from flooding (Estrada López & Rivera Santos, 2018). Climate change is having enormous impacts on the island's ecology. Rising sea levels, higher temperatures, more frequent extreme events such as hurricanes and droughts, fauna and flora degradation, and

reef bleaching are some of the changes already documented. Coastal erosion is one of the most visible impacts with 92 percent of seaside towns having suffered beach erosion and an increasing risk of sea level rise (EPA, 2016). According to the US Environmental Protection Agency (EPA), the sea level has risen by about four inches relative to Puerto Rico's shoreline since 1960, approximately one inch every fifteen years. The forecasts indicate that sea levels may rise from one to three feet in the next century, forcefully threatening coastal ecosystem integrity, including grasslands, marshes, and mangroves (Jury, 2018). Further down the slope, coral reefs are suffering from bleaching and algae due to warmer waters and increased topsoil erosion and sedimentation.

Higher temperatures are likely to interfere with agricultural productivity in Puerto Rico (Álvarez-Berríos et al., 2018). Reduced water availability during the dry season stresses crops, while warmer temperatures could also reduce yields of certain crops such as plantain, banana, and coffee (Fain et al., 2017). Hot temperatures threaten the health of cattle, causing them to eat less, grow more slowly, and produce less milk (EPA, 2016; Ortiz-Colón et al., 2018). Population decline of pollinators and beneficial fauna has already been observed, especially in bees, birds, and amphibians. Simultaneously, there are more mosquitoes due to a favorable heat and humidity combination, and with a wide presence of the *Aedes aegypti* species. As a consequence, vector-borne diseases such as dengue, zika, and chikungunya epidemics are common (de Jesús Crespo et al., 2018). Stronger plant and animal species are occupying niches formerly held by more vulnerable ones, leading to gradual ecosystem changes, as is the case for the exotic pioneer tree *Spathodea campanulata* over native species in secondary forests (Lugo et al., 2012).

The resilience of a system can be conceptualized as the relation between its vulnerability and its coping capacity (Oxfam, 2010). A resilient agricultural system will be able to resist and quickly recover to maintain the delivery of ecosystem services (e.g. food production, biodiversity, soil protection, water quality) in spite of external disruptions (e.g. drought, storms, oil price increases, shortage of external inputs) (Altieri et al., 2015). Puerto Rico's geographical location makes it vulnerable to climate changes, yet the socio-ecological characteristics of the island inhabitants have historically allowed Puerto Ricans to absorb, adjust, and adapt to new conditions, particularly in the agricultural sectors (Lugo, 2019). In the aftermath of the hurricanes in Puerto Rico, agroecological farming systems demonstrated higher resilience than their conventional peers yet the post-disaster recovery of the island needs to be understood in its social and political context.

## The political menace

The hurricanes of 2017 dealt a horrible blow to a country already suffering from years of recession; contraction of public jobs and services as part of local government neglect, in the best cases, or plain mismanagement and corruption, in the worst, together with brutal neoliberal "shock doctrines" imposed by the US

wielding of colonial power over Puerto Rico in an irresponsible and immoral attempt to collect a non-payable and mostly illegal $74 billion local government debt (Wendt, 2017).

Naomi Klein, the political writer and activist who visited the island several times after the hurricanes, observed what she defines as the 'shock doctrine' in post-María Puerto Rico, implemented in the most naked form since New Orleans's public school system and much of its low-income housing were dismantled in the immediate aftermath of Hurricane Katrina in 2005 (Klein, 2018). Klein described post-hurricane Puerto Rico as being immersed in three crises. First came the recession before the 2008 financial crisis, with the island used as a laboratory for neoliberal austerity, changes to laws and regulations to facilitate increased corporate profits, public and government job cuts, abandonment of infrastructure maintenance, and widespread corruption. Second was the heightened control by financial capital through a law of Congress creating a Political Oversight and Management Board – la Junta de Control Fiscal – to extract over $74 billion from an exhausted economy and people, to recoup mostly unpayable, illegal, and illegitimate debts to bondholders. The Junta imposed a budget for 2018–19 that reduced jobs, salaries, and funds for health, security, and education. Third, the hurricanes had severe and unforeseen impacts on health, lives, housing, communications, water, electricity, education, nature, economy, and mental attitudes.

