SEPTEMBER 2018

Final Report

Improving USDA response to reducing the risks of drought and storms and increasing sustainability in agriculture in the Caribbean

USDA Forest Service International Institute of Tropical Forestry

NRCS Agreement number 67-F352-17-262

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Improving USDA response to reducing the risks of drought and storms and increasing sustainability in agriculture in the Caribbean

Final report of activities conducted under the Interagency Agreement between USDA Natural Resources Conservation Service (NRCS) and USDA Forest Service International Institute of Tropical Forestry (IITF)

Introduction

This is the 2017-2018 USDA Forest Service International Institute of Tropical Forestry (IITF) summary report on all activities conducted in the interagency agreement between the USDA Caribbean Climate Hub and the Natural Resources Conservation Service Caribbean Area (NRCS-Caribbean Area). These projects relate to the development and dissemination of environmental information on drought and storm occurrences, and the conservation practices effects to reduce risk to extreme weather. The Caribbean Climate Hub and NRCS-Caribbean Area have been cooperating since the creation of the USDA Climate Hubs in 2014.

The report includes a description for accomplishments made possible by the support of this agreement and its collaborators with other Climate Hubs and other Institute projects. We have included copies of the completed products as an appendix to this report. Copies of the products are available by request.

Background

The success of the Climate Hubs in transferring management practices, decision tools, and information to land management stakeholders can be achieved through close coordination with USDA agencies, regional universities, and non-governmental partners. Partnerships are key to establishing communication between landowners, managers, farmers, and the research community and in establishing coordination within the science and tech-transfer community. The Caribbean Climate Hub has been building collaboration through an outreach and communication strategy that includes webinars, videos, fact sheets, podcasts, social media campaigns, interviews and surveys, meetings, and workshops – all dedicated to delivering a core of scientific information related to climate adaptation. The Hub is filling a gap in bringing together various organizations engaged on issues surrounding agriculture and forestry within the US Caribbean and internationally, as well as providing leadership, direction, and coordination in the development of ideas, science, and tools for sustainable development.

Through this agreement, the Caribbean Climate Hub worked with NRCS Caribbean to develop scientific analyses and outreach tools for farmers in Puerto Rico and the USVI. In FY 17, the Hub conducted a pilot analysis to understand how USDA programs affect vulnerability,

resilience, and adaptive capacity in farming systems throughout the territory. In FY 18, a project was developed to explore how NRCS conservation initiatives help minimize the effects of drought and storms on croplands and livestock.

This agreement provided a formal link between USDA-NRCS and the Caribbean Climate Hub, IITF. This combined resource effort resulted in the enhancement of effective technical assistance services provided to land users who seek to address Caribbean Area excess or insufficient water resource concerns. The Hub created maps to portray the spatial allocation of NRCS practices with respect to areas vulnerable to drought and storms and will provide information on how farmers can best adapt to expected climatic exposure by planning with the most appropriate conservation practices. The maps may serve as the basis for the next generation of conservation planning tools. The USDA Caribbean Climate Hub delivers science-based knowledge and practical information to farmers, ranchers, and forest landowners that will help them adapt to climate change and weather variability by coordinating with local and regional partners in federal and state agencies, universities, and the public.

NRCS is the lead federal agency for conservation on private land. In carrying out this role, NRCS provides voluntary conservation planning, technical and financial assistance to farmers, ranchers, and other landowners to address natural resource concerns on the Nation's private and nonfederal lands.

This agreement supported the salary of Eva Holupchinski, Research Assistant to the Caribbean Climate Hub scientist Dr. Nora Álvarez-Berríos.

Summary of Accomplishments

1. *Prepare and develop maps of drought and storm occurrence, drought and storm impacts, and hotspot of conservation practices in relation to drought and storm vulnerability.*

    a. Maps of drought occurrence, impacts and conservation practices in relation to drought vulnerability

        i. Peer-reviewed publication:

        This agreement allowed contracted technical assistance to carry out a wide-ranging project to determine the areas of Puerto Rico exposed to drought between 2000 and 2016 (Appendix 1). As part of this project, a novel map was created that shows the concentration of practices of

agricultural conservation in relation to areas vulnerable to droughts during the study period (Appendix 2). The study produced several maps associated with the exposure of agricultural land to critical drought conditions (Appendix 3). Four of the maps that were produced for this analysis were published in a research paper in the Renewable Agriculture and Food Systems journal.

The publication was one of the three highlighted papers in the special session on Ag/Food Systems and Climate Change: http://blog.journals.cambridge.org/2018/07/03/confronting-drought-impacts-in-puerto-rico/

Reference: Álvarez-Berríos, N., Soto-Bayó, S., Holupchinski, E., Fain, S., & Gould, W. (2018). Correlating drought conservation practices and drought vulnerability in a tropical agricultural system. Renewable Agriculture and Food Systems, 33(3), 279-291. doi:10.1017/S174217051800011X

ii. Material for the Fourth National Climate Assessment

Scientists from IITF lead the development of U.S. Caribbean Regional Chapter in the Fourth National Climate Assessment (NCA4). The National Climate Assessment is a federal, congressionally-mandated report that presents the historical, present, and projected effects and impacts of climate change on natural and human systems in the United States. The Caribbean chapter includes six key messages that address the risks, vulnerabilities and adaptation actions associated with climate extremes, variability, land cover change, freshwater availability, marine resources, coastal systems, rising temperatures, extreme events, and international initiatives and partnerships.

The key message on extreme events featured a drought-map (Appendix 4) and analyses performed with the support of NRCS through this agreement. The Fourth National Climate Assessment is on schedule to be published in December of 2018.

b. Maps of storm occurrence, impacts and conservation practices in relation to storm vulnerability

i. Maps developed for peer-reviewed publication:

With the support of this agreement, we collaborated in a research project that analyzed hurricanes effects on forest cover and landslides across Puerto Rico and the US Virgin Islands. Technical assistance was provided to create maps of the hurricane force of wind. These maps were computed as the total gale-force wind kinetic energy of Hurricane María over the US Caribbean. The kinetic energy was modeled using wind forecasts created by the National Weather Service (NWS) in 3-hour time steps of the hurricane progression (10 forecasts for María). These maps were also used to model the projected impact of hurricanes of different magnitude and translation velocity. The manuscript of this research was recently published in the Remote Sensing Journal in the recently published scientific paper: Hurricane Maria in the U.S. Caribbean: Disturbance Forces, Variation of Effects, and Implications for Future Storms.

Reference: Van Beusekom, A.E.; Álvarez-Berríos, N.L.; Gould, W.A.; Quiñones, M.; González, G.Hurricane Maria in the U.S. Caribbean: Disturbance Forces, Variation of Effects, and Implications for Future Storms. Remote Sens. 2018, 10, 1386.

ii. Storm recovery package - USDA aid to support hurricane recovery process

In response to the damages in agriculture and forestry caused by Hurricanes Irma & Maria, we developed a hurricane recovery resource package that was also shared on the Hub webpage. In the production of the package, this agreement supported the prompt collection of essential and up to date information about state and federal programs that provide disaster assistance for farmers and landowners in Puerto Rico and the U.S. Virgin Islands (Appendix 5). This information was then converted into a series of novel and adapted disaster assistance resource documents that were printed and distributed in the form of over 500 disaster assistance information packages. The material, produced in Spanish and English, was also used in an inter-agency campaign to bring federal aid to farmers in Puerto Rico. This initiative was led by NRCS California outreach team and the Department of Agriculture of Puerto

Rico and impacted over 300 farmers in Puerto Rico. Adapted versions of the disaster assistance resources were adjusted for relevance in the U.S. Virgin Islands. About 250 printed disaster assistance packages were transferred to USDA collaborators in the USVI for dissemination. The digital package was also shared for further printing onsite as needed.

2. *Prepare two factsheets and one poster: On conservation practices and their contribution to minimizing resource concerns on agricultural lands.*

   a. Factsheet on Drought in Puerto Rico

   We developed a fact sheet to disseminate the results obtained in our research project on droughts in Puerto Rico. The 8 x 11 inch factsheet portrays maps of drought-exposure, projected rainfall patterns, and agricultural lands exposed to drought conditions (Appendix 6). It also shows conservation practices recommended by NRCS to mitigate drought conditions in our region.

   b. Factsheet on Agricultural Drought

   We created a fact sheet that summarizes the impacts of agricultural droughts in the US Caribbean (Appendix 7). This fact sheet is one of a series of seven fact sheets developed during the Caribbean Drought Workshop held in the International Institute of Tropical Forestry on May 30th and 31st, 2018. The workshop was held in collaboration between the Southeast Climate Adaptation Science Center and the USDA Caribbean Climate Hub and hosted over 50 experts on drought, water management, ecology, and agriculture, including representatives from NRCS-Caribbean Area.

   c. A scientific poster on Drought in Puerto Rico

   We created and presented a scientific poster on drought exposure in Puerto Rico– Long-Term Ecological Research Annual Meeting, June 5th, University of Puerto Rico (Appendix 8).

