Improving Access and Use of Products and Tools for Drought

Trinational Drought Summit Report

v. 3.0

Commission for Environmental Cooperation

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List of Abbreviations and Acronyms

AAFC	Agriculture and Agri-Food Canada
CDM	Canadian Drought Monitor
CEC	Commission for Environmental Cooperation
CHIRPS	Climate Hazards Group InfraRed Precipitation with Stations
CIMA	*Centro de Información de Mercados Agroalimentarios* (Center for Information on Agrifood Markets)
CoCoRaHS	Community Collaborative Rain, Hail and Snow Network
Conagua	*Comisión Nacional del Agua* (National Water Commission of Mexico)
ESI	Evaporative Stress Index
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization of the United Nations
FAQ	Frequently Asked Questions
FTP	File Transfer Protocol
GIS	Geographic Information System
IMTA	*Instituto Mexicano de Tecnología del Agua* (Mexican Institute of Water Technology)
MSM	*Monitor de Sequía en México* (Mexican Drought Monitor)
NADM	North American Drought Monitor
NCEI	National Centers for Environmental Information [United States]
NDMC	National Drought Mitigation Center (United States)
NIDIS	National Integrated Drought Information System [United States]
NOAA	National Oceanic and Atmospheric Administration [United States]
NWS	National Weather Service [United States]
US	United States
SADER	*Secretaría de Agricultura y Desarrollo Rural* [Secretariat of Agriculture and Rural Development (formerly Sagarpa)]
SPI	Standardized Precipitation Index
SMN	*Servicio Meteorológico Nacional* (National Meteorological Service, Mexico)
USDA	United States Department of Agriculture
USDM	United States Drought Monitor

Abstract

Canada, Mexico, and the United States have each developed national drought monitors and collaborate on the North American Drought Monitor. These monitors allow for depictions of current drought conditions as well as providing a starting point for preparing for and responding to droughts in the near term. Efforts to monitor drought across the continent has led to a network of professionals developing monthly monitors of drought conditions, as well as other tools and products that serve regions, states, provinces, and local communities. While drought to date has been understood in agricultural, meteorological, hydrological and socioeconomic, terms, it is now understood that drought's footprint and impacts are broad and interact with many sectors and systems, including ecosystems, urban development and infrastructure. As the severity and range of droughts change and remote sensing improves, so must effective and accurate early warning systems, which help local and regional practitioners manage the risks and disasters that drought brings. To better prepare for and respond to episodes of drought, the Commission for Environmental Cooperation (CEC) has gathered perspectives from meteorological and drought professionals across the continent to better understand current hydro-climatological realities, available data products, tools, and the needs of drought professionals to improve drought-related products and tools. Drawing from online surveys, stories from local experts and witnesses, and in-depth consultations during an annual workshop, the 2020 Drought Summit sought to gain core insights for improving the access to and use of the products and tools that may be used to understand vulnerability to drought and build resilience and respond effectively to it.

Note:
The term "practitioners", as used through this document, refers to individuals who may have any of a vast array of responsibilities (planning, preparing and managing a response) in relation to drought.

Executive Summary

This is one of a set of documents prepared by the Commission for Environmental Cooperation (CEC) to aid in the improvement of drought monitoring tools and products vital to early warning systems across the North American continent. These documents have been produced under the guidance of the CEC Steering Committee of meteorological and drought monitoring professionals from Canada, Mexico and the United States.

This report summarizes the results of the online Drought Summit hosted by the CEC from 29 September to 1 October 2020. More than eighty professionals from across sectors in Canada, Mexico and the United States attended the summit. Participants shared information via practitioner case studies that highlighted their work and innovation across various drought-impacted regions of the continent. Five interactive consultation sessions provided a deeper look at the results of two online surveys conducted by the CEC in 2020: *Assessment of North American Drought Information Products and Tools* and *North American Drought Monitor Use Assessment*.

Today, the type of drought most frequently encountered is of short duration and practitioners must draw upon early warning resources frequently for a variety of uses—from assessment to decision support. Insights from surveys and consultations show opportunities for improving national and continental-wide early warning drought products and tools, namely in the areas of access, speed and accuracy, organization, and training for application. Gaps and lags in data remain. Drought monitoring can be improved, especially in rural regions, through the reciprocal partnerships with Indigenous and local drought knowledge holders and observers. Further, there is a need for greater cooperation across jurisdictions, and between sovereign nations, firstly to build stronger drought early warning resources, and then to integrate and apply them effectively to match the large footprint and transboundary nature of drought.

Insights, observations and input garnered through engagement at the summit has informed eight high-level recommendations and a suite of actions that emerged from engagement with North American drought professionals. Central to the recommendations is the need to elevate the visibility and usability of early warning systems, and to improve the cooperation of stakeholders facing more frequent drought events.

Recommended Actions

- Improve awareness of North American online resources related to drought.
- Improve online resources and data availability related to drought.
- Improve the efficacy of drought reporting and forecasting.
- Create multipurpose drought resilience tools.
- Address gaps in data and delays in reporting.
- Create tools and resources that support multi-sectoral drought coordination.
- Develop training and support peer-to-peer networks.
- Create enabling policy and resources for collaboration in early warning systems.

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Summit Themes and Objectives

In 2019, the Commission for Environmental Cooperation (CEC) initiated the project Improving the Effectiveness of Early Warning Systems for Drought, with the following three objectives:

1. Understanding which World Meteorological Organization indicators and indices perform best for monitoring drought in North America, in order to improve the ability of regional and local decision-makers and communities to monitor and prepare for drought conditions.
2. Increasing local capacity to use best practices for preparedness, planning, and risk management by identifying and comparing available drought information and best practices in Canada, Mexico, and the United States, and providing recommendations for local communities on how to access and use these drought products and tools, and how to incorporate drought into multi-hazard risk management.
3. Assessing the use of the North American Drought Monitor (NADM), as well as user needs, to inform improvements to the program, including user access and the development of new user-oriented tools, with an emphasis on transboundary regions across North America.

A three-day virtual Drought Summit was organized as a key activity for completing Objectives 2 and 3. The goals of the Drought Summit were as follows:

- Convene and connect drought practitioners from Canada, Mexico, and the United States who are tasked with planning, preparing, and managing the resources to deal with drought.
- Share experiences, challenges, and innovations in drought monitoring across North America.
- Build on information obtained through two online surveys commissioned by the CEC designed to (a) identify and compare available drought information, products and tools in North America and (b) evaluate the use of the NADM.
- Formulate recommendations to improve access and use of products and tools for drought and multi-hazard planning, including areas for improving information and user access of the NADM.

The summit was held over three days, from 29 September to 1 October 2020. Each day was divided into sessions consisting of presentations and discussion, spread-out over six hours. These sessions included the following topics:

- Trinational Panel: Perspectives from Canada, Mexico, and the United States.
- Current realities and practices.
- Innovation using drought planning resources.
- Drought tool bootcamp.
- Leading practices and the future of drought monitoring, planning, and response.

In addition, participant consultation sessions were held to present and discuss results from the online surveys to gather additional information on North American drought information products and tools and use of the NADM.

Improving Resilience to Extreme Events and Climate Impacts: Drought, Wildfires, Floods

Orlando Cabrera-Rivera, Commission for Environmental Cooperation

Key Insights

This project, led by the CEC, works to create institutional partnerships to advance response capacities to extreme events that affect health, safety, and socio-economic and environmental wellbeing. This is done principally through improving early warning, adaptation planning, emergency management systems and networks, and recovery.

Summary

This CEC project features four activity areas:

1. Using volunteer networks to monitor precipitation and wildfires. This allows for improved assessment of information needs and gaps and explores the feasibility of using citizen science and volunteer observation networks like the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS), which may be expanded upon. [1]
2. Costing floods and other extreme events. The aim is to develop a standardized methodology for assessing the economic impact of flood damage and thinking on multi-hazard assessments while incorporating Indigenous perspectives, local case studies and government perspectives. This project also identified opportunities for uptake of methods into policies at federal, state/provincial and municipal scales and applications.
3. Using remote sensing to prepare for and respond to extreme events. This project identifies the best available option for early warning systems that would benefit from satellite imaging and conducts workshops to better understand how to transmit and use technology correctly in the context of extreme weather events.
4. Improving the effectiveness of early warning systems from drought. The purpose of this area is to identify a set of guidelines for indicators for use in North America across different climate regions. This project also identifies currently available drought information through North American and national drought monitors, as well as best practices, and provides recommendations for improving the access and use of drought early warning systems by users across the continent.

Trinational Panel: Perspectives from Canada, Mexico and the United States

Trevor Hadwen, Agriculture and Agri-Food Canada (AAFC)

Overview

Through recent innovation and developments, including larger data sets, blended indices, Environmental Systems Research Institute (ESRI) story maps, assessment and review tools, improved accuracy and web presence, the Canadian Drought Monitor (CDM) has greatly expanded its exposure and use by local and agricultural communities.

[1] CoCoRaHS is a volunteer network of amateur weather observers who measure and map precipitation in their communities.