Although all Puerto Ricans are US citizens by birth, a structural political and economic colonial dependency-framework is evident in the relation between the Commonwealth and the US Congress. Puerto Ricans do not have voting rights in presidential elections nor for representation in Congress, which amounts to a second-class citizenship. During the first part of the last century US government control over the island of Puerto Rico was characterized by a plantation economy and extreme poverty for vast majorities of the population. The 3.4 million Puerto Ricans on the island have been dealing with severe problems undermining their well-being since the 1980s, when the dependent economic development model escalated into a crisis.

From the 1950s to the 1980s a large middle class was created. US corporations were enticed to move in through generous tax breaks, free and quality infrastructure and services, and cheap, qualified labor. Textiles, oil, pharmaceuticals, and other industries come and go, depending on what other places offered better opportunities. Changes in the legal and tax environment and international business changes increasingly made Puerto Rico less attractive to US manufacturing industries, while becoming a captive client for big retail and fast food corporations. In recent years the US Supreme Court, executive, and Congress have re-affirmed colonial powers over the island, contradicting the 1953 declarations before the United Nations that Puerto Rico had opted out of a colonial relationship.

## Agriculture in Puerto Rico before the disaster

Puerto Rico has a long history of agricultural production. When Spanish settlers invaded Borikén, the Indigenous name for Puerto Rico, they found a diversity of annual and perennial crop species selected for their nutritional properties by the original inhabitants including cassava, corn, pumpkins, beans, guava, and soursop, among others. A large diversity of animal and marine species was consumed across the Caribbean region (Castilla-Beltrán et al., 2018). The 500 years of Spanish rule were characterized by coffee and tobacco production. When this Caribbean island became a non-incorporated territory of the United States after 1898, as a consequence of the Spanish-American War, agricultural production shifted towards sugarcane production for the US market.

In 1917, Puerto Ricans were granted US citizenship, and commercial relations with Puerto Rico became exclusive to the US in 1920 with the signing of the Merchant Marine Act, also known as the Jones-Shafroth Act (Suárez-Gómez & Ayala-Cruz, 2016). During the decade of 1940, the island produced 65 percent of food supplies for a population of two million people, including more than 50 percent of its meats, starchy and other vegetables, dairy products, fruits, and eggs (Hill and Noguera, 1940, cited in Álvarez Febles, 2016). At the same time, sugar, tobacco, coffee, and other agricultural products were exported (Alemán Iglesias, 2018). Local subsistence food was not being produced on the best lands, but on the mountainous and marginal rural areas of the island.

Puerto Rico was a big agricultural player until the 1950s. Ruled by the US Congress since 1898, recent events have completely done away with the self-rule mirage ushered in during 1952 through the creation of the Commonwealth of Puerto Rico (Estado Libre Asociado – ELA, according to the Spanish acronym). The ELA was used by the United States to request that Puerto Rico be considered a decolonized territory under the United Nations in the post-World War II scenario. Under strong local leaderships and intelligent public and financial policies, the ELA served Puerto Ricans over several decades to pull their country out of US sugar-led economic domination and wide-ranging poverty.

With the 1952 Constitution, the island went through a period of rapid industrialization, based on US companies moving in to profit from cheap and trained labor, a tax-free financial haven, infrastructural support, and lax environmental regulations. Under the limited powers granted by the US Congress, Puerto Ricans established schools, excellent health care, electricity, water, and public housing, supported by institutional governance which included a local governor and executive, a parliament and a court system. Industrialization via Operation Bootstrap (Operación Manos a la Obra) catalyzed massive rural-to-urban migrations to major cities on the island and to the US mainland, moving the island's economy away from agriculture (Tormos-Aponte & Ciro-Martínez, 2017). The local farming and food environment changed to favor supermarket imports to sustain consumer needs and benefit the US food and farming sector. The economic boost in urban areas translated into diminished food production and

increased food imports. Smallholder farmers and rural farm workers became industrial laborers.