3. *Prepare a research map publication series: On NRCS conservation practices and their landscape-scale contribution to drought and storms adaptation in Puerto Rico and the USVI.*

a. Research Map - Drought in Puerto Rico

The U.S. Forest Service Research Map series is a national publication series patterned after the Forest Service General Technical Report series to convey new geospatial information derived from Forest Service research. The maps in this research series are peer-reviewed by at least 3 sources, with at least one source from outside the agency. The maps developed at the Institute are all published in English and Spanish. The Institute published its first research map in 2008.

As part of the agreement, we prepared a research map on Drought in Puerto Rico entitled *Droughts of the 21st Century in Puerto Rico* (Appendix 9). The objective of the research map is to provide an overview of local drought conditions since the turn of the century. The research map summarizes the components of a drought, how drought events are monitored, drought history in the region, as well as the effects and management of drought conditions in the agricultural sector. The intended audience for this outreach product is government agencies, schools, libraries and the general public. The map features information on NRCS practices and programs, the map upholds the NRCS duty of providing equal opportunity for program delivery through education.

b. Storm adaptation research

4. *Prepare a final project report that documents project accomplishments and goals achieved. Reports should also address partner efforts to monitor and evaluate the implementation of conservation activities included in NRCS program contracts, and other relevant activities within the approved project area.*

This document constitutes the final report. Our manuscript "Correlating drought conservation practices and drought vulnerability in a tropical agricultural system", provides an evaluation on the location and extent of recent droughts in Puerto Rico and the coverage of NRCS conservation practices that mitigate drought conditions. The research highlighted seven droughts periods registered in the US Drought Monitor from 2000 to 2016, with the most drastic event occurring from 2014 to 2016. The analysis also revealed that drought exposure did not drive the allocation of drought-related practices nor did it motivate significant farmer participation. Our results were shared with NRCS-Caribbean Area leadership and are now taken into consideration on future planning for drought adaptability in US Caribbean.

Additional Accomplishments

1. Coordination of the two-day U. S. Caribbean Drought Workshop
2. Contribution of content and technical support in the Caribbean Chapter of the Fourth National Climate Assessment
3. ADAPTA Workshop series support

1. *Coordination of the two-day U. S. Caribbean Drought Workshop*

   On May 30 and 31st, a workshop was held at the International Institute of Tropical Forestry in the Botanical Garden of Río Piedras, Puerto Rico on the topic of drought in the U.S. Caribbean. This agreement permitted the contracted technical assistance to collaborate in the coordination of the U.S. Caribbean Drought Workshop by providing logistical support to NCASC. Throughout the two-day workshop, the technical assistance also collaborated with workshop facilitation and technical support. The purpose of the workshop was to synthesize the State of the Science on the unique drought impacts in the U.S. Caribbean by sector in Puerto Rico and the U.S. Virgin Islands. Co-hosted by the USDA Caribbean Climate Hub, in collaboration with the USGS National Climate Adaptation Science Center (NCASC) and the regional Climate Adaptation Science Centers (CASCs), the two-day workshop welcomed around 50 representatives from agriculture, natural resources, water supply sectors and multiple levels of government.

   To synthesize the State of the Science on drought impacts by sector in Puerto Rico and the U.S. Virgin Islands, the workshop participants collaborated to:

   1. Identify lessons learned from past drought effects (e.g. 2015);
   2. Highlight key similarities and differences in terms of impacts between the agricultural, ecosystem and water supply sectors;
   3. Identify available data and information for drought monitoring and information gaps to support drought management; and
   4. Discuss future drought scenarios and thresholds, and what projected future conditions will mean for managers.

   Outputs of the workshops include a series of drought-themed factsheets that highlight the unique challenges and characteristics of drought events in the U.S. Caribbean. The topics of the planned factsheets are U.S. Caribbean drought and 1) Crops, 2) Agriculture (Appendix 7), 3) Ecosystems, 4) Water supply, and 5) Future climate. The series is currently under development by various workshop participants. Another outcome of the workshop is that significant progress was made in the incorporation of the U.S. Virgin

Islands to the U.S. Drought Monitor. The Drought Monitor currently published weekly drought data for the continental United States, Hawaii and Puerto Rico. Various workshop participants created a listserv for sharing U.S. Virgin Island data on drought as a next step in the process to include the U.S. Virgin Islands in the Drought Monitor network. The USDA Caribbean Climate Hub also generated a report on the workshop with the support of this agreement (Appendix 10).

2. *Contribution of content and technical support in the Caribbean Chapter of the Fourth National Climate Assessment*

This interagency agreement supported Hub contribution to the previously introduced (in section 1a ii) Fourth National Climate Assessment, a federal and congressionally-mandated document that summarizes the historical, present, and projected effects of climate change on natural and human systems in the United States. Local experts in climate and environmental science contributed to the chapter on the U.S. Caribbean Region specifically. Under this agreement, the Hub chapter authors focused on the key message of extreme events, describing peer-reviewed scientific literature-based information on tropical cyclones, droughts, and flooding.

3. *ADAPTA Workshop series support*

Under this interagency agreement, the final stages of the ADAPTA workshop series were carried out by contracted assistance in cooperation with the Hub team. The aim of the ADAPTA project is to identify and document local successes in sustainable land management practices that farmers, ranchers and landowners in Puerto Rico and the U.S. Virgin Islands could adopt to build climate change resilience. The ADAPTA workshop series provided theoretical and technical training to farmers, agronomists, land-owners and teachers to prepare for and adapt to climate change. Each workshop focused on different climate adaptation practices for dairy, plantain, fruit and vegetable, and forest production. These workshops were held in collaboration with the Bosque Modelo Office.

Contracted support co-coordinated the final ADAPTA Workshops on the following topics: 1) Use of cover crops for climate change adaptation and greenhouse gas mitigation, and 2) Minimizing the carbon footprint of tropical dairy farming: design and use of nutritional diets and good management in dairy herds. In order to carry out these workshops, extensive coordination, communication, and preparation was required to ensure that the workshops were properly planned and executed. This coordination included conference calls and communications with workshop partners, such as the

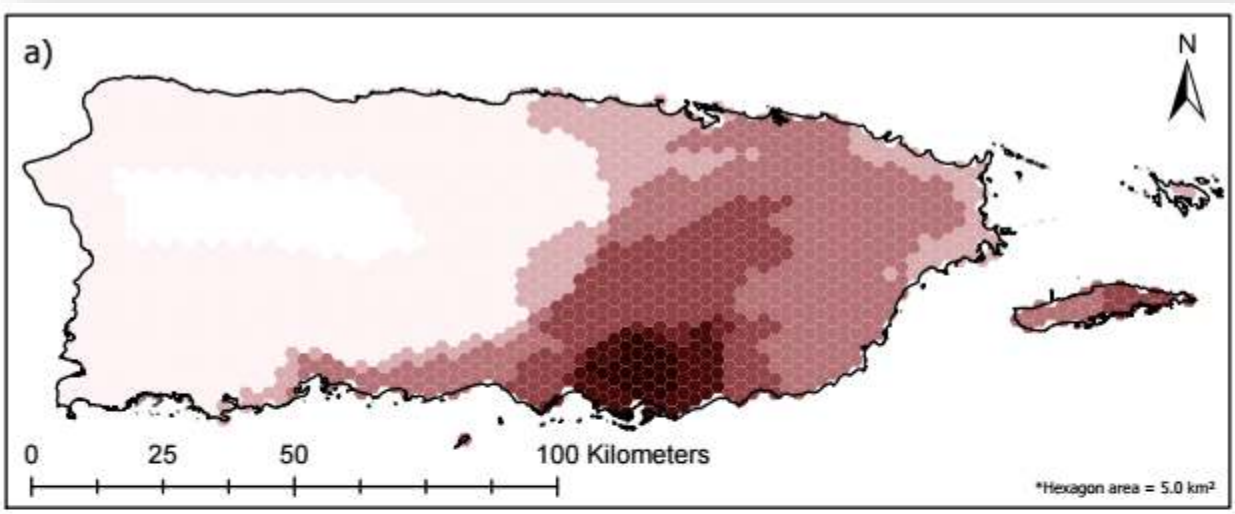
Bosque Modelo Office, the Lajas Experimental Station, and workshop presenters. The contracted assistance and Hub team also provided administrative support by creating name tags, personalized certificates of workshop completion, registration sheets and any other minor details. The workshop series were recorded in order to share the trainings with the general public. The recordings were then refined and reviewed by agreement supported staff to polish into videos for dissemination through social media.