Key Points

- AAFC has been responsible for the CDM since 2003 and creates monthly maps covering all of Canada except Nunavut. Agriculture takes up a very small portion of Canada's land mass and AAFC relies on other experts to create such a large assessment.
- The CDM shares much of the methodology for monitoring and reporting with the NADM.
- Canada faces monitoring challenges given diverse geography and a variable climate with much of the population living within 100 km of the US border. This makes large-scale monitoring, instrumentation and observation from sparsely populated areas challenging. Drought in winter is difficult to monitor and is not well understood in arctic regions. Currently there are a limited number of people participating in drought monitoring.
- Canada's drought monitor has developed blended indices including depictions of drought stress utilizing the Vegetation Drought Response Index and Evaporative Stress Index (ESI).
- To improve engagement with end users, AAFC has created a volunteer monthly Agroclimate impact reporter, and an ESRI product called ArcGIS Story Map, a product of ESRI, to improve observation and better comprehension of drought monitoring at the local level.
- The CDM editor and reviewer application allows for peer review and local perspectives on the efficacy of drought assessments and indicators, as well as making recommendations on Canada's digital drought report maps.

Mexico

Reynaldo Pascual, *Comisión Nacional del Agua, Servicio Meteorológico Nacional*

Overview

Mexico is geographically complex, has many climate zones and few land and water data remote sensing stations. This makes monitoring and early warning systems difficult to develop. The Mexican Drought Monitor (*Monitor de Sequía en México*—MSM) team, while small and limited in resources, continues to innovate. This has included meshing data sources and indices, assembling data sets and engaging open data and continental remote sensing to create the best reports possible.

Key Points

- The national drought monitor began in 2002 with the creation of a simple monitoring system. In 2014, it expanded to drought map and online interface.
- Often drought is characterized as meteorological, but it has cascading effects, beginning as agricultural drought. Rainfall deficits eventually cause a hydrological trend, while socio-economic drought emerges in parallel. Mexico is working to classify drought impacts according to type and sector.
- On the basis of current limited capacities, a bi-monthly report is carried out formulated on rain anomaly, which in turn is based on percentage of normal and has been issued since 2014.
- Due to limited remote sensing and stations across the landscape, an interpolated mesh methodology and Standardized Precipitation Index (SPI) is used. This uses the water availability index in dams, streamflow drought, vegetation indices including the

Vegetation Health Index, Normalized Difference Vegetation Index and soil moisture index (based on the leaky bucket model).

- Mexico's drought maps are available on the National Meteorological Service (*Servicio Meteorológico Nacional*—SMN) web page. Mexico is using Climate Hazards Group InfraRed Precipitation with Stations data (CHIRPS) map approach to include more information to the Mexican Drought Monitor—even though this technique must account for a delay of up to 20 days in data availability. To strengthen the accuracy of the national monitor, percentile precipitation anomalies are used alongside monthly precipitation anomalies.

United States

Richard Heim, National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI)

Overview

- The United States Drought Monitor (USDM) was the first drought monitoring tool to employ the convergence of evidence methodology that integrates the numerous indices and indicators used for drought monitoring over multiple time scales, sectors, and geographical areas. This methodology provides the backbone for drought monitoring across the continent and spurs opportunities for innovation and strengthening of existing and new drought monitoring tools. The NADM data and products are available across a spectrum of three existing websites.
- It is important to consider which drought indices are most appropriate across climate types of North America. Key factors such as hydrology, soil types and soil moisture, evapotranspiration and precipitation regimes vary amongst climate types.

Key Points

- The USDM comprises two pages. The first provides a map of the Continental United States, Alaska, Hawaii, and Puerto Rico with drought conditions, extent and severity of drought represented as polygons. The second page provides a map of the US-Affiliated Pacific Islands and US Virgin Islands with drought conditions represented as points.
- The USDM uses a convergence of evidence approach, which integrates multiple objective drought indices, to determine the drought (Dx) status. The drought status is depicted as drought lines or dots drawn onto the landscape.
- Modern coordinated drought monitoring in the United States began in 1965 with the Palmer Severity Drought Index (PDSI) that blends water supply (precipitation), water demand (evapotranspiration), and soil moisture in a water budget accounting methodology. In ensuing decades additional tools were developed such as the SPI, remote sensing indicators, and indices such as the Surface Water Supply Index (SWSI) which integrated snowpack, streamflow, and reservoir levels as well as precipitation. The PDSI remained the de facto official drought monitoring tool until 2000 when the USDM was introduced. The modern USDM integrates these perspectives and others and now maintains a period of record that is approximately 20 years old.
- The NADM extends the USDM convergence of evidence concept and methodology continent-wide. The NADM is available online in Geographic Information System (GIS) format and is produced by NOAA, AAFC (Canada) and SMN (Mexico) and features a narrative, data tables, graphs, and maps.

- Starting in 2000, some US regions, notably the Southwest, entered prolonged and extensive droughts, or "mega droughts."

Panel Discussion

On improving public and user engagement:

- Trevor Hadwen noted that improving engagement, especially with new users and provincial agencies in Canada, has been an objective for AAFC. This includes presentations at conferences, agricultural and farm events and affording new opportunities for integrating local observation and improving drought tools. Enhanced engagement, partnerships and new perspectives have proven as important as drought indicators themselves. To support new users, the AAFC Drought Watch website also provides a primary source for training and additional user engagement.

On centralizing efforts and access to drought monitoring resources:

- Richard Hiem commented that when considering a single consolidated web resource for all drought monitoring resources for North America, one needs to keep in mind the three NADM websites—at NCEI, National Integrated Drought Information System (NIDIS) Drought Portal/drought.gov, and National Drought Mitigation Center (NDMC)—were developed and are funded independently by different agencies. The original NADM is housed at NCEI. The second is housed in the NIDIS drought portal and is funded by NIDIS. The third was developed separately by NDMC and is funded through the United States Department of Agriculture (USDA). Each web site has some similar information and some unique information not available on the other sites. The NIDIS web site is an extension of work done for US drought monitoring, where tools developed for the United States are being extended to the continent as well as globally. The NDMC web site is an extension of tools developed for the USDM and extended to the continental scale. Until now, housing them together has not been considered due to logistical, IT, and programmatic obstacles, but emerging survey responses point us in that direction.
- Reynaldo Pascual commented that continental-level drought indicators are in use by each of the three countries of North America, and due to NADM, the methodologies used are compatible across the nations. A unified database could reside in one place with a centralized drought resource. National agencies and organizations have the tools and data to do this and it would allow authorities to better handle drought discontinuity and adjustment along border areas and generate seamless reports across indicators.

On local and traditional ecological knowledge in drought early warning systems:

- Richard noted that local and traditional ecological drought knowledge remains valuable; however, it is currently underutilized in early warning systems. The creation of the USDM product engages more than 400 people, including Indigenous nations and communities, as local observers. Workshops with local and Indigenous communities in Alaska, for example, have provided insight into local drought experiences in the Arctic and improved our understanding and monitoring of drought in remote and high latitude regions—an area of drought which is especially difficult to understand.

Our Stories: Current Realities and Practices

The Massachusetts Drought Story, a Changing Experience

Viki Zoltay, Massachusetts Department of Conservation and Recreation, United States

Overview

- Understanding complex interactions of surface and ground water, urban development, land and water use, and the impacts of changing meteorological conditions due to climate change, has proven a difficult but necessary pursuit as the State of Massachusetts aims to monitor and manage drought more effectively.
- Being able to isolate and integrate regional and local level drought early warning systems and data, from larger assemblies like the USDM, allows validation of in-house observations, as well as improved accuracy in state level drought early warning systems and water resource management activities.

Key Points

- Drought monitoring in Massachusetts draws from hundreds of data sites monitoring surface and groundwater, as well as fire danger and crop moisture through remote sensing. This creates a monthly hydrologic condition report that is presented to the state drought task force.
- Many larger-scale, continental drought assessments and indicators are not used at the local and state scale. When it is attempted, larger data sets do not interact well with state-level analysis or jurisdiction.
- The state drought management plan is currently being revised and is led by a drought management task force. A revised plan will feature new indices covering thresholds, severity of drought, and temperature effect on water budget and evapotranspiration rate to more accurately monitor and respond to drought. The plan will also address the heightened need to respond to record low streamflow and groundwater levels.
- Along with the updated drought management plan, the state has begun a public science communication campaign to aid in drought response and plan implementation. This campaign includes color-coded, county-level drought maps, infographics and recommended activities designed to save water, and opportunities for public engagement in the implementation of the state's drought management plan.

Drought at the Community Level

Ana Ortiz Ángeles, *Grupo Semilla*, Coahuila, Mexico

Overview

- When developing drought early warning systems, it is critical to connect with the most marginalized populations during design to ensure the dissemination of drought early warning and forecasts to those living rurally with limited access to Internet technology and web-based forecasts and data. This will ensure drought early warning serves rural agricultural producers and the most vulnerable in society.

