Drought in the U.S. Affiliated Pacific Islands:

Impacts to Agriculture

By: John Borja (Guam Department of Agriculture), Jonathan Deenik (UH Manoa), Abby Frazier (East-West Center), and Christian Giardina (USDA IPIF)

Drought has variable impacts on the agricultural sector in each of the 6 jurisdictions of the United States Affiliated Pacific Islands (USAPI). Traditional crops vary by island but some of the main commercial and cultural crops include taro, breadfruit, coconut, banana, sweet potato, yam, and citrus fruit (Polhemus, 2017). Drought impacts high elevation islands and low elevation atolls differently with certain crops more vulnerable to the impacts of drought (e.g., coconut production declined by 20% from 1998-1999 and did not fully recover for over 4 years in the Federated States of Micronesia during the 1997-1998 El Niño Drought) (Polhemus, 2017). Crops respond to drought through reduced growth, increased mortality, and reduction in overall production with rain-fed crops having higher vulnerabilities to drought compared to irrigated crops. In addition to affecting food production and availability, crop changes can have impacts downstream from agricultural systems. For example, drought effects on agriculture can increase the rate of erosion, forest cover loss, nutrient runoff into water bodies, and other aquatic and marine impacts. However, mitigation efforts and improving existing infrastructure can help increase agricultural systems' resilience and resistance to drought in the USAPI.