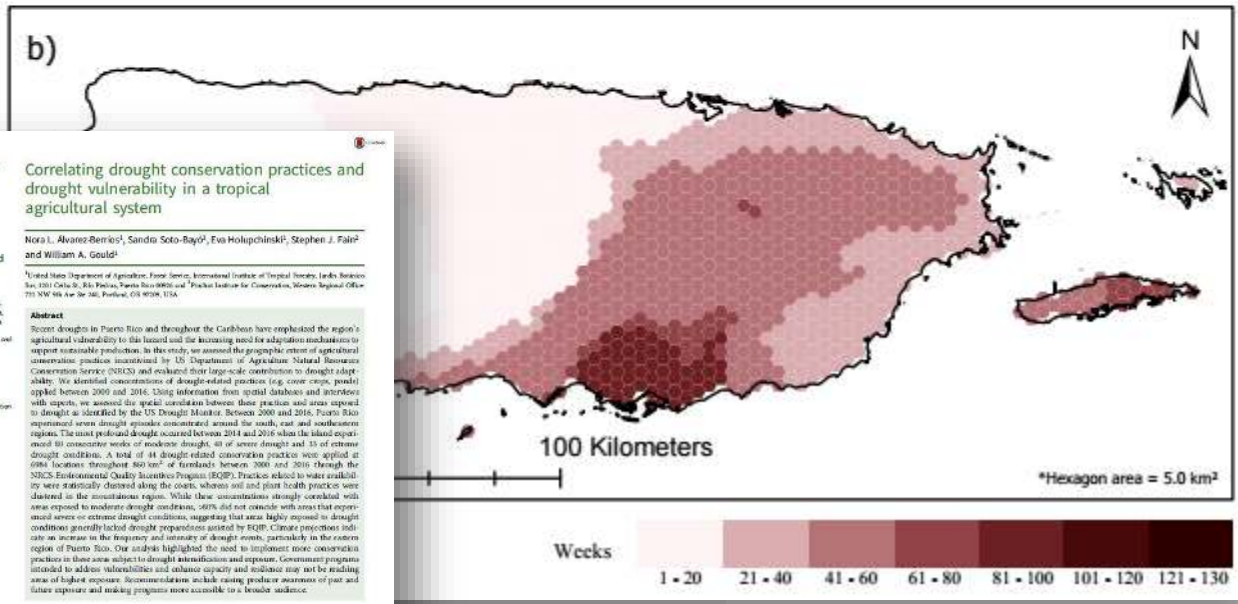
Acknowledgements

These projects were made possible thanks to the NRCS Agreement 67-F352-17-262. Our special thanks to NRCS Project Manager José Castro and Plant Materials and Grazing Lands Specialist Edwin Más for their guidance and collaboration throughout the year. We also thank our colleagues from the Southeast Climate Adaptation Science Center and the National Drought Mitigation Center for their collaboration in the US Caribbean Drought Workshop and associated projects.

Appendices

Appendix 1: Drought accumulation for a) 2000 – 2016 and b) 2014-2016 created for the publication pictured below: Álvarez-Berríos, N., Soto-Bayó, S., Holupchinski, E., Fain, S., & Gould, W. (2018). Correlating drought conservation practices and drought vulnerability in a tropical agricultural system. Renewable Agriculture and Food Systems, 33(3), 279-291. doi:10.1017/S174217051800011X





Renewable Agriculture and Food Systems

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Correlating drought conservation practices and drought vulnerability in a tropical agricultural system

Nora L. Álvarez-Berríos[1], Sandra Soto-Bayó[2], Eva Holupchinski[2], Stephen J. Fain[2] and William A. Gould[1]

Themed Content: Ag/Food Systems and Climate Change

Abstract

Recent droughts in Puerto Rico and throughout the Caribbean have emphasized the region's agricultural vulnerability to this hazard and the increasing need for adaptation mechanisms to support sustainable production. In this study, we assessed the geographic extent of agricultural conservation practices incentivized by US Department of Agriculture Natural Resources Conservation Service (NRCS) and evaluated their large-scale contribution to drought adaptability. We identified concentrations of drought-related practices (e.g. cover crops, ponds) applied between 2000 and 2016. Using information from spatial databases and interviews with experts, we assessed the spatial correlation between these practices and areas exposed to drought as identified by the US Drought Monitor. Between 2000 and 2016, Puerto Rico experienced seven drought episodes concentrated around the south, east and southeastern regions. The most profound drought occurred between 2014 and 2016 when the island experienced 80 consecutive weeks of moderate drought, 40 of severe drought and 15 of extreme drought conditions. A total of 44 drought-related conservation practices were applied at 6984 locations throughout 860 km² of farmlands between 2000 and 2016 through the NRCS Environmental Quality Incentives Program (EQIP). Practices related to water availability were statistically clustered along the coasts, whereas soil and plant health practices were clustered in the mountainous region. While these concentrations strongly correlated with areas exposed to moderate drought conditions, >80% did not coincide with areas that experienced severe or extreme drought conditions, suggesting that areas highly exposed to drought conditions generally lacked drought preparedness assisted by EQIP. Climate projections indicate an increase in the frequency and intensity of drought events, particularly in the eastern region of Puerto Rico. Our analysis highlighted the need to implement more conservation practices in those areas subject to drought intensification and exposure. Government programs intended to address vulnerabilities and enhance capacity and resilience may not be reaching areas of highest exposure. Recommendations include raising producer awareness of past and future exposure and making programs more accessible to a broader audience.

Introduction

The effects of climate change threaten the world's most sensitive agroecosystems and our potential to reach agricultural productivity levels needed to feed a projected global population of 9.7 billion people by 2050 (Delgado, 2011). Projections of global mean temperature indicate that even a 1–2°C rise could disrupt agricultural systems and production in low-latitude regions (23.5°N–23.5°S), and a rise >3°C would negatively affect food production worldwide (Easterling et al., 2007). Decreases in mean precipitation are projected in mid-latitudes and regions of the dry tropics, diminishing water availability in areas of rain-fed crops (e.g., Central America), while extreme increases in precipitation are likely in major agricultural production areas (e.g., Southern and Eastern Asia) (Easterling et al., 2007). Models also indicate that changes in seasonal timing, frequency and severity of climatic events can result in serious consequences for agricultural production beyond those derived from changes in average precipitation and temperature (Easterling et al., 2007; Wahlhall et al., 2012). Multiple stressors, such as drought, increasing temperatures and economic recession can align to push interconnected social and agroecosystems past crucial tipping points, forcing a reformation of network connections, affecting current and future adaptive capacity and yield potential (Folke, 2006).

To minimize the effects of climate change and extreme weather events on agriculture, scientists and policy makers highlight the importance of air, soil and water conservation as fundamental to climate adaptation and mitigation and for improving food security (Wahlhall et al., 2012; Delgado and Li, 2016). Hence, governments around the world are increasingly investing