Key Points

- Grupo Semilla is a non-profit civil association working across four states of Mexico. It works with agricultural producers who experience vulnerability to drought and are highly marginalized economically.
- Drought is experienced by people whose livelihood is in semi-desert climatic zones. The association works across 20,000 hectares to mitigate the impact of drought in the area by ensuring producers and land-use managers efficiently use, conserve, and recover water for secondary uses, when possible.
- Retention methodologies and upkeep—such as cleaning muddy dams, and dirty canals and gutters—have improved water capture and distribution, ensuring that the little rainfall received is used efficiently.

Modernizing Our View of Drought: from Risk to Resilience

Roger Pulwarty, National Oceanic and Atmospheric Administration, United States

Overview

- Drought risk has a large footprint and is globally networked, with direct and indirect impacts across systems and scales. Given complex interdependencies of global trade, problems caused by drought events in one region can rapidly cascade, impacting distant markets, supply chains, food systems, and economies. Increased stressors of drought may push us beyond thresholds of sustainability and past environmental/economic/other tipping points, leading to systemic failure.
- Knowing and monitoring drought, with an eye on tipping points and thresholds, affords more effective management of drought as a systemic risk connected to global markets and systems.
- We must modernize our understanding of drought and move from risk framing to resilience framing. This takes us from knowing risk and reporting on losses, to action and preparedness.

Key Points

- Studies on sustainability partnerships in the US-Mexico borderlands region offer new understandings of drought governance and resilience. Namely, these partnerships explore how single, multilateral, and comprehensive scoped issues like drought can be addressed across stakeholder groups and sectors to improve joint planning and transboundary approaches, using consensus-based approaches. These include strategies and targets that are in line with United Nations Sustainable Development Goals, objectives adopted by both the United States and Mexico in 2015.
- More technical information or assessments, while useful, are not enough. Information and planning insight must be provided to the people who really need it at the local level.
- Moving from drought risk and monitoring to resilience requires strengthening a collaborative framework between research and management that maximizes the value of existing assets for drought-related security and resilience and making investments in resilience within communities and countries. Drought vulnerability addresses all systems, from food production to human psychology.
- Drought resilience means characterizing systemic risks, identifying disruptions and opportunities or entry points. Entry points are strategic opportunities for action in global networks that address risk of drought. These points can include food system security, population health, drought management (temporary conditions) and long-term strategies and adaptations to desertification (the transformation to a permanent arid condition). Entry points and proactive action can be supported with better knowledge of drought, including research, data products and technology barriers/opportunities. Lastly, good governance, financing networks, as well as implementation that can handle uncertainty and a changing environment, can build lasting global drought resilience**.**

Panel Discussion

On monitoring the cumulative effects of drought

- Cumulative effects frameworks offer a chance to understand the interactive nature of changing meteorological conditions and human activities on drought conditions. This includes the complex interaction between groundwater and surface water, impact of drought on vegetation, urban development and land-use change, industrial use and climate change. Effectively monitoring all connected factors may improve the efficacy of future drought early warning systems and water resource management efforts.

Our Stories: Innovation Using Drought Planning Resources

Minding the Gap: From Science to Drought Action and Policy

Mark Svoboda, NDMC, United States

Key insights

- Drought early warning information and products must be put into the hands of decision makers and managers, so they are able to develop actionable policy.
- Common triggers, values, thresholds, and severity levels need to be developed and drought impacts need to be linked to indicators and data products. This will allow clear and timely translation into drought decisions and operations.
- Publicizing drought planning efforts through media to civil society and engaging political officials in drought plan creation may help to secure political will to ensure a plan is accepted and ultimately implemented.
- Integrated drought management requires a collaborative approach within and between sectors and jurisdictions.

Summary

- The NDMC, founded in 1995, is based in the United States but works globally.
- Drought is a "wicked problem" and a "max stressor" unlike any other hazard, because of its high mortality rate, long timespan, and large footprint on the systems it impacts.
- The three pillars of drought risk reduction and resilience (monitoring and early warning, policy and planning, and risk assessment) are applied to everything the NDMC does.
- The aim of a resilience approach is to tip the scales toward proactive drought risk management, focusing on what can be done before, during, and after drought, to reduce the risk. Drought preparedness plans can be independent or integrated with other plans. There is no one size fits all.
- Working with tribes has been exciting because of the issues of sovereignty and civil jurisdiction, which affords them the opportunity to act more autonomously and respond more rapidly to changing conditions.
- Scenario planning and drought management exercises are effective drought resilience activities which can make use of drought datasets, monitoring systems, and early warning systems to navigate uncertainty in the creation of plans.

Our Climate Change and Drought Plans

Shanny Spang Gion, Northern Cheyenne Nation, United States and Marissa Spang, Northern Cheyenne Nation, United States

Overview

- Indigenous methodologies, knowledge, and ways of planning bring significant contributions to the field of drought resilience and water resource management, grounded in place-based, long-term relationships with natural resources. Indigenous approaches by this Tribal Nation are centered on reciprocity with water and natural systems. This means maintenance of natural capital without depletion and a focus on long-term sustainability, intergenerational use, stewardship, and adaptation.
- Tribal Nations, under Federal Indian Law and signed treaties, are quasi-sovereign entities with civil jurisdiction which are innovating drought monitoring using local values and approaches.
- Ensuring strong local participation in drought monitoring and planning ensures local needs and voices are central and plans are known widely by decision makers and citizens alike, which strengthens successful implementation.

Key Points

- Drought planning and climate adaptation at the Northern Cheyenne Nation engages a kinship and land-based paradigm. This follows the belief that we are a part of nature, not apart from it or above it, and that plan creation and response to be a "good relative" to lands and waters happens at the community level.
- The Northern Cheyenne worldview and way of life follow where water comes from and goes. These Cheyenne values are utilized in planning drought management.
- Rather than high social vulnerability without a clear cause, the Nation notes they are not merely vulnerable—they are targeted and have been intentionally destabilized through federal Indian policy since the 1800s. This has led to a population, food system, livelihoods, and economy that are overly sensitive to the impacts of drought. The Nation uses its own metrics of vulnerability, well-being, and wealth in the face of drought and environmental change. Data are protected by tribal protocol.
- The Nation has a Climate Change Program that blends observations from state and national drought monitoring with biocultural approaches. Using local methodology, local land-use surveys have gathered local perceptions and observations of how the water, land, and biodiversity are changing, and how these changes affect traditional activities.
- Citizens provide recommendations for managing resources amidst drought and change and, based on engagement, surveys, and local cultural values, the Tribe has created its own metrics for its plans and development.
- Maintaining data sovereignty, the ownership, control, access, and possession, as well as clear protocols are vital to the management of tribal lands and waters.

Emergency Drought Management and Range Conservation

Selso Villegas, Tohono O'odham Nation, United States

Overview

- Tribal Nations have stewarded arid homelands from the beginning of time with populations now situated on federally allocated, and immovable land areas. Tribes maintain traditional approaches and the ability to pass laws governing their waters and lands due to quasi-sovereign status as Nations and often maintain water rights. Tribal Nations can be strong partners with nearby cities, counties, and basins to build effective regional drought resilience.
- Commitment to long-term reciprocal relationships and good faith dialog with Tribal Nations can lead to innovation in drought early warning systems and planning, as well as joint drought management in the southwest borderlands.

Key Points

- The Tohono O'odham Nation, located in southern Arizona, is a tribal nation of 38,000 citizens on 2.7 million acres spread across both sides of the US-Mexico border. The O'odham's Indigenous homeland predates the US-Mexico border.
- The Nation and the State of Arizona are experiencing a long-term, 21-year drought, which features hotter temperatures, less abundant surface water, drier soil, parsed vegetation, and wildfire.
- The Nation has 40 weather monitoring stations that it oversees and engages traditional knowledge holders in drought management. Current drought data and monitoring are added to a 100-year-old database. Traditional stories talk of the end of the earth and the role of the O'odham People as stewards of their lands.
- The Nation completed an extensive climate change adaptation plan in 2018, based on which they have deployed drought strategies and actions. These include monitoring drought through the NIDIS Drought.gov portal and USDA Rainfall Index; use of pasture, rangeland, and forage insurance for crops; and a relief plan for fuel and water trucks.
- The Nation's Natural Resources Department is developing a Drought Mitigation Plan. Due to current conditions, an Emergency Drought Relief Plan is being prepared for approval by the Tribal Council.

Innovations in Drought Monitoring in Montana

Michael Downey, Montana Department of Natural Resources and Conservation, United States

Overview

- States and provinces offer a unique scale for innovation and deployment of early warning systems and improving the interface with decision making, management and planning in their Mesonets and Drought Impact Reporters and GIS-based dashboards.
- Offering a local reporting interface, paired with weekly analysis, offers more nuanced management of short-term and novel forms of drought, in state, tribal and county jurisdictions across the arid Midwest and Pacific Northwest.