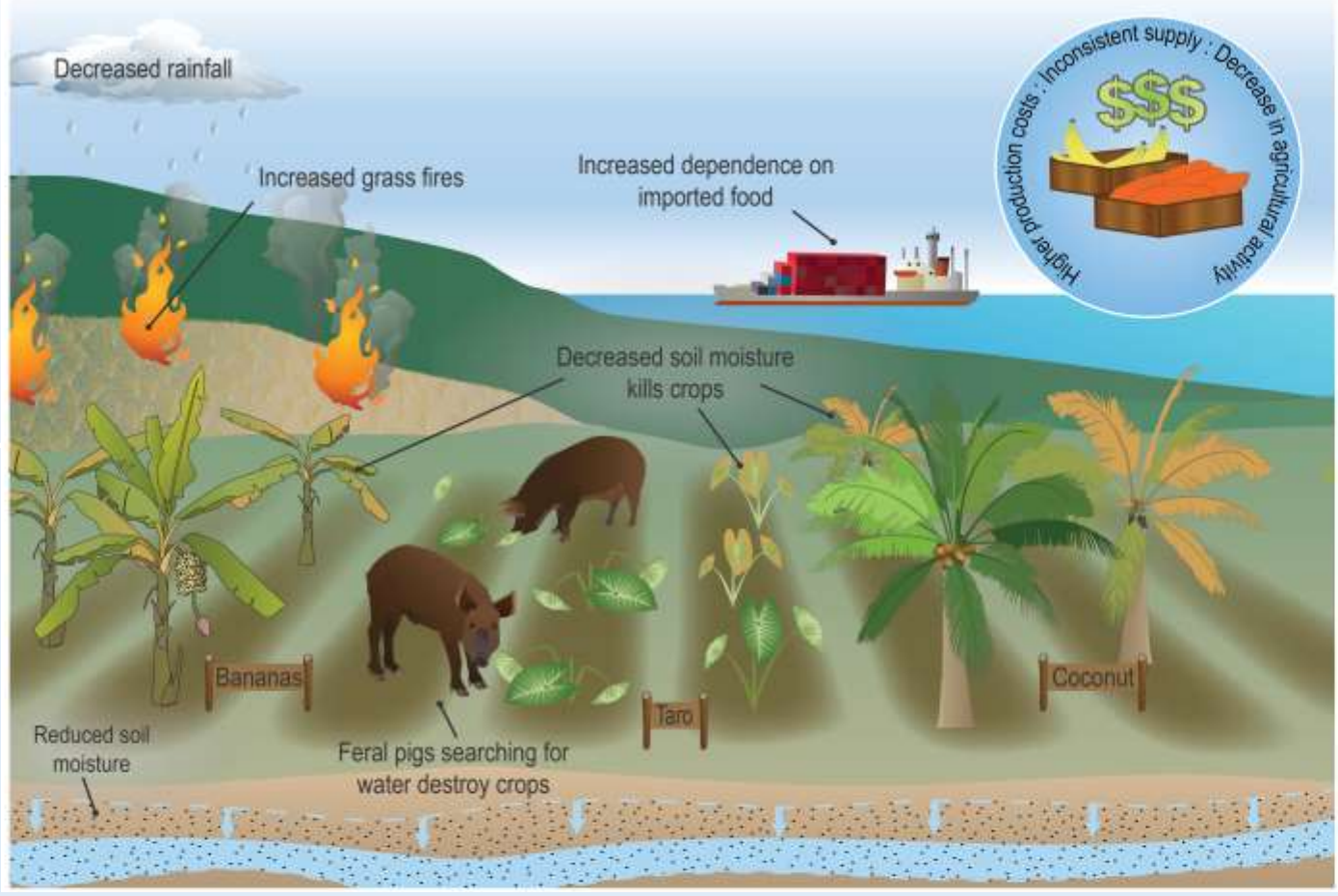

Diagram produced by the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu).

Closer Look: 2016 Drought Impacts in Guam

Guam is divided into the Northern, Central, and Southern farming areas. Most of the Northern farms (58%), where Guam supports the largest number of farmers, sit on the Island's most important aquifers, which are a primary source of fresh water to the Island's civilian and military residents. Northern commercial farms vary in size from 5 to 50 acres and are located closer to road and water infrastructure and markets, making this area the most suitable for crop production. The Southern farms (32%) make up Guam's second largest agricultural sector, and farmers in this area are highly dependent upon surface water from the Fema Dam and the Ugam River. Southern farms range in size from under 3 acres to over 60 acres. The Central farms (10%) are smaller in size and rely primarily on above ground production systems, especially hydroponic production of micro- greens and nursery based production of ornamentals.

Guam's weather differs strongly between its dry season, which runs from December through June, and the wet season, which runs from July to November. Importantly, most farming happens during the dry season. Non-irrigated farming during the dry season is highly sensitive to drought, as loss of access to rainwater poses many challenges to crop production, with 92% of all produce already being imported to Guam during low production periods.

During these periods, there also are compounding factors that affect crop productivity or cause crop loss. Drought imposes a range of constraints on crop production and has serious impacts on the environment. Without irrigation, crops suffer losses in productivity due to water stress and are also vulnerable to destruction by feral pigs in search of water and food. Most impacted are farm operations in the south where irrigation is limited and arson fires are wide spread. An increased incidence of grass fires and wind erosion negatively impact sensitive areas, including the steep sloping lands of southern Guam.

In 2016, Guam experienced a severe drought during the month of April, which received less than half the normal amount of rainfall (Daleno, 2016). This severe drought was linked to El Niño, reduced crop production, and most directly affected growers not connected to the civilian water supply (Daleno, 2016). Many of these farmers are dependent upon a "rain-fed" water supply because utilities and associated infrastructure that support irrigated farming are limited. In these areas, severe drought will impact farmers by reducing crop production, raising demand on imported crops, and so raising commodity prices. Critically, impacted farmers may be set back economically for months to years, while recovery of plant productivity for woody crops like breadfruit that survive drought can be delayed for years after normal rainfall conditions return.

SHORT- AND LONG-TERM IMPACTS

- Crop death from not enough water
- Crop damage from disease and ungulates
- Increased incidence of wild fires
- Increased erosion and impacts to downstream and coastal areas
- Decreased growth and fruit production
- Impacts to seed and soil conditions
- Reduced farm viability
- Inconsistent supply of products
- Reduced food availability
- Increased dependency on imports
- Higher commodity prices
- Degraded agricultural sector

Increasing Agricultural Resilience to Drought:

Opportunities exist to increase resilience in agricultural communities in the USAPI:

- **Agroforestry:** Diverse and traditional agroforesty provides resilience for communities and cultures.
- **Infrastructure:** Agricultural resistance and resilience to drought is highly dependent on existing water storage infrastructure and distribution, as well as access to natural and man-made resources.