According to the United States Department of Agriculture (USDA) and the Puerto Rico Department of Agriculture (PRDA), the number of farmers and the number of farms dramatically decreased since the first part of the 20th century: from 52,790 in 1935, to 13,159 in 2012. Between 1950 and 2008, the economic contribution of agriculture to gross internal product decreased from 25.6 percent to 0.5 percent, while agricultural employment went from 36.2 percent in 1950 to 1.2 percent in 2008 (Álvarez Febles, 2016). Currently, the agricultural industries supported through subsidies are coffee, cattle breeding, and poultry. These subsidies principally support conventional practices (e.g. high external input systems, monocultures, absence of soil conservation). More recently, hydroponic systems have been promoted, as well as vegetable production and the biotech-dominated seed industry. The latter occupy the best agricultural lands in southeastern Puerto Rico, which feature dry weather, excellent agricultural soils, level terrain, and accessible underground aquifers.

Even though early scientific studies demonstrated that traditional local foods and diets could provide good nutrition to the population (Axtmayer & Cook, 1942, cited in Álvarez Febles, 2016), malnutrition due to poverty and inequality accompanied a shift toward fast foods, high-protein, and high-carbohydrate diets. Obesity, diabetes, cardiovascular disease, and other lifestyle illnesses have become epidemic (Palloni et al., 2005). Food imports in Puerto Rico were as high as 85 percent before the hurricane (Comas Pagán, 2009). In the aftermath of Hurricane María this number rose significantly and was magnified by a complete lack of electrical energy, telephone communication, and accessible roads. Puerto Rico has a long tradition of sustainable farming practices under difficult conditions (Avilés-Vázquez, 2014), yet María's shock to the island came to disrupt an already vulnerable food and agricultural system (Félix & Holt-Giménez, 2017).

## Hurricane María: the biophysical shock

Hurricane María entered the island of Puerto Rico through the town of Yabucoa on September 16, 2017 with wind gusts over 300 kilometers per hour, sustained on a trajectory from southeast to northwest across the island. Just over a week earlier another strong hurricane hit the island, Irma, causing severe damage to infrastructure, nature, and society. Just as the hurricanes stripped trees of their leaves, conditions of long-standing poverty, social inequality, run-down roads, depreciated electric and water utilities, and deteriorated health, education and other public services became more than evident (Carmona Báez, 2018).

The storm revealed the long-term lack of infrastructure investment on the island. María's wind speeds knocked down 80 percent of the electrical lines, resulting in a total loss of power. Previous lack of maintenance and the scope of damage had some island communities living almost a year without electricity.

The power grid will need an investment of over $30 billion for power to be restored and upgraded after years of neglect (Carmona Báez, 2018). The disaster revealed the precarious pre-existing conditions faced by many Puerto Ricans, such as the striking difference in the poverty rate between Puerto Rico (45 percent) and the mainland US (13 percent). The assessments showed that more than $140 billion would be needed for recovery and reconstruction (García, 2019).

Estimates after the hurricanes by the local Department of Agriculture were that 80 percent of Puerto Rico's crops had been completely destroyed, having a two billion dollar impact to the economy. A study conducted with 400 farmers several months after María by the University of Vermont and the Puerto Rican Agriculture Extension Service, concluded that the great majority of farmers island-wide had significant losses due to the hurricane (Rodríguez Cruz & Niles, 2018):

- 42.5 percent reported a total loss, 45.5 percent significant damages, and 10.5 percent reported moderate damages.
- The top-reported damages were to crops (77.6 percent), infrastructure (69.4 percent), and livestock (27.1 percent).
- 89.8 percent of respondents faced at least one obstacle toward recovering from Hurricane María.
- The most common obstacles included: 43.7 percent reported farm-related obstacles (e.g. infrastructure damages, lack of laborers, etc.); 31.3 percent reported government-related obstacles (e.g. lack of aid/assistance, etc.); 23.0 percent reported utility-related obstacles (e.g. no power or water).
- 94.7 percent of respondents agreed or strongly agreed that the global climate is changing, and 93.2 percent agreed that average global temperatures are increasing.
- 86.8 percent agreed that anthropogenic activities are a significant cause of climate change, and 94.4 percent of farmers agreed that the effects of climate change are being felt today.

In the aftermath of the hurricane, US federal agency funds were slow and difficult to materialize. Thousands fled the island and moved to the continental US, many not to return (Hinojosa et al., 2018). Together with migration and food issues, the island has experienced poor and declining health care; tax incentives for the foreign rich to move in; funding cuts to local schools, the universities, and cultural institutions; high crime rates due to tolerated drug trafficking and reduced police funding; and the studied neglect of roads, electric, and water services. These conditions are seen by some as criteria for possible genocide accusations in the handling of the humanitarian crisis in the post-hurricane period. The government held on for almost a year to the ridiculous claim of only 64 hurricane-related deaths, until other studies documented much higher numbers: 1,139 excess deaths (Santos-Lozada & Howard, 2018); 2,975 excess deaths

(GWU, 2017); and up to 4,645 excess deaths (Kishore et al., 2018). The high variations between mortality estimates corresponded to comparisons during the same periods in the aftermath of María compared to previous years on record.