Key Points

- The state of Montana has moved from a monthly to weekly analysis of drought conditions to improve risk assessment and response to rapid-onset events and short-term drought. This approach emerged from a 2017 rapid onset "flash" drought when a monthly analysis, based on percentage of annual average, missed early warning signs, and quickly worsening drought conditions. This left the state unprepared for a severe and rapidly developing drought.
- Montana has incorporated weekly participation and consultation with the USDM into normal operations and improves local reporting and forecasting.
- Montana is updating its Drought Management Plan (emphasizing evaluation of drought risk, drought sensitivity and drought adaptation) and is developing a state drought portal.
- In 2017, the Montana Drought Impacts Reporter was created which offers localized reporting of moisture conditions, crop and range conditions, planting and harvest status, drought impacts across sectors, qualitative descriptions, and images. The reporter feeds into the state ArcGIS-based Drought Impact Dashboard.[2] They are working toward a state drought portal.

[2] ArcGIS is a GIS developed by the ESRI for working with maps and geographic information.

The Nexus of Drought and Agriculture in Mexico

Sol Ortiz, *Secretaría de Agricultura y Desarrollo Rural*, Mexico

Overview

- Global perspectives and partnerships can bring emerging best practices to play in national drought early warning systems and management.
- Affording crop-level analysis in monthly forecasts, and engagement through cross-sector committees, can ensure early warning systems and forecasts get into the hands of decision makers and agricultural communities most at risk of drought.

Key Points

- The primary focus of the Mexico Secretariat of Agriculture (Sader, formerly Sagarpa) is on agricultural drought but the connection to meteorological drought and socioeconomic drought is observed. Mexican history informs us of the major and lasting effects of drought, from hunger and migration to the loss of human life.
- The 2018 drought in Mexico had significant and lasting implications on the economy and national production, with US$65 Million in losses impacting 48 million citizens. This impacted two out of three cultivated hectares and killed millions of head of livestock.
- Changes in rainfall patterns directly impact agricultural activities where more than 50 percent of producers employ temporary, above-ground irrigation using seasonally available rainfall.
- Since 2016, Mexico has been conducting monthly agricultural monitoring in partnership with the Food and Agriculture Organization (FAO) of the United Nations, using the Global Information and Early Warning System in stride with the Agricultural Stress Index and Agricultural Market Index to generate monitors.
- The system is accessed via the Center for Information on Agri-food Markets (*Centro de Información de Mercados Agroalimentarios*—CIMA) page and provides monthly agricultural monitoring reports and rainfall forecast maps of affected crops by type and regional extent.
- Local technical agroclimatic committees and illustrated bulletins with recommendations based on forecasts, are being developed across Mexico and Central America to promote evidence-based decision-making and discussion across sectors around changes in climate and drought management. These committees offer a space for discussion across stakeholders, including the federal and local governments, agricultural producers, academics, and holders of traditional knowledge. Future roundtables are planned.

Provincial River Forecasting and Drought in British Columbia

Ashlee Jollymore, River Forecast Centre, British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Canada

Overview

- Clearly identified drought levels, with associated thresholds and objectives, can create clear pathways between drought observations and the planning and regulatory responses necessary to govern drought.
- Early warning systems, when paired with strong legislation, can ensure maintenance of ecological flows and timely response to socioeconomic stress during drought conditions.

Key Points

- British Columbia has developed a provincial Drought Response Plan, which mainly engages hydrological drought with attention to the protection of aquatic ecosystems and fisheries. The plan identifies core indicator thresholds for snow, runoff, precipitation and streamflow; incorporates monitoring; recommends actions to mitigate impacts; and establishes drought levels. These drought levels range from 1 (normal) to 4 (extremely dry). The higher levels trigger restrictions and regulatory actions to ensure maintenance of socioeconomic and ecosystem needs.
- Implementation of the Drought Response Plan is coordinated by a technical working group, which includes representatives of local and First Nation governments.
- The British Columbia Drought Information Portal provides a dashboard with maps of drought levels, a stream watch, historical drought record and streamflow.
- The BC Water Sustainability Act (2016) provides regulatory tools and updates British Columbia's strategy for protecting, managing, and using water efficiently throughout the province.
- There is still a need to create locally tailored drought responses and delineate between true drought and newly arid regions, given a changing climate.

Panel Discussion

On movement and migration due to drought:

- Selso Villegas noted the Tohono O'odham tribes used to move freely across the region but cannot move anymore. They have designated land reserves and their rights to land tenure are locked in. If they move, they lose their territory. That reality is both a good, and a bad thing in the face of drought. They need to take care of where they live now and work with others, as drought does not respect political boundaries.

On partnerships in drought:

- Selso Villegas commented that any collaboration or partnership with the O'odham must be honest, genuine and have the intent to follow through and create change—to make a committed effort to improve the region. Tribes are willing to help in the face of drought and climate change. They want to work proactively on drought but, in the end, they need committed and collaborative efforts, as drought affects all of us.
- Marissa Spang commented that they built good relationships with agencies like the Bureau of Indian Affairs, who have been good managers of Northern Cheyenne geospatial data. But this is based on protocol and consent. External partners need to understand the context and history when partnering with Tribal Nations: this offers clarity around the source of sensitivity and mistrust, responses grounded in a history of data being misused and used against the interests of the Tribal Nations and Indigenous Peoples. Partnerships in drought early warning must acknowledge this history, build relationships, and be grounded in consent.
- Michael Downey commented that the success of work and completion of weekly reports depends on a collaborative effort between local and Tribal partners. In the state of Montana, where there are five different authors compiling the information and developing recommendations, it is a constant collaboration and people have shared ownership. It is important to work together and use the tools often, and before a crisis emerges, so lines of communication and networking are already in place.
- Shanny Spang Gion noted that the Northern Cheyenne Nation shares the Tongue River watershed with other users, and political boundaries with other tribes, the state, counties, and towns. This offers a great opportunity to collaborate and develop improved remote sensing, gauging stations, and collection of better drought information.

Drought Tool Bootcamp

Canada's New CDM Data Products, ESI and 1-Month Drought Forecast

Trevor Hadwen, Agriculture and Agri-Food Canada

Overview

- Continued innovation in integrating indices, data products and emerging methods like advanced reviewer tools, drought storytelling tools, and more frequent reporting offers insight into early warning systems of value to all CEC countries.
- Canadian data products offer clear thresholds and pathways to action at provincial levels in dealing with short-term drought.

Key Points

- The CDM is integrating the VegDRI model in Canada. This is a hybrid drought index which combines satellite observations of vegetation health with climate station information and land biophysical information to determine drought categories. Larger observer networks and blended indices offer higher spatial resolution of drought impacts than previously available as well as clear regional insights in impact reports.
- Canada is beginning to integrate the ESI into the Drought Watch website. This satellite-derived content can better capture rapid onset drought events in remote areas, borderlands, and areas distant from agricultural regions.
- The CDM Editor and Reviewer Applications offer authors and reviewers direct edit and comment on assessments, using a cloud-based ARC Online environment.
- A Drought Indices Table provides a quick assessment of each indicator for each climate station in the country, incorporating indicators into short- and long-term objective blends.
- Development efforts have afforded greater assessment efficiency, more indices, more frequent assessments, stronger drought analysis tools and an improved user interface. A Drought Forecast and Outlook tool will offer monthly forecasts starting in 2021.

Mexico's Drought Monitor

Reynaldo Pascual, *Comisión Nacional del Agua*

Overview

- The National Water Commission of Mexico (*Comisión Nacional del Agua*—Conagua) website offers monthly drought monitors and precipitation forecasts by region, while offering raw data and geospatial databases. Few resources compete with this resource nationally, providing a clear pathway for users to improve early warning systems.

Key Points

- Reports can be downloaded at the municipal level, represented as graphics or tables and may be downloaded as complete datasets for use in local assessment and planning.
- Internal and external servers currently house datasets and shapefiles of monitor reports. Additional data resources and map layers are available to regional drought practitioners by request to the MSM.
- Of the three NADM websites, NDMC's is the only one providing state-level assessments for Mexico. Here, maps, graphs and statistical data can also be downloaded.

Mesoamerican Drought Monitor

Mauricio Osorio González, *Instituto Mexicano de Tecnología del Agua*

Overview

- This new Mesoamerican drought monitor, "Tzolkin", offers relevant analysis, transboundary tools, and monitoring of drought at the units of governance most relevant to drought management and integrated water resource planning, for example local government, city, and state levels.

Key Points

- Tzolkin is named after the Yucatec Mayan word for the Maya sacred calendar and is based on open access information sources and open-source packages. This has been operated by the Mexican Institute of Water Technology (*Instituto Mexicano de Tecnología del Agua*—IMTA) since April 2020.
- Based on 38 sources of direct observation and remote sensing, Tzolkin offers monitoring of environmental variables, simple interpretation, multiple preset configurations, and is adaptable to specific analytical objectives.
- Analysis engages data sets, including runoff, precipitation, and soil moisture, and is calculated in a multivariate cube based on six drought indices across 1,496 cells. These cells cover a region including Mexico, Central America, and the Caribbean. Drought intensity and magnitude are quantified.
- Drought conditions are presented as animated maps based on indices, time-scale and date-range graphs down to the one-month time-scale. Maps can be tailored to political division, hydrological region, local and basin council levels of jurisdiction and analysis. The intensity and magnitude of drought are available for download by municipality.