References: Daleno, G. Dumat-ol. 2016. Severe drought hits region, El Niño the culprit. Guam Pacific Daily News (2016/04/13); Guam Department of Agriculture Farm Reports; Polhemus, D. A. 2017. Drought in the U.S.- Affiliated Pacific Islands: A Multi-level Assessment. https://doi.org/10.21429/C9ZS74.

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Drought in the U.S. Affiliated Pacific Islands:

Impacts to Ecosystems

By: Susan Cordell (USFS), Abby Frazier (East-West Center), Clay Trauernicht (UH Cooperative Extension), and Yin-Phan Tsang (UH Mānoa)

Drought has variable impacts on ecosystems in each of the 6 jurisdictions of the United States Affiliated Pacific Islands (USAPI). Available information on drought impacts to ecosystems varies by jurisdiction, but in general, few studies have addressed the impacts of drought on ecosystems. The available information highlights that the main impact of drought on ecosystems in the USAPI is the increased intensity of wildfires. Ecosystems in the USAPI are not adapted to wildfires, especially in jurisdictions such as Pohnpei and Kosrae, where, historically, fire has not been a stressor on ecosystems. In particular, increased wildfires from drought are important for high islands in the USAPI, and especially for Guam. The relationship between drought and wildfire is also affected by El Niño-Southern Oscillation (ENSO) cycles. The most devastating combination is when you have a wet year with excessive fuel buildups, followed immediately by a dry El Niño year. The initial ignitions of wildfires are almost always human-induced; however, drought conditions affect the intensity and duration of the wildfire events that impact ecosystems in the USAPI.