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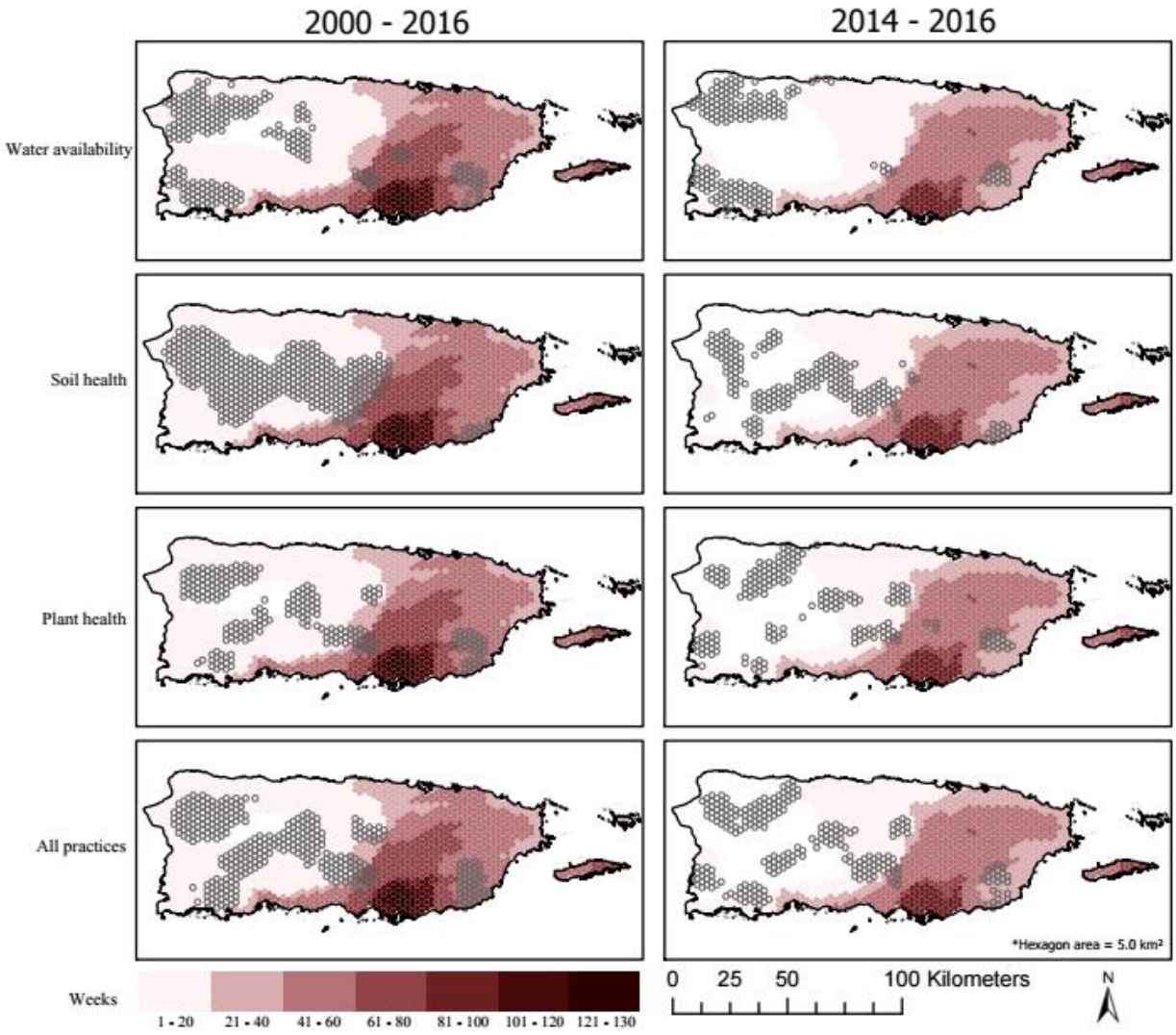
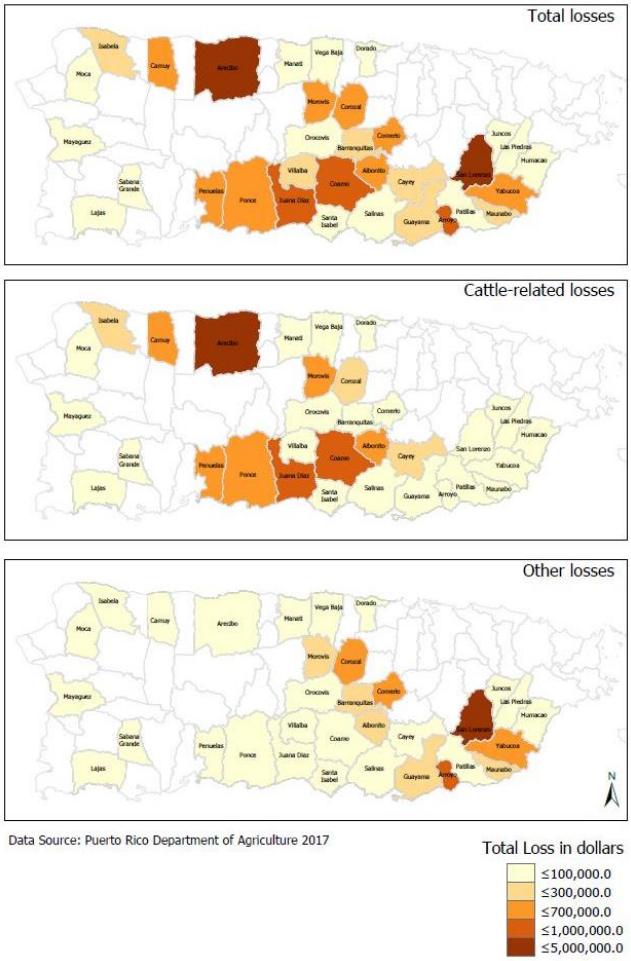
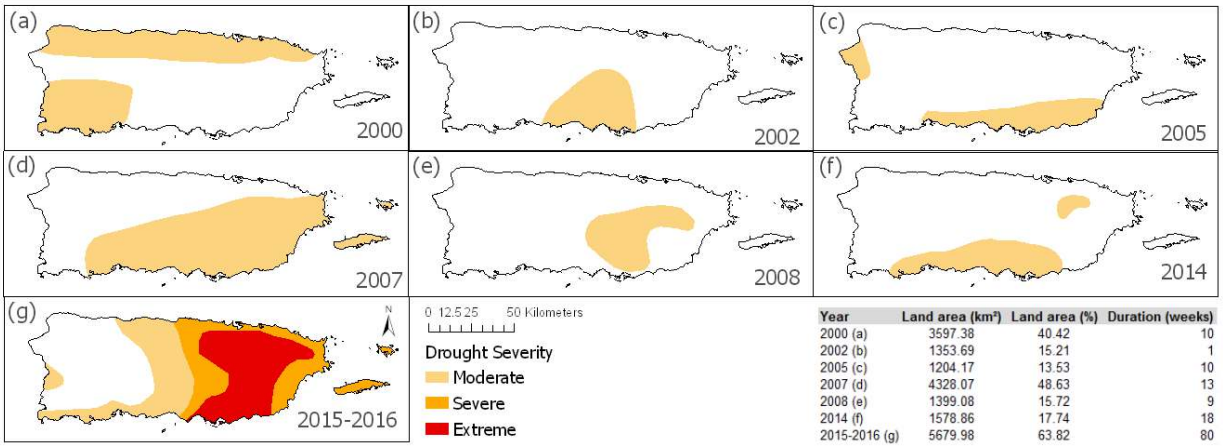
Appendix 2: NRCS drought-related conservations practice hotspots for four categories: water availability, soil health, plant health, and all practices combined; featured with drought accumulation for the periods 2000 – 2016 and 2014 - 2016.





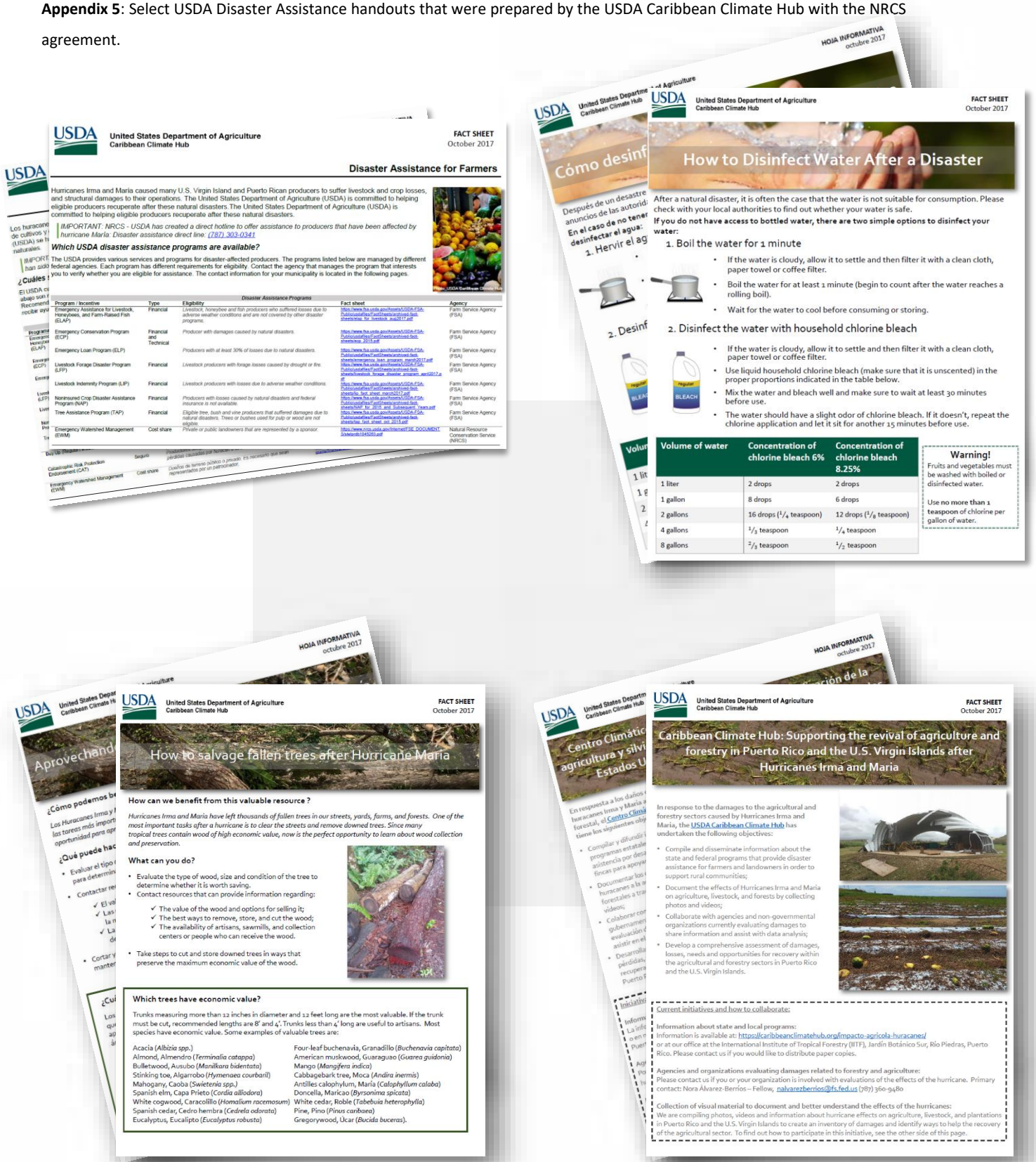
Appendix 3: Agricultural losses by municipality resulting from the 2015 drought.