## Social resilience is inherent to agroecological systems

Puerto Ricans have historically shown a great commitment to their country, both in social and ecological terms (Avilés-Vázquez, 2014; García-López, 2018). Civil society organizations led many of the emergency relief efforts for people living deep in the mountains and to communities cut off by mudslides or overflowing rivers. Alongside this emergency aid, many individuals, communities, and groups generated activity and support in the weeks and months after María in areas such as agriculture, culture, education, health, and local political activism (McCune et al., 2018).

More than fifty organizations served as articulating centers for short-term recovery and long-term planning of post-María support, including farms, community centers, and newly created Mutual Aid Centers (Centros de Apoyo Mutuo or CAM[1]). There was a significant and radical shift toward an increase in local agriculture, food production, and the development of a sustainable community-based agroecological movement (Moulton & Machado, 2019). Interest in agriculture in general has been growing in recent years as an alternative livelihood in the face of the economic crisis. Yet, official policies tended to support big agribusiness, high levels of external inputs, artificial fertilizers, and pesticide-based monoculture cropping strategies.

The brigades or *brigadas* are groups of volunteers who came together to perform tasks on the farms, an expression of traditional solidarity among rural Puerto Ricans that the agroecological movement has adopted (McCune et al., 2018). Days after the hurricane, brigades began to support farming families, especially in the interior, since two thirds of the surface of the island is of mountainous topography. It is a way to provide work solidarity and technical training through practice, and to generate spaces for theoretical and political capacity building.

Equipped with machetes, sawmills, and mechanical saws, roads were opened and fallen trees and other debris removed. With hoes, picks, and shovels, volunteers began to repair the terraces, clean the ditches, and prepare land for new plantings. In mid-October, despite all the limitations (lack of electricity, fallen trees in the square, transport problems, poor agricultural production), the first post-hurricane ecological market was held at the Roosevelt Plaza in Hato Rey (Álvarez Febles, 2018). Meanwhile, the different agroecological and related organizations coordinated at the national level to obtain support for equipment, tools, seeds, and money. Through the five ecological markets active in Puerto Rico, more than 100 farming families were identified and aided economically and with supplies during the first months after the hurricanes so they could repair or rebuild their homes and nurseries, and resume production (e.g.

VisitRico[2]). The brigades were consolidated as spaces for agroecological recovery, and itinerant voluntary camps were established throughout the Puerto Rican archipelago and beyond (Félix et al., 2018).

The inventiveness and solidarity generated new projects, like the Guagua Solidaria[3] of the Resilience Fund of Puerto Rico via support from the US-based non-governmental organization (NGO), America for Conservation + the Arts (AFC+A). A bus, equipped to carry volunteers, documentary film-makers, equipment, and tools, moved brigades across the island, supporting dozens of farms and projects in two years. The recovery phase became an opportunity to integrate alternative technologies such as solar energy, local systems to filter water, and experimentation with new crops and agricultural strategies (e.g. Casa Pueblo[4]). Many of the agroecological processes and activities after the hurricane have been documented by members of Organización Boricuá, local and external NGOs, and by researchers from the international community (Diaz & Hunsberger, 2018; García-López, 2018; Lugo, 2019; McCune et al., 2019).

After the hurricanes, local communities and organizations of religious and social origin had the most rapid and real impact in delivering prompt and effective relief to communities and to people far from main roads or most severely isolated by the devastation, especially difficult-to-access farmers who have little or no access to the internet (WCK-JP/HRO-CCP, 2018). Regional and local agricultural groups already active in farming areas were effective in delivering aid to farmers deep in remote settings, where government aid was late in coming or just did not arrive.