US www.drought.gov and www.climateengine.org.

Justin Huntington, Desert Research Institute, United States, and Rocky Bilotta, NOAA's NCEI, United States

Overview

- The NIDIS Drought Portal team is working toward cloud-based processing and visualization of climate and satellite data for advanced drought and natural resource monitoring; and is working to automate ingestion of large data sets and processing using Linux, Conda, Python and GIS Tools. It has applicability to NADM (which is housed in the NIDIS drought portal) as well as to the GDIS (Global Drought Information System) and GDM (Global Drought Monitor), which are also housed within the NIDIS drought portal.
- Open-source approaches, like Climate Engine, allow users with limited resources to access large and open geo-databases, recent remote sensing, new and improved models, as well as improved analysis, while strengthening efforts by regions and countries through an Application Programming Interface.

Key Points

- Automated processing allows for greater and more specific geographic information raster tiles for indices-specific drought reporting.
- Climate Engine is making large drought and climate datasets cloud-based and open-sourced. Their web platform also allows practitioners to run custom analysis of vegetation, climate, and hydrology, as well as trends in drought conditions at the desired regional scale.
- Climate Engine offers an API to improve use across systems, hardware and devices. This allows national, regional and local drought monitors to draw from the other initiatives and for software development. APIs can allow for greater analytical ability and interoperability between tools and facilitate new and improved drought early warning systems across the continent.

Our Stories: Leading Practices and the Future

Arbuckle-Simpson Aquifer Drought Contingency Plan and the Chickasaw Nation

Barney Austin, Chickasaw Nation and Aqua Strategies, United States

Overview

- As stewards of their collective territories, the Choctaw and Chickasaw Nations consider it their ethical duty to protect and sustain the land and water resources of their homeland. In 2011, Tribal leadership initiated the development of Oklahoma's first sustainability-based water plan—the Choctaw-Chickasaw Regional Water Plan.

Key Points

- The Arbuckle-Simpson Aquifer is the sole source of drinking water for most of the region. The plan for the aquifer establishes seven essential concepts serving as a foundational framework for the plan: regional unity, sustainability, urban needs, town and rural needs, drought defense, agriculture, and tourism.
- The Aquifer Drought Contingency Plan consists of five core components: sector vulnerabilities, a regional climate vulnerability assessment, a robust drought monitoring system, drought mitigation and response actions, and an implementation schedule. Creation and implementation of the plan is overseen by a task force of towns and natural resource districts with a supporting advisory group that includes government agencies and civil society organizations.
- Challenges in this drought monitoring and planning process include a lack of regulatory authority. Further, conservation measures that were recommended to improve drought resilience but which incur a loss of revenue by the water authority, illustrate the policy hurdles with which this type of drought contingency planning must engage.
- Response actions can in some instances be more cost-effective than pre-drought actions that involve creation of new water supplies.

Drought Monitoring and Planning in South Dakota

Laura Edwards, South Dakota State University Extension, United States

Overview

- An accurate USDM offers the clarity needed to deploy drought disaster assistance to farmers who increasingly rely on this type of aid.
- State-level tools like the Mesonet and strong observer networks help drought professionals to create more accurate early warning reports at local scales and inform state-level response.
- It is important to establish regular communication between partners *before* a major drought event occurs.

Key Points

- The South Dakota Drought Mitigation Plan, created in 2015, is led by a task force that includes representatives of all state agencies plus the state climatologist. A designation of "D2" on the USDM report triggers the governor to activate the task force. The drought plan is an appendix to the state multi-hazard plan.
- The Mesonet is a weather station network which can be used to address large-scale meteorological occurrences. In South Dakota, this network includes underground soil moisture sensors at varied depths to better understand soil response to precipitation events across the region.
- A supplementary drought dashboard outside the Mesonet has national and state datasets and offers snapshots of the monthly North America Drought Monitor.
- Increasing the number and distribution of state weather stations remains a challenge, but would improve drought early warning accuracy. Local observers, who once made up a state network, are now in declining numbers, largely due to an aging population in rural and agricultural regions.
- With newly awarded federal funding, there are plans to expand the state-level Mesonet across the Upper Missouri River Basin, interacting with other state-level Mesonets to create a larger connected regional Mesonet to serve the basin.

Rain Gauges for Range Monitoring: Co-developing Tools and Best Practices for Ranch-Scale Drought Detection

Mike Crimmins, University of Arizona, United States

Overview

- Low tech interventions like rain gauges, paired with remote information upload, can provide valuable input and better data assemblies in rural regions, thereby strengthening locally relevant early warning systems for drought.
- Observer reporting, across user groups and the state, allows for larger datasets and collaborative drought planning across sectors and jurisdictions.

Key Points

- Rain gauges are used as range and precipitation monitoring tools in remote regions in Arizona.
- Public land provides most available grazing land. The region experiences seasonal drought and depends on monsoonal weather patterns for forage production. Precipitation monitoring is important, so rain gauges are critical for measurement and planning.
- Range precipitation monitoring requires practical and easy-to-read rain gauges.
- Efforts are underway to solve the "where, when and what does it mean" of drought and rainfall. This will help agricultural producers assess and inform their plans for moving cattle to forage. Often it is difficult to understand whether rain events provide the volume and rate of precipitation to make a difference in local drought conditions. Gauges give rapid results and inform people immediately whether a rainfall event significantly contributed to water storage and impacted soils, grasslands, and vegetation.

Water Crisis from a Conservation Perspective

Mauricio de la Maza-Benignos, Pronatura Noreste

Overview

- The northern region of Mexico requires a comprehensive vision of water security that will ensure biological diversity. This is enshrined in the Mexico Constitution, where rights to a healthy environment and the human right to water are recognized.
- A vision of water security is needed, based on the conservation of ecological systems.

Key Points

- Mexico is entering a drought cycle and drought management does not consider the impacts on biodiversity and ecology. This lack of inclusion, and weak regulations and institutions to enforce them, will lead to the deterioration of life support systems and natural landscapes, as well as worsening existing civil conflict.
- Technical information collected through monitoring can be used to adapt regulations to the current reality for water availability and improve governance. Water monitoring, effective and already in place in the United States and Canada, can be implemented with local users and producers in Mexico. Agricultural and industrial uses of water during drought should be better balanced with the needs of the environment and people.

Drought Learning Network and Transboundary Drought

Emile Elias, USDA Southwest Climate Hub

Overview

- Development of a drought learning network of experts is currently underway and will include decision makers, advisors, planners and communicators from different agencies and Tribal Nations.

Key Points

- The network will offer peer-to-peer learning and exchange through case studies, resilience reporting, a list server, a shared calendar, workshops, and a drought management database.
- A survey was conducted to gather information to better understand practitioner preferences. The survey found that managers highly desire access to information about drought-related best practices and lessons learned by other resource managers.
- The USDA Southwest Climate Hub leads networking and learning resources for early warning systems professionals as well as transboundary research on native waters on arid lands.

Assessment of North American Drought Information Products and Tools

In 2020, the CEC launched a series of three online information-gathering surveys as part of the project *Improving the Effectiveness of Early Warning Systems for Drought.* The second survey, which launched in June 2020, was entitled *Assessment of North American Drought Information Products and Tools.* The objective of this second survey was to identify and compare available drought information, products, and tools in North America relative to local and regional preparedness, planning, and risk management.

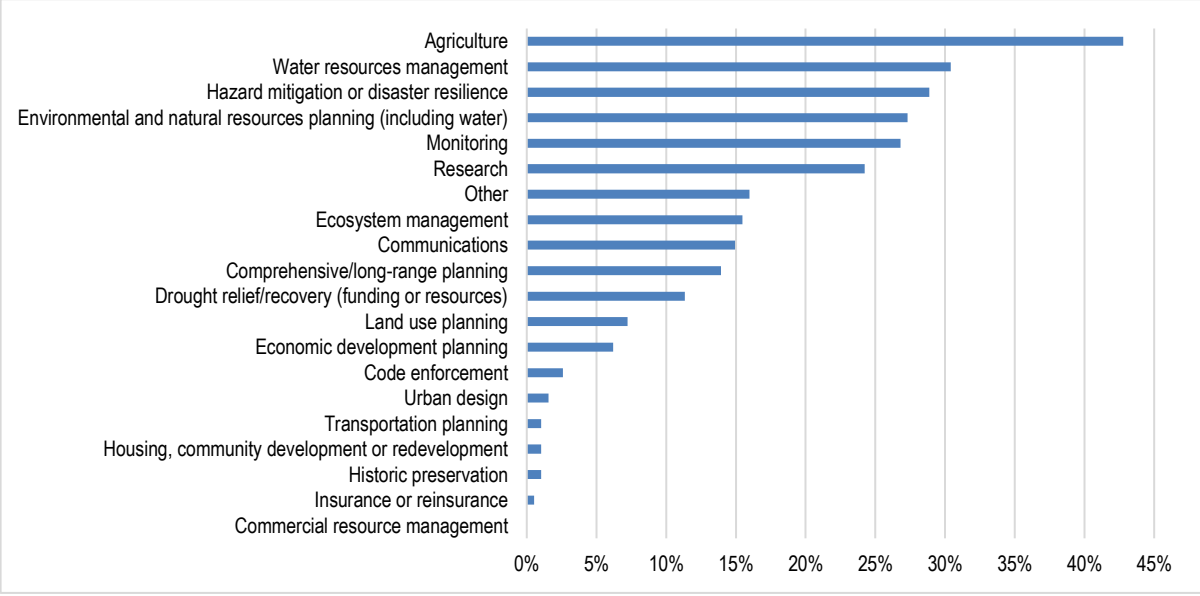
This survey garnered a total of 228 completed responses and 173 partial responses. Of these, 60% indicated they currently have a role in drought management; 15% of which work in Canada, 15% work in Mexico and 70% work in the United States.