Appendix 4: Maximum extent of all registered drought events from 2000 – 2016 based on USDM data.



Year	Land area (km²)	Land area (%)	Duration (weeks)
2000 (a)	3597.38	40.42	10
2002 (b)	1353.69	15.21	1
2005 (c)	1204.17	13.53	10
2007 (d)	4328.07	48.63	13
2008 (e)	1399.08	15.72	9
2014 (f)	1578.86	17.74	18
2015-2016 (g)	5679.98	63.82	80

Appendix 5: Select USDA Disaster Assistance handouts that were prepared by the USDA Caribbean Climate Hub with the NRCS agreement.



United States Department of Agriculture
Caribbean Climate Hub

FACT SHEET
October 2017

Disaster Assistance for Farmers

Hurricanes Irma and María caused many U.S. Virgin Island and Puerto Rican producers to suffer livestock and crop losses, and structural damages to their operations. The United States Department of Agriculture (USDA) is committed to helping eligible producers recuperate after these natural disasters. The United States Department of Agriculture (USDA) is committed to helping eligible producers recuperate after these natural disasters.

IMPORTANT: NRCS - USDA has created a direct hotline to offer assistance to producers that have been affected by hurricane María. Disaster assistance direct line: (787) 303-0341

Which USDA disaster assistance programs are available?

The USDA provides various services and programs for disaster-affected producers. The programs listed below are managed by different federal agencies. Each program has different requirements for eligibility. Contact the agency that manages the program that interests you to verify whether you are eligible for assistance. The contact information for your municipality is located in the following pages.

Disaster Assistance Programs

Program / Incentive	Type	Eligibility	Fact sheet	Agency
Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish (ELAP)	Financial	*Livestock, honeybee and fish producers who suffered losses due to adverse weather conditions and are not covered by other disaster programs.*	https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/archived-fact-sheets/elap_for_livestock_aug2017.pdf	Farm Service Agency (FSA)
Emergency Conservation Program (ECP)	Financial and Technical	*Producer with damages caused by natural disasters.*	https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/archived-fact-sheets/ecp_2015.pdf	Farm Service Agency (FSA)
Emergency Loan Program (ELP)		*Producers with at least 30% of losses due to natural disasters.*	https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/archived-fact-sheets/emergency_loan_program_march2017.pdf	Farm Service Agency (FSA)
Livestock Forage Disaster Program (LFP)	Financial	*Livestock producers with forage losses caused by drought or fire.*	https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/archived-fact-sheets/livestock_forage_disaster_program_april2017.pdf	Farm Service Agency (FSA)
Livestock Indemnity Program (LIP)	Financial	*Livestock producers with losses due to adverse weather conditions.*	https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/archived-fact-sheets/lip_fact_sheet_march2017.pdf	Farm Service Agency (FSA)
Noninsured Crop Disaster Assistance Program (NAP)	Financial	*Producers with losses caused by natural disasters and federal insurance is not available.*	https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/archived-fact-sheets/NAP_for_2018_and_Subsequent_Years.pdf	Farm Service Agency (FSA)
Tree Assistance Program (TAP)	Financial	*Eligible tree, bush and vine producers that suffered damages due to natural disasters. Trees or bushes used for pulp or wood are not eligible.*	https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/archived-fact-sheets/tap_fact_sheet_oct_2015.pdf	Farm Service Agency (FSA)
Emergency Watershed Management (EWM)	Cost share	*Private or public landowners that are represented by a sponsor.*	https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1045263.pdf	Natural Resource Conservation Service (NRCS)

United States Department of Agriculture
Caribbean Climate Hub

FACT SHEET
October 2017

How to Disinfect Water After a Disaster

After a natural disaster, it is often the case that the water is not suitable for consumption. Please check with your local authorities to find out whether your water is safe.

If you do not have access to bottled water, there are two simple options to disinfect your water:

1. Boil the water for 1 minute
   - If the water is cloudy, allow it to settle and then filter it with a clean cloth, paper towel or coffee filter.
   - Boil the water for at least 1 minute (begin to count after the water reaches a rolling boil).
   - Wait for the water to cool before consuming or storing.
2. Disinfect the water with household chlorine bleach
   - If the water is cloudy, allow it to settle and then filter it with a clean cloth, paper towel or coffee filter.
   - Use liquid household chlorine bleach (make sure that it is unscented) in the proper proportions indicated in the table below.
   - Mix the water and bleach well and make sure to wait at least 30 minutes before use.
   - The water should have a slight odor of chlorine bleach. If it doesn't, repeat the chlorine application and let it sit for another 15 minutes before use.

Volume of water	Concentration of chlorine bleach 6%	Concentration of chlorine bleach 8.25%
1 liter	2 drops	2 drops
1 gallon	8 drops	6 drops
2 gallons	16 drops (1/4 teaspoon)	12 drops (1/8 teaspoon)
4 gallons	1/3 teaspoon	1/4 teaspoon
8 gallons	2/3 teaspoon	1/2 teaspoon

Warning!
Fruits and vegetables must be washed with boiled or disinfected water.

Use **no more than 1 teaspoon** of chlorine per gallon of water.

United States Department of Agriculture
Caribbean Climate Hub

FACT SHEET
October 2017

How to salvage fallen trees after Hurricane María

How can we benefit from this valuable resource ?

Hurricanes Irma and María have left thousands of fallen trees in our streets, yards, farms, and forests. One of the most important tasks after a hurricane is to clear the streets and remove downed trees. Since many tropical trees contain wood of high economic value, now is the perfect opportunity to learn about wood collection and preservation.

What can you do?

- Evaluate the type of wood, size and condition of the tree to determine whether it is worth saving.
- Contact resources that can provide information regarding:
  - ✓ The value of the wood and options for selling it;
  - ✓ The best ways to remove, store, and cut the wood;
  - ✓ The availability of artisans, sawmills, and collection centers or people who can receive the wood.
- Take steps to cut and store downed trees in ways that preserve the maximum economic value of the wood.

Which trees have economic value?

Trunks measuring more than 12 inches in diameter and 12 feet long are the most valuable. If the trunk must be cut, recommended lengths are 8' and 4'. Trunks less than 4' long are useful to artisans. Most species have economic value. Some examples of valuable trees are:

Acacia (*Albizia spp.*)
Almond, Almendro (*Terminalia catappa*)
Bulletwood, Ausubo (*Manilkara bidentata*)
Stinking toe, Algarrobo (*Hymenaea courbaril*)
Mahogany, Caoba (*Swietenia spp.*)
Spanish elm, Capa Prieto (*Cordia alliodora*)
White cogwood, Caracolillo (*Homalium racemosum*)
Spanish cedar, Cedro hembra (*Cedrela odorata*)
Eucalyptus, Eucalipto (*Eucalyptus robusta*)
Four-leaf buchenavia, Granadillo (*Buchenavia capitata*)
American muskwood, Guaraguao (*Guarea guidonia*)
Mango (*Mangifera indica*)
Cabbagebark tree, Moca (*Andira inermis*)
Antilles calophylum, María (*Calophyllum calaba*)
Doncella, Maricao (*Byrsonima spicata*)
White cedar, Roble (*Tabebuia heterophylla*)
Pine, Pino (*Pinus caribaea*)
Gregorywood, Ucar (*Bucida buceras*).