The level of social solidarity originating from the US, both on the part of Puerto Ricans of the diaspora, as well as progressive US organizations, was crucial. In addition to money, electric generators, hundreds of pounds of seeds, solar lighting equipment, machinery, tools, and important quantities of basic necessities have been received. Volunteer groups to support the recovery arrived from Vermont cooperatives, working groups from corporations committed to recovery, specialists in the installation of alternative electrical systems, and numerous other solidarity efforts (Álvarez Febles, 2018). Volunteer groups of organic farmers from the southern US, members of the international organization La Vía Campesina, and of the US Climate Justice Alliance also arrived in Puerto Rico (Félix et al., 2018), as well as internationally renowned agroecology scientists from Food First on the US mainland and SOCLA (the Latin American Scientific Society for Agroecology).

## Farmer resistance and recovery

An important element in the sustainability of agroecological strategies is the recovery and adaptation of local and traditional knowledge through practice and participatory research. An agricultural knowledge-base, skills, and philosophies have been developed by societies with a long history of interaction with their environment. For rural and Indigenous peoples, local knowledge establishes the

basis for decision-making in fundamental aspects of daily life. Such knowledge is an integral part of a cultural system that combines language, classification systems, resource-use practices, social interactions, rituals, and spirituality. These unique systems of knowledge are important elements of the world's cultural diversity and are the basis of sustainability adapted to the local way of life.

The first studies that demonstrated the improved resilience of agroecological systems over conventional ones after a hurricane were made in Central America after the passage of Hurricane Mitch, in October 1998 (Holt-Giménez, 2002). It was found that family and peasant farms who practiced agriculture with criteria of ecological sustainability fared better than their conventional neighbors after the hurricane: they had more arable land, more soil moisture, less erosion, and fewer economic losses. Some of the agroecological practices that contributed to the resistance of smallholder farmers to adverse climate conditions include:

- Diversification of agroecosystems against monocultures: polycultures, multiplicity of micro-agroecosystems, and an increase in agrobiodiversity.
- Integrated agricultural systems: vegetables, fruits, poultry, livestock, aquaculture, beekeeping, among others.
- Water management, conservation, and harvesting.
- Integrated and diversified agroforestry systems, from coffee plantations to timber forests, hedgerows, and silvopastoral systems – forests with animal husbandry.
- Seeds of traditional local crops, with good agroecosystem and social adaptation.
- Animal production systems integrated into production cycles.
- Soil management: life, use of organic matter, cover-cropping, and carbon harvest in the soil.
- Traditional ecological knowledge and farmers' local technologies.
- Community development with social infrastructures capable of supporting extreme external events: a relationship between social and ecological resilience.

Further, the dual hurricanes in Puerto Rico helped wake up many who had not yet realized the dire consequences of living in a completely dependent economic and physically isolated environment (Félix & Holt-Giménez, 2017). After just one week, food scarcity became one of the main worries island-wide. The following case-studies illustrate on-the-ground experiences of Puerto Rican farms and how they have shown diverse forms of resistance and recovery, to resume production despite hurricane disturbance.

## *Perennial fruit crops*

Arboleda El Tintillo is a family farm of seven acres in Guayama (southeast part of the island), where a variety of tropical fruits and medicinal plants are

produced for the bi-monthly organic market of the Cooperativa Orgánica Madre Tierra, located in the capital city of San Juan. Main crops include native and exotic fruits such as papaya, lemons, soursop, passion fruit, pomegranate, anón, ketembilla, corazón, and avocado, amongst others. Management practices included burning fallen branches in a bonfire and taking the ashes to the highest areas of the farm so that the runoff spreads the nutrients downslope to the rest of the farm, making good use of the moderate slope conditions. The roads, terraces and waterways were designed by the US National Resources Conservation Service (NRCS) and no occurrence of landslides were noticeable. After the hurricane, the vegetation appeared burnt. Yet the design and management of the farm (e.g. agroforestry systems, natural regeneration, and soil conservation practices) conferred resistance and quick recovery to damages caused by the hurricane. Several months after the passage of the hurricane, over forty-five different species were observed during a rapid ethnobotanical assessment, including 60 percent fruits, 31 percent ornamentals, and 9 percent medicinal plants.