A total of 50% of the respondents reported that they worked for government: 28% for federal government and 22% for provincial or state government. Another 31% reported that that they were involved in academia or research.

Survey respondents were asked to indicate the total population size of the geographical area(s) for which they were responsible. The results ranged from less than 10,000, to 5 million or greater. The majority (78%) were responsible for populations between 10,000–249,000 (35%) or greater than 1 million (43%).

Respondents were asked in which activities they currently work. The largest proportion of responses was agriculture (43%) followed by water resources management (30%), hazard mitigation or disaster resilience (29%), environmental and natural resource planning (27%), monitoring (27%), and research (24%) (Fig. 1).

Figure 1. Work activities of North America Drought Information Products and Tools survey respondents



Three separate sessions during the Drought Summit were devoted to questions about the results of the *Assessment of North American Drought Information Products and Tools* survey. These discussions supplemented the information collected through the survey and helped participants gain greater insight into specific topics. For each session, summit participants were presented with a summary of survey results, and then one or more questions related to the subject were posed to the participants. The resulting discussion was moderated by the summit facilitator.

Presentation: Drought Decision Support and Policymaking

Ernest W. T. Cooper, E. Cooper Environmental Consulting

Summary

Almost all of the respondents (99%) to the *Assessment of North American Drought Information Products and Tools* survey reported they were slightly to extremely concerned about drought in their geographical area of responsibility. Half (48%) of respondents indicated they were very concerned or extremely concerned. Only 1% said they were not at all concerned. Respondents from Mexico reported the greatest concern, with 87% very or extremely concerned.

None of the survey respondents reported that their geographical area of responsibility had not experienced drought in the last 10 years. A total of 96% reported drought occurred in their geographic area from one to more than five times, and almost half (47%) indicated drought had occurred three to five times during that period. Most Mexican respondents and almost half of US respondents indicated drought had occurred three to five times in the past 10 years.

Only 5% of respondents (seven from the US and one from Mexico) indicated drought in their geographical area of responsibility typically lasted more than 12 months. The majority (91%) reported a typical drought lasted from less than one month to 12 months, and 75% noted a typical drought lasted six months or less. Short-term drought lasts less than six months, and long-term drought lasts more than six months. A duration of one to three months was the most reported time frame for all three countries.

Most survey respondents (90%) stated they have access to the tools and/or information needed to respond to drought in their geographical area of responsibility. However, 10% of the respondents indicated they did not. A total of 26% of the Mexican, 13% of the Canadian, and 5% of the US respondents said they did not have access to the required tools and information included.

Discussion questions

- What are your current drought monitoring needs?
- What kind of timelines do you face in your operations?
- What analyses are most useful to you for dealing with short and long-term drought?
- How can you best be supported as you inform decision makers and prepare forecasts, policies and plans?

Comments

Participants noted that drought is a phenomenon that requires both local and global drought-related information to be monitored and the resulting data should be linked. In order to understand the impact of drought, it is necessary to know when drought starts, how long it lasts, and when it ends. Plus, it is important to link the impact of drought to climatic factors that affect the formation or development of drought and soil moisture. There is also a need to better incorporate socioeconomic impacts into drought management.

Participants commented there are many tools, but access to them is scattered and coordination and cooperation between the various groups that provide them are poor. The use of platforms to disseminate information is varied and there is an oversaturation of available sites. Users need to be able to navigate, integrate, and rapidly deploy different tools and data products in drought early warning. It would be more useful for decision makers if all these efforts and tools could be accessed via a single portal. Respondents commented that more timely data would help management and decision-making, as would better information at the local level—such as specific county or municipal and ecosystem level modeling. To that end, weekly satellite information would be valuable, if available. In Canada and Mexico there is a widespread need to increase the number of established monitoring stations. Respondents also noted that more predictive models would be helpful but did not elaborate on what additional information was needed.

Presentation: National Drought Monitors

Ernest W. T. Cooper, E. Cooper Environmental Consulting

Summary

The *Assessment of North American Drought Information Products and Tools* survey asked participants to score the usefulness of different sources of information for responding to short- and long-term drought in their geographical areas of responsibility. It is not surprising that national drought monitors were scored highly by respondents from the relevant countries:

- The CDM was scored as very or extremely useful for responding to short-term drought by 78% of Canadian respondents.
- The MSM was scored as very or extremely useful for responding to short-term drought by 65% of Mexican respondents.
- The USDM was scored as very or extremely useful for responding to short-term drought by 79% of US respondents.

The results were similar for long-term drought, although the national drought monitors were scored slightly lower by respondents:

- The CDM was scored as very or extremely useful for responding to long-term drought by 75% of Canadian respondents.
- The MSM was scored as very or extremely useful for responding to long-term drought by 58% of Mexican respondents.
- The USDM was scored as very or extremely useful for responding to long-term drought by 77% of US respondents.

It is worth noting the US National Weather Service (NWS) was scored highly by Mexican and US respondents:

- NWS was scored as very or extremely useful for responding to short-term drought by 77% of Mexican respondents and 83% of US respondents; and very or extremely useful for responding to long-term drought by 75% of Mexican respondents and 77% of US respondents.

Respondents from all three countries scored the NADM as less useful than the national drought monitors for responding to short-term or long-term drought. The NADM was scored as very or extremely useful for responding to short-term drought by 57% of Canadian respondents, 46% of Mexican respondents and 56% of US respondents; and as very or extremely useful for responding to long-term drought by 60% of Canadian respondents, 46% of Mexican respondents and 48% of US respondents. It is interesting that Canadian respondents scored the NADM higher than did those of the other countries.

The US NIDIS NADM Use Assessment Survey Results: Use of the NADM Drought Portal survey choice was scored as very or extremely useful for responding to short-term and long-term drought by 57% and 53% (respectively) of US respondents. Most Canadian and Mexican respondents did not score the NIDIS Drought Portal as very or extremely useful for responding to short-term or long-term drought.

Survey participants were asked to score the same list of information sources as to their usefulness for *drought planning*. In this case the national drought monitors were the only sources of information for which most respondents scored highly:

- The CDM was scored as very or extremely useful for drought planning by 64% of Canadian respondents.
- The MSM was scored as very or extremely useful for drought planning by 59% of Mexican respondents.
- The USDM was scored as very or extremely useful for drought planning by 61% of US respondents.

Survey participants were also asked to score the usefulness of different sources of information for *managing* drought, but respondents did not clearly indicate regional or national preferences. More than 50% of respondents scored 15 separate sources of information as very or extremely useful for managing drought. Canadian respondents provided the clearest preference for information sources with 100% scoring precipitation departure from normal as very or extremely useful. Crop status and 7-day weather forecast were both scored as very or extremely useful by 95% of Canadian respondents. Amongst Mexican respondents, 92% scored crop status as very or extremely useful, followed by reported drought impacts (88%) and vegetation health (83%). US respondents agreed less on preferred sources of information for managing drought, with 70% scoring 7-day weather forecast as very or extremely useful, followed by vegetation health (66%) and streamflow (63%).

Discussion questions

- How do you use your national drought monitors?
- What is the role of national drought monitors in managing drought?
- Do you feel these products are accurate and consistent? Why or why not?
- What resource for monitoring drought is missing in your context?

Comments

Participants commented that up-to-date, reliable data from federal, state and local governments, as well as real-time reports of impacts, are extremely important in monitoring drought conditions and effectively communicating the consequences. They depend on the national drought monitors and NADM products to determine the presence, longevity, and severity of drought, which helps prepare producers in making management decisions for the short and long term.

Participants noted each of the information sources provides a wealth of information that is important to monitoring drought. The national drought monitors and the NADM are valuable because they are readily accessible and provide credible, reliable, data-driven assessments that are routinely updated. The amount of information coming from each source is considered extremely important and is routinely used to monitor drought conditions. Canadian users commented that the CDM provides consistent spatially-based information on a timely basis, with a variety of information, maps, and tools with regular updates. Mexican users commented that some practitioners in Mexico prefer to use the NADM because the information provided is more current than what is available on the MSM.