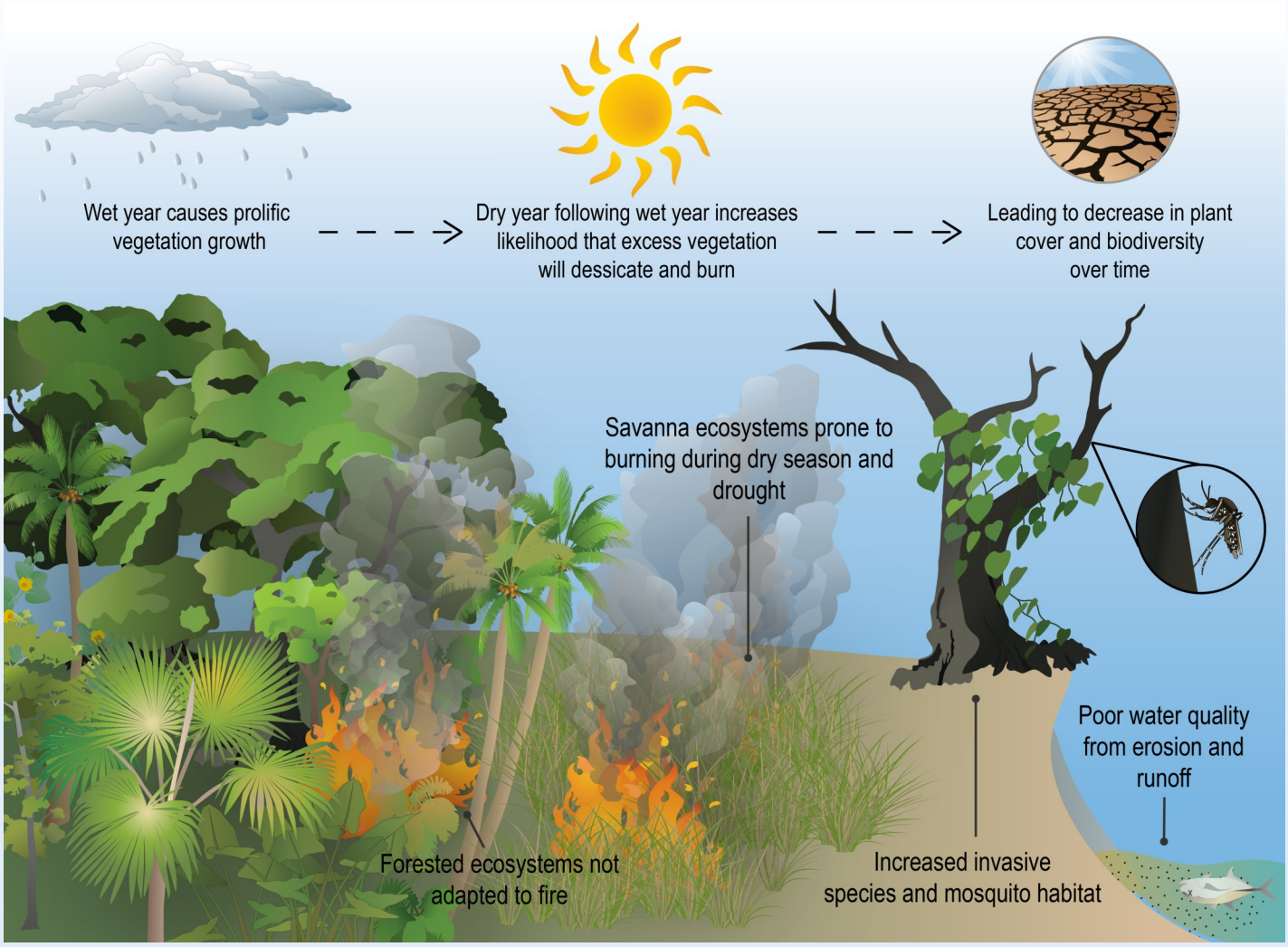

Diagram produced by the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu).

Drought Effects on Ecosystems in the USAPI

Drought has both direct and indirect effects on terrestrial and aquatic ecosystems of the Pacific islands with varying impacts per jurisdiction (Polhemus, 2017). Drought-related stress can directly increase mortality of plants and animals, or make them more vulnerable to predation and disease (Trauernicht et al., 2015). Indirect impacts on native ecosystems have manifested through drought-induced land use change and loss of habitats. For example, Pohnpei saw rapid increases in watershed deforestation following 1997-98 El Niño as lowland crop losses led farmers to shift in sakau (kava) cultivation to upland areas (Merlin and Raynor, 2005). The prolonged drought decreased the availability of habitats for freshwater species and the connectivity between streams and estuaries for migratory species. However, our understanding of the impact on the species of these ecosystems due to the loss of habitats is limited due to the lack of studies.

Wildfires in the Pacific region are often devastating. Despite the fact that fires are almost entirely a result of human-caused ignitions, drought has increased fire extent and intensity. The western islands, including Palau, Yap, and the Marianas, where grassland ecosystems can comprise 10-20% of island land cover, often have pronounced annual dry seasons which already create conditions for fire in the absence of ecological drought. However, El Niño events can greatly exacerbate drought and create conditions for large fires even on the wetter islands to the east. For example, an estimated 25% of Pohnpei and 10% of Guam burned during the El Niños of 1982-83 and 1997-98, respectively (van der Brug 1986). Drought and fire are also connected to reef health and game management. Invasive ungulates (e.g., goats) worsen post-fire erosion and transport of sediment down to coastal areas, which damages coral reef ecosystems.

SHORT & LONG-TERM IMPACTS

- Drought-induced wildfires reduce forest area, impacting species inhabiting these areas
- Areas affected by drought-induced wildfire are also susceptible to invasion of non-native animals or plants, which provide more fuel for the spread of wildfires
- Wildfire and non-native ungulates increase erosion, which impacts near-shore ecosystems such as coral reefs
- Reduced carbon cycling resulting from a decrease in forest productivity
- Increased likelihood of forest pests and pathogens
- Longer recovery time of aquifers following marine over-wash events
- Ecosystems in Guam are particularly impacted by the effects of wildfire and drought dynamics

Cross-Sector and other Impacts

The impacts of drought on ecosystems have consequences for water supply and downstream marine habitats:

- **Freshwater Supply and Delivery:** Drought lengthens the recovery from marine over-wash events, which are expected to increase in frequency. This salt water inundation degrades infrastructure, freshwater supplies, agriculture, and habitats for threatened and endangered species. Extended drought often ties in with El Niño events in Pacific region, which lessens the groundwater recharge, lowers the groundwater table, and changes freshwater delivery to many unique ecosystems. One of those is the mangrove estuaries, which provides valuable habitats as rear ground for fishes (Drexler and Ewel, 2001). Another is the nearshore lakes, which support unique jellyfish species (Dawson et al., 2001; Polhemus, 2017)
- **Marine ecosystems:** Rain after extended drought and wildfire increases erosion and sediment delivery to nearshore environments negatively impacting coral reefs.