## *Agroecological vegetables*

The agroecological farm El Josco Bravo, in Toa Alta, lost about 90 percent of its crops after Irma and María. Yet, through the way the soil is worked and prepared using agroecological principles, the farm demonstrated its low vulnerability and high adaptive capacity. This ensured rapid recovery and resilience after the storms. Recently, El Josco Bravo reported the following production statistics for 2018 (Marxuach, 2019): in less than one acre of land (0.83), over 12,000 pounds of produce were harvested, specifically 2,816 pounds of leafy greens, 1,651 pounds of root vegetables, 712 pounds of aromatic herbs, 6,908 pounds of fruits and vegetables, and 560 pounds of starchy vegetables. This level of productivity roughly represents ten kilograms per square meter of fresh food. Simultaneously, El Josco Bravo continued to operate the successful Promotor@s Agroecológic@s program through which nearly 300 new farmers have been trained since 2013. This interesting combination of small-scale production and education is one of the ways to break with the dominant model of industrial agriculture based on the use of agrochemicals, which have deleterious consequences on environmental quality.

## *Conventional livestock*

Vaquería El Ramanso is a cow milk producer located in Camuy which features 225 cows and 100 heifers on 100 acres (36 hectares) of grasslands. The farm produces 4,600 litres of milk per day during the cold season and 3,500 litres during the warm season, using fifty rolls of hay, and 2,400 hundredweight of concentrated feed acquired externally. Hurricane María destroyed a main stable and the food granary and killed eighteen animals. Damages were exacerbated during the following weeks because of landslides, fallen trees, and destroyed houses that

blocked access roads to the farm. Moreover, there was no electrical service nor water availability. Thus, fuel, hay, and animal feed were completely inaccessible. The cows still needed to be fed and milked twice per day. The solidarity and compromise of family farm members and farm employees was crucial to overcome the rough period after the hurricane.

One of the basic principles of agroecology, and a key difference between conventional and industrial agricultural systems, is that human communities occupy a central place in design and practice (FAO, 2018). In the post-María scenario, the agroecological movement demonstrated a great capacity for responding, both at the level of action for the recovery of the farms and their production, as well as in the restoration and strengthening of social structures and systems. That response was possible due to the degree of formal organization and informal structures that had been developing for over two decades.

## Toward food sovereignty in Puerto Rico

In the agroecological movement it is understood that part of the search for food sovereignty implies a move toward an agriculture that works in favor of nature, with the responsibility of bringing people a better diet, coupled with a commitment towards a sustainable social recovery throughout the territory and for the future. Puerto Rico must have the right to decide on its own agro-food system: what it wants to produce; what forms of agriculture are desirable; the design of appropriate production and marketing systems; and to eat according to local nutritional, cultural, and economic criteria.

A noticeable increase in farmers interested in ecological strategies for integrated diversified farms has led to increased experiences with no-till farming, efficient microorganisms, soil conservation on hillside farms, biodiversity as both a conservation and productive ally, and local production of compost. At the same time, conventional farmers are opening up to the use of sustainable strategies as part of their management plans.

Through a 2016 law, Puerto Rico's government has set aside 600,000 acres, one fourth of its territory, for agricultural production. We argue that if that area is used for agroecological production, on the basis of four persons per acre, we could supply two-thirds of the food for 3.4 million Puerto Ricans, the current population. Back in 1939, 65 percent of all food was produced on the mountain slopes for two million people, at a time when the prime lands were dedicated to sugar, coffee, tobacco, and other crops for export. If Puerto Rico could redevelop at least 24,000 agroeological farms at an average of 25 acres, this would create over 100,000 direct jobs (Álvarez Febles, 2016).

Despite the efforts towards food self-sufficiency on behalf of coffee farmers across the rural mountains of the island (Diaz & Hunsberger, 2018; McCune et al., 2019), the Coca Cola Company has purchased classic Puerto Rican coffee brands, channelling much of the production disguised as the Puerto Rico Coffee Roasters and putting at risk the survival of local and diversified peasant

economies (McCune et al., 2019). If these coffee mountain agroecosystems would be reduced to monocultures using high-yielding varieties and external input, some of the key elements that confer greater ecological resilience to sustainably managed mountain agroecosystems would be lost (McCune et al., 2019). The widespread presence of subsistence food crops in coffee plantations such as plantains and bananas, yautía and malanga, oranges and grapefruits, and many others would cease to co-exist with coffee bushes. The provision of habitat and food sources to bees, butterflies, and other insects that pollinate the coffee (and other relevant crops), as well as for amphibians and birds would be dramatically decreased. The lost richness and abundance of important shade trees would impede the design of pest-suppressive landscapes (e.g. for the control of coffee berry borer and coffee rust disease). The contribution to atmospheric carbon storage in the trunks of trees and coffee bushes, their roots, and the extensive microbiome associated with soil processes on the coffee farms would severely be diminished.