The NADM was praised for providing near real-time data with a holistic view of the region, and, along with the National Weather Service and NIDIS, identifying areas of drought based on measurable patterns and impacts. However, respondents also commented that better local data collection and modeling is needed (but did not specify) and it would be preferable to have more data in one or two locations to make obtaining the information easier. Not all of the summit participants were aware of the NADM prior to the drought summit.

A point that was repeatedly made was that there are many tools and sources of information available, and it would be very useful to have a single webpage of resources, listed by topic, that drought practitioners could access and use to navigate the growing collection of drought resources.

Presentation: Types of Drought of Most Concern

Ernest W. T. Cooper, E. Cooper Environmental Consulting

Summary

The climatological community classifies drought into the following types:

- Agricultural: when crops become affected.
- Ecological: when terrestrial and aquatic ecosystems and their goods and services are impacted.
- Hydrological: when low water levels become evident in streams, reservoirs, and groundwater.
- Meteorological: when dry weather patterns dominate an area.
- Socioeconomic: when the supply and demand of goods and services, as well as non-commodities, are impacted due to water supply constraints.

Respondents were presented with these definitions and asked how important each is in their geographic area(s) of responsibility. Most responded that they consider all five types of drought to be important, with hydrological drought scoring the highest and socioeconomic drought scoring the lowest. The percentage of respondents that scored each type of drought as very or extremely important is as follows: hydrological drought (88%), agricultural drought (83%), meteorological drought (80%), ecological drought (71%), socioeconomic drought (63%).

Conversely, 2% of respondents indicated they did not consider agricultural, ecological, or socioeconomic drought to be at all important; and 1% reported they did not consider hydrological or meteorological drought to be at all important.

Twenty-four respondents (28%) reported "other" types of drought were very or extremely important. Of these, nine provided comments to specify what type of drought they were referring to. Most of these comments referred to impacts, rather than types of drought. However, individual respondents noted that intermittent drought, snow drought and vegetative drought (versus agriculture drought for crops) were extremely important in their geographic areas. Two other respondents (one in from Canada and one from the United States) commented that flash drought was important in their geographic areas, noting the need to integrate the flash drought and agricultural drought.

It is unclear to what extent these results are influenced by the professions and/or activities of the respondents. Elsewhere in the survey it was noted that 43% of the respondents worked in agriculture, and 27%–30% were active in monitoring, environmental and natural resources planning, hazard mitigation or disaster resilience, or water resources management. Experts in other fields (e.g., ecologists or sociologists) may have scored the different types of drought differently.

Discussion questions

- How can North American drought tools and resources better support you in responding to all types of drought?
- What reports and information from online and other resources would afford new insights to help address the drought types and interaction with other systems? For short-term drought? For long-term drought?

Comments

Participants discussed the difficulty in measuring the magnitude or impact of ecological and socioeconomic drought, as these forms of drought are challenging to quantify unless specific indices and/or indicators can be developed. Both the timber harvesting industry and recreational industry are affected by ecological drought and could be sources of relevant data, perhaps based on economic value. The health sector is also heavily impacted by drought and a means to integrate health data to drought data could be insightful.

NADM Use Assessment

In August 2020, the CEC launched the third online information-gathering survey for the project *Improving the Effectiveness of Early Warning Systems for Drought*. The objective of the *North American Drought Monitor Use Assessment* survey was to evaluate the use of the NADM in order to identify users' needs for the improvement of the program, including users' access and the development of new user-oriented tools.

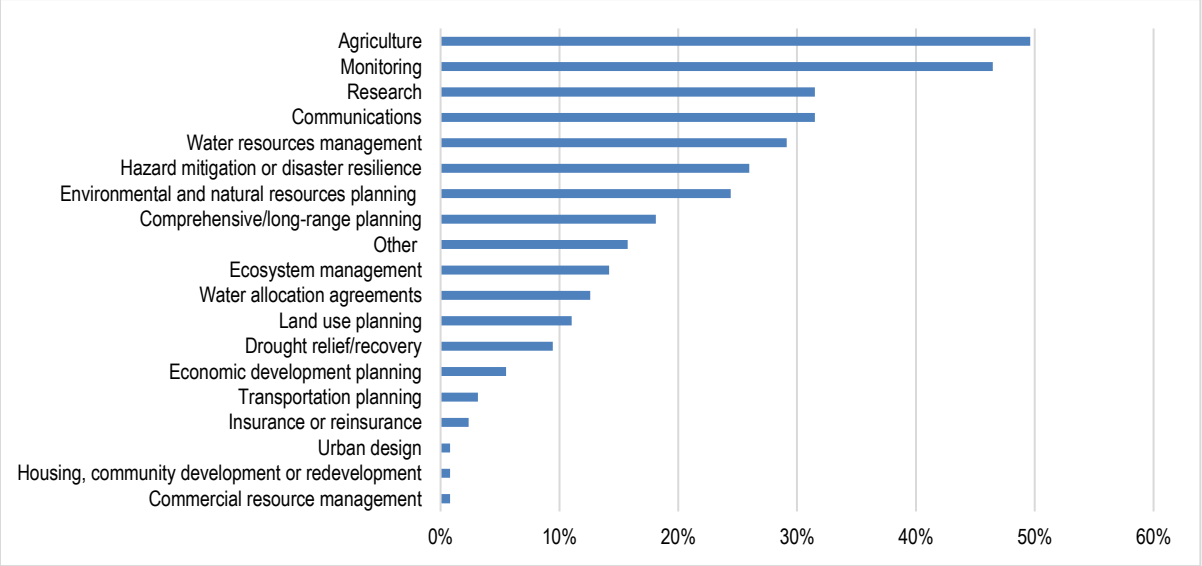
The *North American Drought Monitor Use Assessment* survey garnered a total of 89 completed responses and 92 partial responses. Of these, 53 respondents indicated they worked in Canada, 22 were employed in Mexico, and 72 worked in the United States. Three indicated they worked in another country but did not identify where. One indicated that they provide drought-monitoring data for the continental United States and "food-insecure countries around the globe."

Most respondents (71%) reported they worked for government: 50% for the federal government, 20% for provincial or state government, and 1% for Indigenous government. Another 19% reported they were involved in academia or research and 13% were agricultural producers.

Respondents were asked to indicate in which activities they currently work. Half (50%) reported they were active in agriculture and 46% reported they were active in monitoring. Other activities, which more than 20% of the respondents selected, included: communications (31%), research (31%), water resources management (29%), hazard mitigation or disaster resilience (26%), and environmental and natural resource planning (24%) (Fig. 2).

Two sessions during the drought summit were held to discuss questions related to the results of the NADM use assessment survey. The purpose of these discussions, as with the previous survey consultations, was to supplement the information already collected and gain greater insight into the survey results. For each session, summit participants were presented with information gathered during the survey, and then questions related to the subject were posed to the participants. The resulting discussion was moderated by the summit facilitator.

Figure 2. Work activities of NADM use assessment survey respondents



Presentation: NADM Use Assessment Survey Results: Use of the NADM

Ernest W. T. Cooper, E. Cooper Environmental Consulting

Different NADM data are currently available on three separate websites: the NADM main website (housed and maintained by NCEI), the Drought.gov supplemental NADM website (housed on the NIDIS drought.gov portal), and the NDMC supplemental NADM website. Most survey respondents (60%) indicated they were not aware of these three websites before starting the survey. This included 65% of Canadian, 82% of Mexican and 50% of US respondents. When asked how useful the three websites are for obtaining information about drought conditions in their geographic area of interest, most of the respondents did not indicate any of the three websites was very or extremely useful. Only 42% answered that the NADM main website was very or extremely useful. However, 24% of the respondents also indicated they had not used the NADM main website. Fewer respondents felt the NDMC or Drought.gov websites were very or extremely useful (39% and 34% respectively), and 37% of the respondents indicated they have not used either website.

Survey respondents were asked for what purposes they have used NADM products, and were offered the choices of monitoring drought conditions, planning for drought (developing a plan of action), preparing for drought (acquiring and allocating resources) and responding to drought (putting a plan into action). Respondents could select all that applied. Most respondents (83%) indicated they have used NADM products for monitoring drought. Fewer than 20% of respondents selected any of the other options. Several respondents reported they used NADM products for research purposes such as for assessing climatic risk during crop yield forecasting; understanding how different sources of information are useful with respect to drought; and ensuring there is cross-boundary alignment between US and Canada, and US and Mexican drought data.

Another question in the survey asked how useful the NADM products were for responding to short-term drought (lasting less than six months) vs long-term drought (lasting six months or more). A total of 49% of survey respondents indicated NADM products were very or extremely useful for responding to short-term drought, and 43% reported they were very or extremely useful for responding to long-term drought. For short-term drought, 24% reported they did not know, and 28% reported they did not know for long-term drought.

When asked about the consistency of NADM products, 67% of respondents agreed the NADM map was consistently accurate, and 64% agreed the NADM provides consistent guidance.

Discussion questions:

- Which barriers and realities do we need to understand in using the NADM in your work?
- Do you have thoughts about the accuracy, applicability, relevance, or scale covered by the NADM tools?
- What additional information would assist you to monitor drought in your local region or sector?
- Is there information that could be added to the NADM sites that could increase their value for planning, preparing for or responding to drought?