United States Department of Agriculture
Caribbean Climate Hub

FACT SHEET
October 2017

Caribbean Climate Hub: Supporting the revival of agriculture and forestry in Puerto Rico and the U.S. Virgin Islands after Hurricanes Irma and María

In response to the damages to the agricultural and forestry sectors caused by Hurricanes Irma and María, the USDA Caribbean Climate Hub has undertaken the following objectives:

- Compile and disseminate information about the state and federal programs that provide disaster assistance for farmers and landowners in order to support rural communities;
- Document the effects of Hurricanes Irma and María on agriculture, livestock, and forests by collecting photos and videos;
- Collaborate with agencies and non-governmental organizations currently evaluating damages to share information and assist with data analysis;
- Develop a comprehensive assessment of damages, losses, needs and opportunities for recovery within the agricultural and forestry sectors in Puerto Rico and the U.S. Virgin Islands.

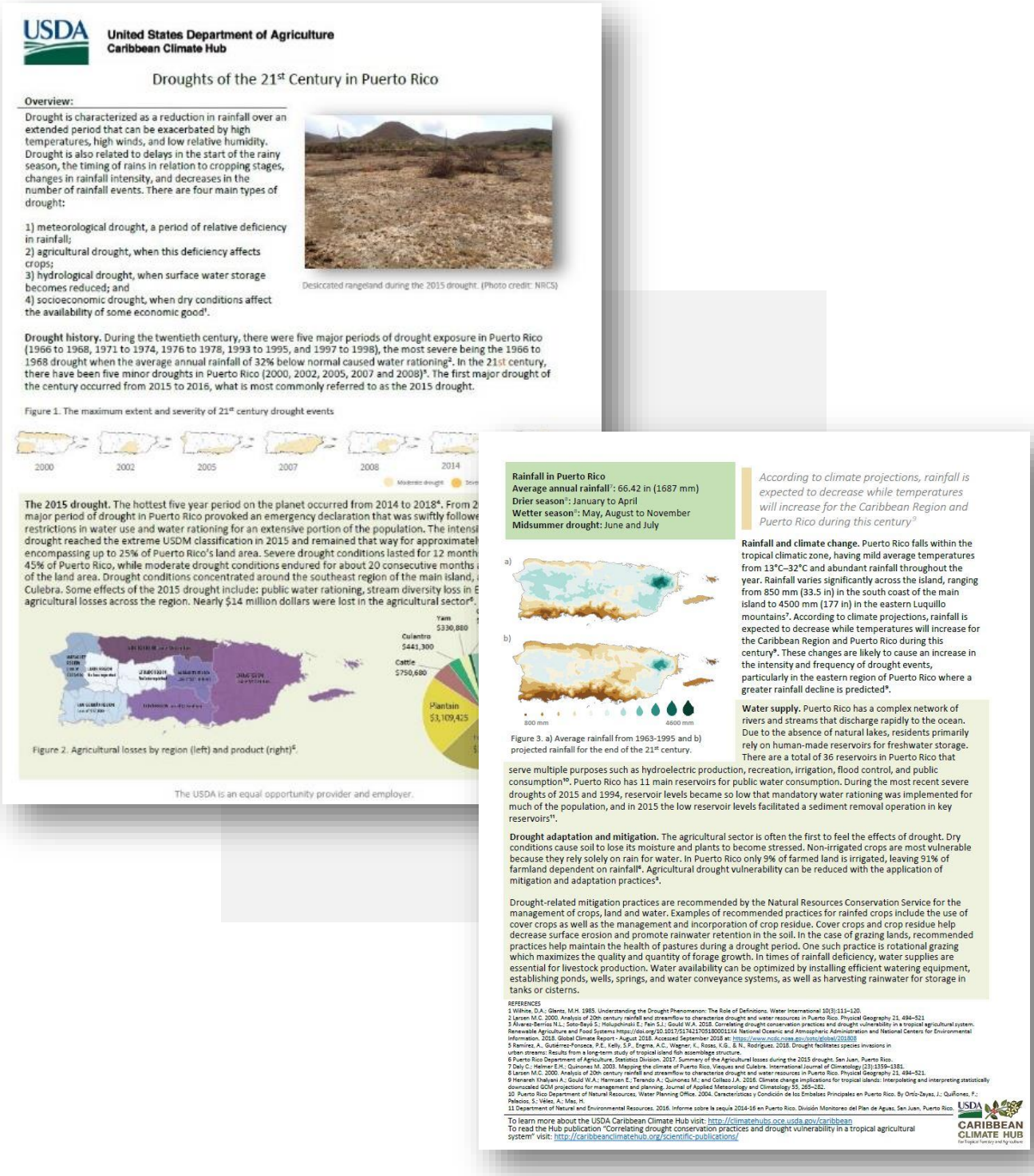
Current initiatives and how to collaborate:

Information about state and local programs:
Information is available at: https://caribbeanclimatehub.org/impacto-agricola-huracanes/
or at our office at the International Institute of Tropical Forestry (IITF), Jardín Botánico Sur, Río Piedras, Puerto Rico. Please contact us if you would like to distribute paper copies.

Agencies and organizations evaluating damages related to forestry and agriculture:
Please contact us if you or your organization is involved with evaluations of the effects of the hurricane. Primary contact: Nora Álvarez-Berríos – Fellow, nalvarezberrios@fs.fed.us (787) 360-9480

Collection of visual material to document and better understand the effects of the hurricanes:
We are compiling photos, videos and information about hurricane effects on agriculture, livestock, and plantations in Puerto Rico and the U.S. Virgin Islands to create an inventory of damages and identify ways to help the recovery of the agricultural sector. To find out how to participate in this initiative, see the other side of this page.

Appendix 6: Factsheet on droughts of the 21st century in Puerto Rico



USDA
United States Department of Agriculture
Caribbean Climate Hub

Droughts of the 21st Century in Puerto Rico

Overview:

Drought is characterized as a reduction in rainfall over an extended period that can be exacerbated by high temperatures, high winds, and low relative humidity. Drought is also related to delays in the start of the rainy season, the timing of rains in relation to cropping stages, changes in rainfall intensity, and decreases in the number of rainfall events. There are four main types of drought:

1) meteorological drought, a period of relative deficiency in rainfall;
2) agricultural drought, when this deficiency affects crops;
3) hydrological drought, when surface water storage becomes reduced; and
4) socioeconomic drought, when dry conditions affect the availability of some economic good[1].

Desiccated rangeland during the 2015 drought. (Photo credit: NRCS)

Drought history. During the twentieth century, there were five major periods of drought exposure in Puerto Rico (1966 to 1968, 1971 to 1974, 1976 to 1978, 1993 to 1995, and 1997 to 1998), the most severe being the 1966 to 1968 drought when the average annual rainfall of 32% below normal caused water rationing[2]. In the 21st century, there have been five minor droughts in Puerto Rico (2000, 2002, 2005, 2007 and 2008)[3]. The first major drought of the century occurred from 2015 to 2016, what is most commonly referred to as the 2015 drought.

Figure 1. The maximum extent and severity of 21st century drought events

2000 2002 2005 2007 2008 2014

The 2015 drought. The hottest five year period on the planet occurred from 2014 to 2018[4]. From 2
major period of drought in Puerto Rico provoked an emergency declaration that was swiftly followe
restrictions in water use and water rationing for an extensive portion of the population. The intensi
drought reached the extreme USDM classification in 2015 and remained that way for approximatel
encompassing up to 25% of Puerto Rico's land area. Severe drought conditions lasted for 12 month
45% of Puerto Rico, while moderate drought conditions endured for about 20 consecutive months
of the land area. Drought conditions concentrated around the southeast region of the main island,
Culebra. Some effects of the 2015 drought include: public water rationing, stream diversity loss in E
agricultural losses across the region. Nearly $14 million dollars were lost in the agricultural sector[6].

Yam $330,880
Culantro $441,300
Cattle $750,680
Plantain $3,109,425

Figure 2. Agricultural losses by region (left) and product (right)[6].