References: Dawson, Mike N; Martin, Laura E; Lolita K, Lolita K.; Penland. 2001. Jellyfish swarms, tourists, and the Christ-child. Hydrobiologia. Springer Netherlands. 451: 131–144; Drexler, J. Z., & Ewel, K. C. 2001. Effect of the 1997–1998 ENSO-related drought on hydrology and salinity in a Micronesian wetland complex. Estuaries, 24(3): 347-356; Merlin, M. and Raynor, W., 2005. Kava cultivation, native species conservation, and integrated watershed resource management on Pohnpei Island. Pacific Science, 59(2): 241-260; Polhemus, Dan. A. 2017. Drought in the U.S.- Affiliated Pacific Islands: A multi-level assessment. https://doi.org/10.21429/C9ZS74; Trauernicht, C., E. Pickett, C. P. Giardina, C. M. Litton, S. Cordell and A. Beavers. 2015. The contemporary scale and context of wildfire in Hawaii. Pacific Science 69 (4): 427-444; van der Brug. 1986. The 1983 drought in the western Pacific. US Geological Survey Open-File Report 85-418.

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Drought in the U.S. Affiliated Pacific Islands:

Impacts to Water Resources

By: Stephen S. Anthony (USGS Pacific Islands Water Science Center)

Water Resources in the USAPI

The U.S. Affiliated Pacific Islands (USAPI) is comprised of the Territories of American Samoa and Guam, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia (FSM), the Republic of the Marshall Islands (RMI), and the Republic of Palau. These islands, which contain water resources of significant economic and ecological importance, can generally be classified as either high islands (i.e., volcanic or limestone islands with an elevated land mass) or low-lying islands (i.e., islands along the perimeter of a coral atoll). Most of the islands typically receive more than 100 inches of rain annually, but rainfall can vary substantially from year to year and season to season (van der Brug, 1986). Water resources in the USAPI include rainwater, groundwater, and intermittent or perennial streamflow. Maintaining adequate freshwater supplies in the islands is of critical concern as demographic and climatic changes place stresses of uncertain magnitude on already fragile water resources (Keener et al., 2012). Populations on low-lying atoll islands are particularly vulnerable to freshwater-supply shortages and agricultural-crop losses during droughts. Hydrologic drought associated with El Niño events complicates the understanding and management of water resources in the USAPI.