The Josco Bravo experience shows that what mainstream agricultural policies consider impossible is a reality. In Puerto Rico there are over 150,000 acres of high agricultural value lands. Farming on 10 percent of that legally protected land for agriculture, at 12,000 pounds per acre, per 15,000 acres, leads to a production of 180 million pounds of food per year. For a population of 3.4 million inhabitants it yields fifty-three pounds of food per person per year on an island that can be currently described as a "food desert." An ecological production of this magnitude would represent permanent change in the country to achieve local food security and sovereignty. Increasing yields in rural and urban settings through improved resource-use efficiencies would undoubtedly create a critical mass capable of achieving food self-sufficiency and boost the island's economy.

The intensification of ecological processes on-farm and at landscape scales could advance the sustainability of agricultural food production via the mobilization of local biological diversity to address global changes (Tittonell et al., 2016). Such a move towards agroecological sustainability of the agro-food system in Puerto Rico would require radical changes in public policies and a clear orientation towards climate change-resilient designs (e.g. landscape scale agroecological approaches) instead of solely technical fixes (e.g. high-yielding coffee varieties or "slick genes" for livestock). Strategic actions that would upscale the implementation of agroecological principles throughout the territory include efforts to:

- Map current agroecological experiences;
- Promote farmer-to-farmer knowledge exchanges;
- Support conversion of conventional farmers towards agroecology.

A first step at the policy level would be to stop subsidizing destructive and polluting practices such as heavy machinery use in fragile mountain environments and end chemical pollution from herbicides and synthetic fertilizer usage. As in

some other places, fines could be used to redirect funds towards agroecological research and subsidies, such as for integrating more people into sustainable farming activities. At the same time agroecological farms and downhill enterprises could benefit from other types of institutional support, such as tax breaks for environmental rehabilitation, positive climate change reduction practices, and health, cultural, and educational activities.

## Concluding remarks

Hurricanes Irma and María devastated the Caribbean island of Puerto Rico late in 2017, greatly damaging the flora, fauna, rivers, coastlines, electrical, transport, housing, and water infrastructures. In the months afterwards, long-standing poverty and inequality was brought to the forefront of problems facing this United States colonial territory. All the while, Puerto Ricans were suffering the impact of a triple structural crisis: economic recession since 2016; financial control of local government through a mechanism created by the US Congress to recover $73 billion of a mostly illegal or immoral debt; and long-term neoliberal government neglect leading to deteriorating infrastructure, governmental down-sizing, reduction of essential public services, and job destruction, and a manifold environmental crisis.

Agroecology is seen by many in Puerto Rico as central for local food and agricultural sovereignty. There is growing evidence that such farming can produce more food per area, while at the same time promoting conservation and restoration of natural resources. Using the land set aside by law for food production (about a quarter of the archipelago's territory), agroecology could have a positive global impact on food production, ecosystem enhancement, and social and economic sustainability. This would also enhance climate change mitigation at a local level. A pending matter is how to develop complete food sovereignty despite the current colonial relationship with the United States, in order to optimize ecological and sustainable local food production and agriculture according to the needs and possibilities of the Puerto Rican people. Fostering synergies among science, practitioners, and social movements is central to these important goals.

María produced heavy damage to all farming operations, both in rural and urban areas. Puerto Rico had a small yet dynamic agroecological movement when the hurricanes hit. Smallholder family farms, mostly in the hilly mountain ecosystems, were producing food for self-sufficiency, while local farmers' markets and specialty restaurants gradually recovered from the shock. This stands against the idea that only the rich survive, and demonstrates the importance of solidarity and small-scale resilience. Six months after the hurricanes, agroecological farms in Puerto Rico were able to resume operations and production faster than conventional high external input farms. Community building, social justice, and farmer-to-farmer solidarity, coupled with material and economic support from farmer and non-governmental organizations out of Puerto Rico, were key elements after the storms to "bounce forward" the island's once-neglected food production system.

## Notes

1 https://redapoyomutuopr.com/puerto-rico-organizations/
2 www.visitrico.org/
3 www.afcanatura.org/lasolidaria
4 http://casapueblo.org/

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