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Rainfall in Puerto Rico
Average annual rainfall[7]: 66.42 in (1687 mm)
Drier season[8]: January to April
Wetter season[8]: May, August to November
Midsummer drought: June and July

According to climate projections, rainfall is expected to decrease while temperatures will increase for the Caribbean Region and Puerto Rico during this century[9]

a)
b)
800 mm
4600 mm

Figure 3. a) Average rainfall from 1963-1995 and b) projected rainfall for the end of the 21st century.

Rainfall and climate change. Puerto Rico falls within the tropical climatic zone, having mild average temperatures from 13°C–32°C and abundant rainfall throughout the year. Rainfall varies significantly across the island, ranging from 850 mm (33.5 in) in the south coast of the main island to 4500 mm (177 in) in the eastern Luquillo mountains[7]. According to climate projections, rainfall is expected to decrease while temperatures will increase for the Caribbean Region and Puerto Rico during this century[9]. These changes are likely to cause an increase in the intensity and frequency of drought events, particularly in the eastern region of Puerto Rico where a greater rainfall decline is predicted[9].

Water supply. Puerto Rico has a complex network of rivers and streams that discharge rapidly to the ocean. Due to the absence of natural lakes, residents primarily rely on human-made reservoirs for freshwater storage. There are a total of 36 reservoirs in Puerto Rico that serve multiple purposes such as hydroelectric production, recreation, irrigation, flood control, and public consumption[10]. Puerto Rico has 11 main reservoirs for public water consumption. During the most recent severe droughts of 2015 and 1994, reservoir levels became so low that mandatory water rationing was implemented for much of the population, and in 2015 the low reservoir levels facilitated a sediment removal operation in key reservoirs[11].

Drought adaptation and mitigation. The agricultural sector is often the first to feel the effects of drought. Dry conditions cause soil to lose its moisture and plants to become stressed. Non-irrigated crops are most vulnerable because they rely solely on rain for water. In Puerto Rico only 9% of farmed land is irrigated, leaving 91% of farmland dependent on rainfall[6]. Agricultural drought vulnerability can be reduced with the application of mitigation and adaptation practices[3].

Drought-related mitigation practices are recommended by the Natural Resources Conservation Service for the management of crops, land and water. Examples of recommended practices for rainfed crops include the use of cover crops as well as the management and incorporation of crop residue. Cover crops and crop residue help decrease surface erosion and promote rainwater retention in the soil. In the case of grazing lands, recommended practices help maintain the health of pastures during a drought period. One such practice is rotational grazing which maximizes the quality and quantity of forage growth. In times of rainfall deficiency, water supplies are essential for livestock production. Water availability can be optimized by installing efficient watering equipment, establishing ponds, wells, springs, and water conveyance systems, as well as harvesting rainwater for storage in tanks or cisterns.

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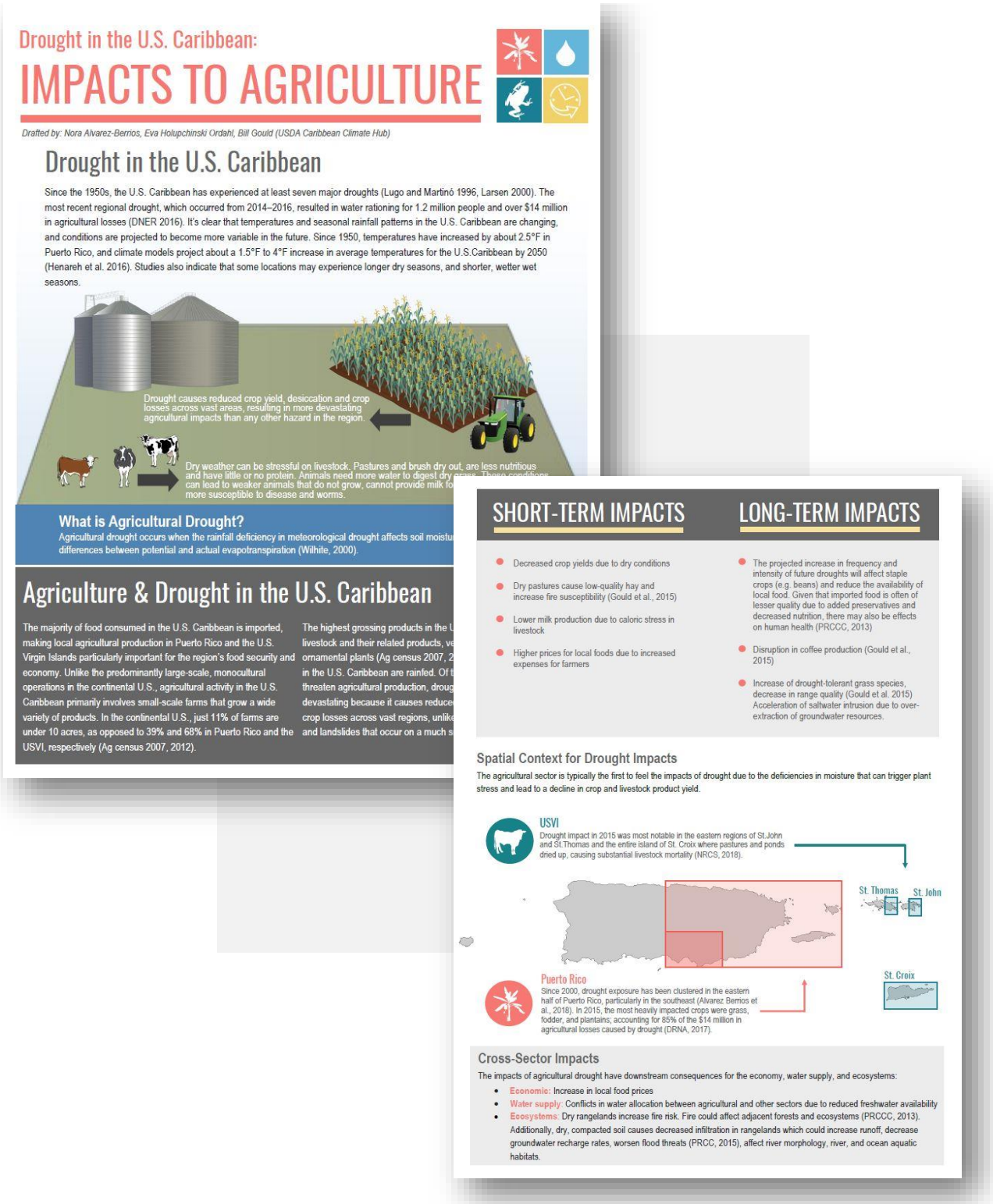
To learn more about the USDA Caribbean Climate Hub visit: http://climatehubs.oce.usda.gov/caribbean
To read the Hub publication "Correlating drought conservation practices and drought vulnerability in a tropical agricultural system" visit: http://caribbeanclimatehub.org/scientific-publications/

USDA CARIBBEAN CLIMATE HUB

Appendix 7: Factsheet on drought impacts to agriculture prepared by the USDA Caribbean Climate Hub as a product of the US Caribbean Drought Workshop, made possible thanks to the NRCS agreement.



Drought in the U.S. Caribbean:

IMPACTS TO AGRICULTURE

Drafted by: Nora Alvarez-Berrios, Eva Holupchinski Ordahl, Bill Gould (USDA Caribbean Climate Hub)

Drought in the U.S. Caribbean

Since the 1950s, the U.S. Caribbean has experienced at least seven major droughts (Lugo and Martinó 1996, Larsen 2000). The most recent regional drought, which occurred from 2014–2016, resulted in water rationing for 1.2 million people and over $14 million in agricultural losses (DNER 2016). It's clear that temperatures and seasonal rainfall patterns in the U.S. Caribbean are changing, and conditions are projected to become more variable in the future. Since 1950, temperatures have increased by about 2.5°F in Puerto Rico, and climate models project about a 1.5°F to 4°F increase in average temperatures for the U.S.Caribbean by 2050 (Henareh et al. 2016). Studies also indicate that some locations may experience longer dry seasons, and shorter, wetter wet seasons.

Drought causes reduced crop yield, desiccation and crop losses across vast areas, resulting in more devastating agricultural impacts than any other hazard in the region.

Dry weather can be stressful on livestock. Pastures and brush dry out, are less nutritious and have little or no protein. Animals need more water to digest dry

What is Agricultural Drought?

Agricultural drought occurs when the rainfall deficiency in meteorological drought affects soil moistu
differences between potential and actual evapotranspiration (Wilhite, 2000).