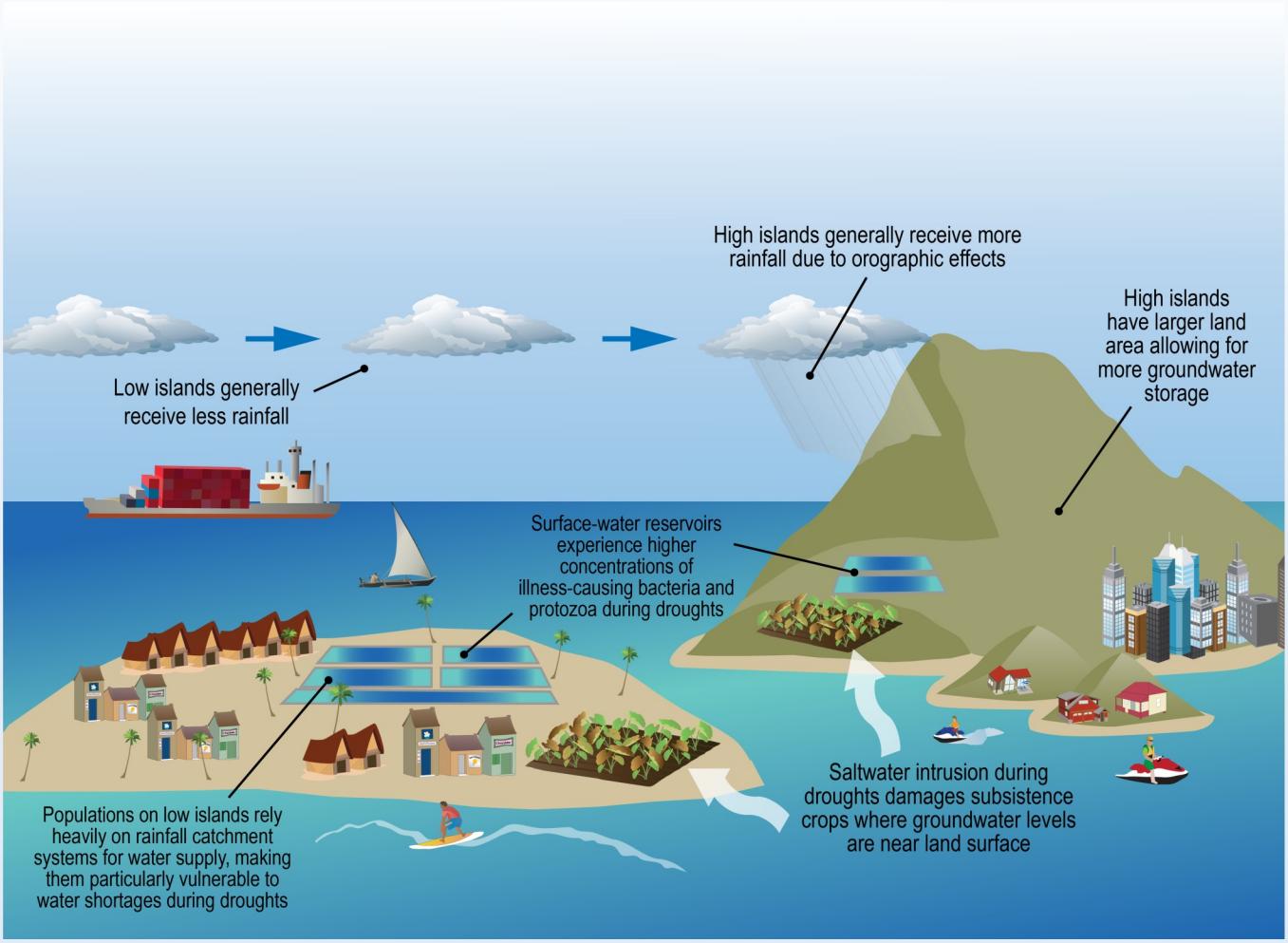

Diagram produced by the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu).

Drought Impacts on Water Resources in the USAPI

Drought impacts tend to be most severe during the winter and spring months following El Niño events. Several of the more populated areas of high islands are served by municipal water-supply systems. In contrast, populations living in rural areas, particularly on low-lying atoll islands in the FSM and RMI, are dependent on groundwater from shallow wells or rain from private catchment systems. Where surface water is used for public supply, drought impacts are more severe than impacts where groundwater is used.

Water resources on most atoll islands are extremely vulnerable to droughts of any severity. Contamination of water resources commonly occurs during drought conditions. Surface-water reservoirs may experience lower levels of oxygen, contributing to higher concentrations of illness-causing bacteria and protozoa. Groundwater contamination from saltwater intrusion during droughts and inundation during periods of high sea level threaten subsistence crops such as taro, breadfruit, and bananas.

Short- and Long-Term Impacts

- Water supplies that rely on rainfall and surface water are the first to be impacted by drought; often after 2-3 months of little to no rain
- Water rationing is common for populations dependent on rainfall- and surface-water-supply systems
- Bacteriological contamination of surface-water supplies is common during extended droughts and can threaten human health
- Multi-year droughts can significantly impact groundwater storage and salinity
- Long-term droughts could cause abandonment of farming activities and emigration
- Intrusion of saltwater into groundwater systems impacts production of subsistence crops

Cross-Sector Impacts

Droughts impact not only water supply but also human health and ecosystems:

- **Human Health:** Droughts lead to human-health challenges caused by water shortages and associated food shortages, and those caused by contaminated water, which people may be forced to drink when water is scarce.
- **Ecosystems:** Nutrient/sediment inputs and reduction of freshwater flows during droughts have the potential to negatively affect the structure and function of mangrove forests (Drexler and Ewel, 2001).