Agriculture & Drought in the U.S. Caribbean

The majority of food consumed in the U.S. Caribbean is imported, making local agricultural production in Puerto Rico and the U.S. Virgin Islands particularly important for the region's food security and economy. Unlike the predominantly large-scale, monocultural operations in the continental U.S., agricultural activity in the U.S. Caribbean primarily involves small-scale farms that grow a wide variety of products. In the continental U.S., just 11% of farms are under 10 acres, as opposed to 39% and 68% in Puerto Rico and the USVI, respectively (Ag census 2007, 2012).

The highest grossing products in the U
livestock and their related products, ve
ornamental plants (Ag census 2007, 2
in the U.S. Caribbean are rainfed. Of t
threaten agricultural production, droug
devastating because it causes reduce
crop losses across vast regions, unlike
and landslides that occur on a much s

SHORT-TERM IMPACTS

- Decreased crop yields due to dry conditions
- Dry pastures cause low-quality hay and increase fire susceptibility (Gould et al., 2015)
- Lower milk production due to caloric stress in livestock
- Higher prices for local foods due to increased expenses for farmers

LONG-TERM IMPACTS

- The projected increase in frequency and intensity of future droughts will affect staple crops (e.g. beans) and reduce the availability of local food. Given that imported food is often of lesser quality due to added preservatives and decreased nutrition, there may also be effects on human health (PRCCC, 2013)
- Disruption in coffee production (Gould et al., 2015)
- Increase of drought-tolerant grass species, decrease in range quality (Gould et al. 2015) Acceleration of saltwater intrusion due to over-extraction of groundwater resources.

Spatial Context for Drought Impacts

The agricultural sector is typically the first to feel the impacts of drought due to the deficiencies in moisture that can trigger plant stress and lead to a decline in crop and livestock product yield.

USVI

Drought impact in 2015 was most notable in the eastern regions of St.John and St.Thomas and the entire island of St. Croix where pastures and ponds dried up, causing substantial livestock mortality (NRCS, 2018).

St. Thomas
St. John
St. Croix

Puerto Rico

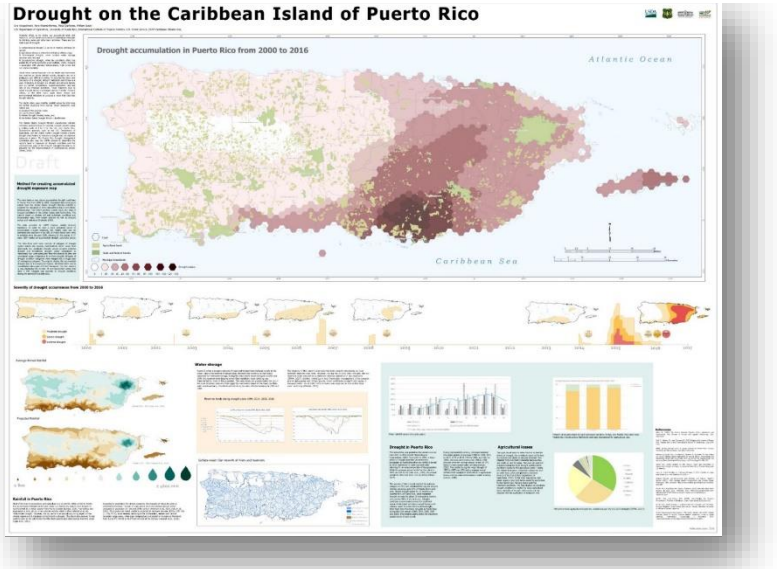
Since 2000, drought exposure has been clustered in the eastern half of Puerto Rico, particularly in the southeast (Alvarez Berrios et al., 2018). In 2015, the most heavily impacted crops were grass, fodder, and plantains; accounting for 85% of the $14 million in agricultural losses caused by drought (DRNA, 2017).

Cross-Sector Impacts

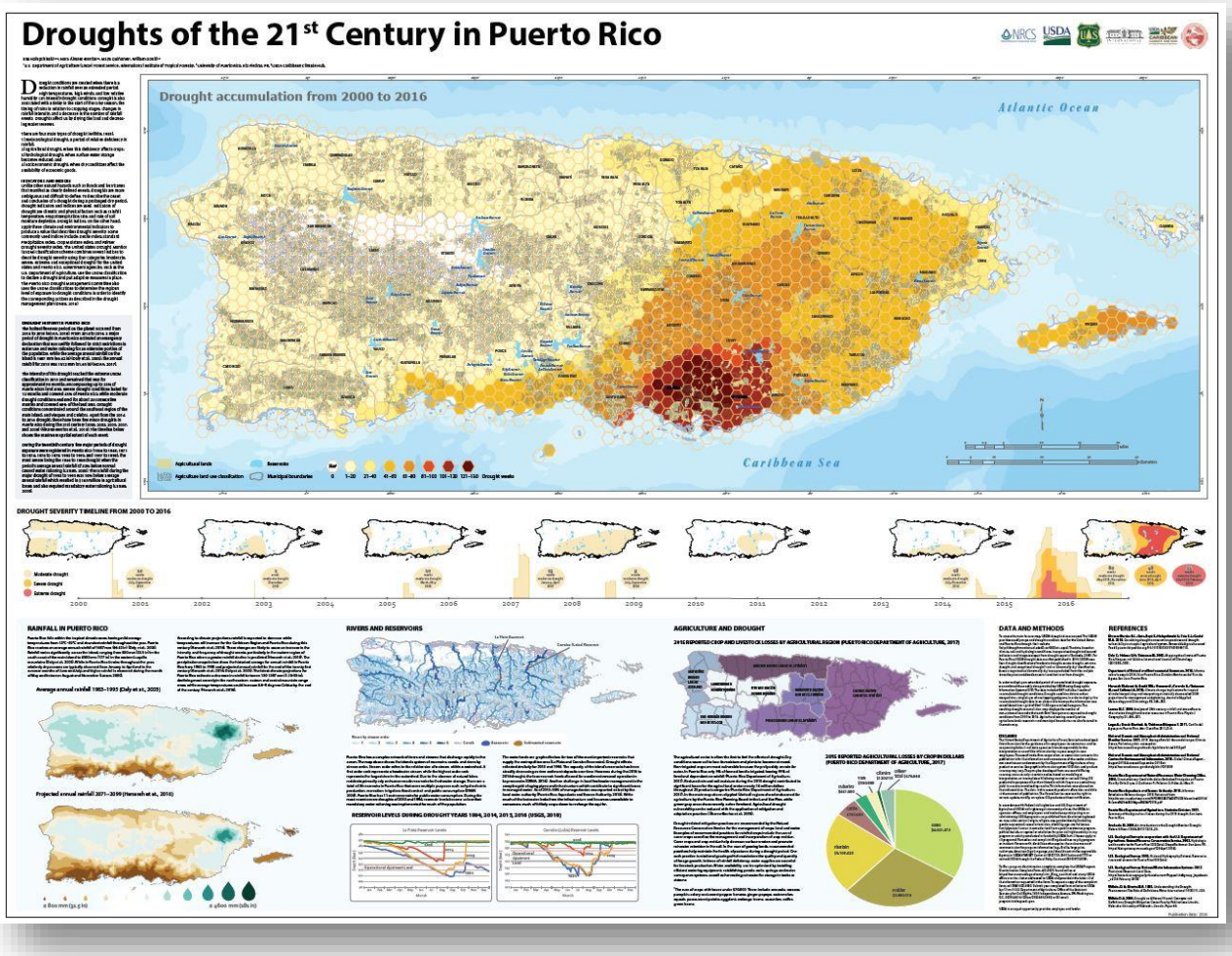
The impacts of agricultural drought have downstream consequences for the economy, water supply, and ecosystems:

- **Economic:** Increase in local food prices
- **Water supply:** Conflicts in water allocation between agricultural and other sectors due to reduced freshwater availability
- **Ecosystems:** Dry rangelands increase fire risk. Fire could affect adjacent forests and ecosystems (PRCCC, 2013). Additionally, dry, compacted soil causes decreased infiltration in rangelands which could increase runoff, decrease groundwater recharge rates, worsen flood threats (PRCC, 2015), affect river morphology, river, and ocean aquatic habitats.

Appendix 8: Scientific poster on the 2014 – 2016 drought in Puerto Rico, present at the 2018 Annual Long Term Ecological Research meeting.



Appendix 9: Research map on an overview of drought history in Puerto Rico, currently under review for publication.



Appendix 10: The US Caribbean Drought Workshop Report, produced with the support of the NRCS agreement.