References

Drexler, J.Z. and Ewel, K.C., 2001, Effect of the 1997–1998 ENSO-related drought on hydrology and salinity in a Micronesian wetland complex. Estuaries, 24(3), pp.347-356.

Keener, V.W., Izuka, S.K., and Anthony, S.S., 2012, Freshwater and Drought on Pacific Islands. In V.W. Keener, J.J. Marra, M.L. Finucane, D. Spooner, and M.H. Smith (Eds.), Climate Change and Pacific Islands: Indicators and Impacts. Report for the 2012 Pacific Islands Regional Climate Assessment (PIRCA). Washington, DC: Island Press.

van der Brug, O., 1986, The 1983 drought in the western Pacific. U.S. Geological Survey Open-File Report 85-418, 89 p.

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Drought in the U.S. Affiliated Pacific Islands:

Drought Monitoring

By: Brian Fuchs (National Drought Mitigation Center), Richard Heim (NOAA NCEI) , David Simeral (Desert Research Institute, Western Regional Climate Center)

Drought monitoring in the United States Affiliated Pacific Islands (USAPI) is currently carried out by NOAA National Center's for Environmental Information (NCEI), the National Drought Mitigation Center (NDMC), United States Department of Agriculture (USDA), NOAA Climate Prediction Center (CPC), and the Western Regional Climate Center (WRCC) in collaboration with National Weather Service (NWS) Offices and other USAPI partners, including Pacific ENSO Application Climate Center. As of March 2019, the USAPI is now part of the regular U.S. Drought Monitor production and has 7 rotating lead authors from NOAA, NDMC, USDA who are responsible for the data analysis and creation of the weekly drought map. It was released online with all the regular products April 8, 2019. The maps are now available at droughtmonitor.unl.edu with the suite of products and data.

The primary quantitative data utilized in the USAPI drought monitoring come from a limited number of observational stations across the USAPI. Historical data are based on NOAA Global Historical Climatology Network-Daily data. In addition, some supplementary data are available from other non-NOAA stations (i.e., National Park Service – American Samoa, Saipan) as well as experimental satellite-based precipitation estimates from NASA SPoRT (Short-term Prediction Research and Transition Center) in cooperation with NOAA. In terms of drought indices, Standardized Precipitation Index (SPI) data are available for some USAPI locations where longer station records exist and can be accessed via the NWS Honolulu at www.prh.noaa.gov/hnl/hydro.

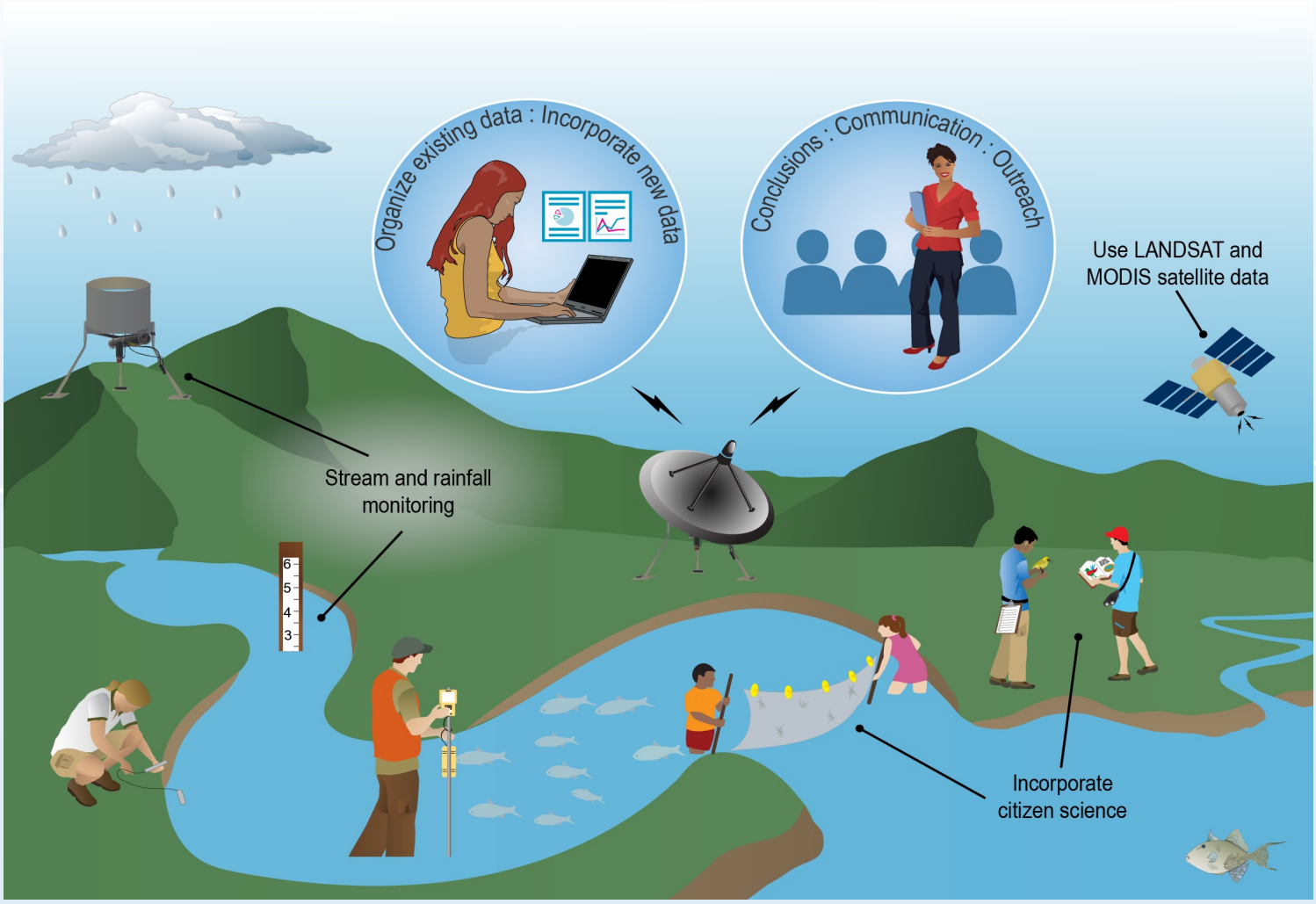

Diagram produced by the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu).

DATA NEEDS

- Inventory of available resources, stations, and impacts by islands
- Need for systematic collection of impacts related to drought in the region
- Additional observing stations with modern real-time data transmission systems
- Explore computing of satellite-based drought indices through NCEI and other partners
- Additional satellite-based products including vegetation health indices from LANDSAT and MODIS
- Explore deploying soil moisture, groundwater, and streamflow sensors
- Improved timeliness of manually reported station data (e.g., daily rainfall data)
- Incorporate longer, more complete historical rainfall records and determine methods to fill in data gaps
- For station rainfall data, compute SPI or precipitation percentiles for monthly totals and for running 30-day totals, compute number of consecutive days with no rain or little rain below certain thresholds, and the historical frequency of occurrence below these thresholds

CHALLENGES

- Capturing spatial variability of precipitation on the larger high islands where orographic effects influence the amount and distribution of rainfall.
- Some observational data utilized are from low-lying coastal plains and may not be representative of the climatological conditions at higher elevations.
- Cloud cover and spatial resolution for smaller islands can be a limitation when using satellite-based products.
- Funding and staffing for operations and maintenance of existing and new observational sites.

Citizen Science and Outreach

The use of citizen science information and increased outreach to users and among partners is needed:

- **Citizen Science:** Develop and incorporate citizen science data to increase available information.
- **Outreach Efforts for Data Use:** Improve on-the-ground efforts for local outreach and communication, and improve the transitioning of data and information. Use citizen science to engage the public and increase observations and reporting of drought impacts.

References: National Drought Mitigation Center. United States Drought Monitor. Access at https://droughtmonitor.unl.edu/; National Weather Service Honolulu, Hawaii Weather Forecast Office. Standardized Precipitation Index (SPI) Data. Access at www.prh.noaa.gov/hnl/hydro.

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