Comments

Several participants from Canada and Mexico felt the NADM products are not as accurate or as precise as needed, due to the low numbers and wide dispersal of monitoring stations in many areas. Apparently, attempts have been made to compensate for the lack of monitoring stations through remote sensing, but that approach also has limitations. The need to improve the scale of data, particularly in Mexico, was repeatedly emphasized. Some participants thought it would be helpful if the NADM map could be downloaded by state, province, or municipality.

One participant suggested adding forecasting tools to the NADM would be more useful than just monitoring drought as it is happening. This was considered important because, in Mexico, planning by the forestry, health, and civil protection sectors includes information from the NADM. Another noted it was important to distinguish between the current drought monitor as a product and the ideal monitor for decision making. They commented that, rather than monthly data, it would be more useful if the NADM provided hourly, daily or pentadal (five-day) data; and a short-term monitor would be more useful to a decision maker.

Other participants suggested the NADM is not meant to be used for planning and preparing, but only for monitoring drought. Adding that media, local managers, and state agencies use NADM products the most. The NOAA Climate Prediction Center issues the Monthly and Seasonal Drought Outlook products, which are 30-day and 90-day drought forecasts, using the USDM as a starting point and Canada is developing a 30-day forecast using the information compiled from its own national drought monitor.

Comments from survey respondents suggest that there are four basic purposes for accessing NADM products: analysis of drought conditions, research, communication, and data confirmation through comparison of the NADM with national drought monitors or other drought information sources. The following comments provide insight into how the NADM is used for each of these purposes:

Analysis

- "My primary concern pertains to drought as it impacts wildfire and to a lesser extent, potential impacts on forest health. The NADM provides me with a good regional overview vetted by experts that surpasses what I can produce on my own."
- "Used to determine when drought-related products need to be issued by the National Weather Service, collaborate with water officials to determine drought classification for eastern Kentucky."
- "NADM maps are used to monitor current and forecast future drought conditions, which impact local agricultural, fire, weather, hydrologic conditions, and weather forecasts."

Research

- "I have used NADM products to develop research regarding impacts of drought, as well as to develop watershed-based recommendations regarding drought mitigation and adaptation. They will also be used in the future to help local municipalities develop drought plans."
- "Used to develop drought simulation games, exploring the output's efficacy for comparative drought impacts."
- "Given my research interests in drought occurrence, I occasionally visit the NADM site to see where drought in North America is occurring, how fast it advances, how long it persists, and how quickly it terminates."

Communication

- "Since 2017 we include the NADM drought report for Puerto Rico in our weekly report on water monitoring and quality that is part of the podcast Repaso Noticioso."
- "As a meteorologist in the National Weather Service, the NADM data/products are useful in qualifying the extent and potential impacts of ongoing droughts (and putting droughts into historical context). This information is useful, and necessary, when composing Drought Information Statements, which are required to be produced by the National Weather Service when the drought reaches/exceeds certain drought levels."
- "Report to citizens of Calgary on general drought conditions and levels across the Province of Alberta, the prairies and Canada."
- "Largely for communications, explaining the causes of fluctuating water levels in the Great Lakes."
- "Drought information forms a part of the monthly North American Seasonal Fire Assessment and Outlook for wildland fire, to which Canada, Mexico and the United States contribute. Drought depictions also form part of the seasonal fire weather briefing content presented to the Canadian Interagency Forest Fire Centre and other Canadian agencies."

Data Confirmation

- "Sometimes, if there has been a different drought classification across the border in Canada, it has prompted deeper investigation into the data in the United States."
- "Monitoring areas outside of the continental US for potential impacts in my area of concern."
- "I advise and coordinate others who are making decisions at local, state, and federal levels, primarily on weather and water related issues, as they may directly or indirectly impact various public and private sectors. Plus, I provide direct/weekly input into the analysis of drought conditions for my geographic area of interest and occasionally spearhead that effort. The NADM is especially important to me because I quite often coordinate on cross-border (Canada/US) issues, ranging from drought status and weather and water related impacts across the sub-seasonal to seasonal spectrum."
- "Currently I rely on Ontario's surface water monitoring center for drought-related products; however, accessing the NADM products is a good check of conditions reported by the surface water monitoring center."
- "Comparing the data to that available in the MSM."
- "Comparison of rainfall/rainfall deficits with drought categories in the monitor maps."

Other common suggestions were to update the NADM on a bi-monthly schedule, and to add soil moisture conditions. Several users requested better access to gridded data, perhaps through a text file or File Transfer Protocol (FTP) site.

Canadian users requested the <drought.gov> supplemental website include more Canadian information, including links to national drought information such as the CDM, NADM and more detailed forecasting/predictions for Canada. Additional transboundary information suggestions included requests for cross-boundary river and forest fire conditions, extremes data for Mexico and more information on what is going into local drought classification decisions near the country borders. It was noted the "Drought Impact Reporter" form should be available in Spanish.[3]

[3] NDMC also produces the Condition Monitoring Observer Reports (CMOR) which is another citizen science drought impact reporting tool. Both the CMOR and the Drought Impact Reporter are available on the NDMC website. They are funded by NIDIS and operated by NDMC.

Presentation: NADM Use Assessment Survey Results: Preferred Types of Online Drought Management Resources

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The NADM use assessment survey asked respondents to choose how they liked to receive NADM drought information. A total of 74% chose via a website, and 53% chose via email subscription. Few respondents chose social media (29%), smartphone application (18%) or regular mail (2%).

When asked how often they accessed the NADM websites, the responses varied from one to two times per year to 12 or more times per year. One respondent commented they had accessed an NADM website once in the past decade, while another noted they used the NADM daily. A total of 27% indicated they had never accessed the main NADM website, 38% had never used the drought.gov supplemental website, and 40% had never used the NDMC supplemental website. Mexican respondents were the most likely to report they had not used the NADM websites, and US respondents were the least likely. Most Canadian and Mexican respondents had never accessed either the NDMC or drought.gov supplemental NADM websites, and most Mexican respondents had never accessed any of the three websites.

The breakdown of responses, by country, was as follows:

- Had never accessed the main NADM website: Canada, 23%; Mexico, 60%, United States, 17%.
- Had never used the NDMC supplemental NADM website: Canada, 67%; Mexico, 65%, United States, 19%.
- Had never used the drought.gov supplemental NADM website: Canada, 52%; Mexico, 59%, United States, 28%.

Survey respondents that had accessed the NADM websites were asked to score the usefulness of the information products available on each:

- Sixty-one percent of the respondents indicated the Monthly Drought Indicators and Data were very or extremely useful, and 57% reported the Monthly NADM Maps were very or extremely useful. The other products available on the website— Monthly NADM Text Discussions, Geographical Reference Maps, and NADM overview were not considered very or extremely useful by most respondents.
- All the products available on the NDMC supplemental website were scored as being very or extremely useful by most respondents. Percent Area in Drought was considered very or extremely useful by 70% of the respondents, followed by Change Maps (69%), Time Series Graphs (57%) and Statistics Table (56%).
- For the drought.gov supplemental website, Percent Area of North America was scored as being very or extremely useful by 55% of the respondents, and Time Series Graphs by 51%. Statistics Table and Percent of the North America Population in Drought were not considered very or extremely useful by most respondents.

When asked which of the websites best met their drought-information needs, the majority (66%) chose the NADM main website—including 86% of the Canadian respondents, 100% of the Mexican respondents, and 54% of the US respondents. Fifty-one percent of the US respondents also indicated the NDMC supplemental NADM website met their drought information needs (some respondents selected both). Only a minority of respondents indicated the drought.gov supplemental NADM website met their drought information needs.

Discussion questions:

- Most practitioners interact with NADM resources by email subscription or via websites. How can we improve your navigation of online resources and coordination for drought monitoring and management?
- A few official supplementary or secondary websites exist alongside national drought monitor websites for each country. How can we improve your connection with these resources and the analyses and reports you desire?
- For practitioners using secondary websites, many turned to geospatial reports and visualizations. How can we improve these?
- What data products or tools are missing from main and supplementary NADM websites?
- How else can we improve online drought monitoring and early warning resources in North America? Training and education?

Comments

A common suggestion for improving access to the NADM was to develop a well-maintained and easy-to-use downloadable "app" (application) for accessing and using the NADM products on smartphones. One commenter noted "it is 2020 and many folks do not have a computer, but they use a smartphone every waking hour of the day." This sentiment was emphasized for application to Mexico because most farmers and producers in Mexico have no access to computers.

Numerous respondents questioned why there were three different websites providing NADM products. They suggested it would be less confusing if there were only one website, or at least an overview that explains why there are three sites and what information is available on each. It was noted that perhaps a nongovernmental institution could host the NADM products on a single website.

Users also suggested it would be helpful to improve the linkages among the NADM websites, national drought monitors and other useful websites providing drought information. The idea of developing a single "landing page" that would provide an overview and links to the different websites would be valuable.

Several users commented on the NADM maps. One noted that the maps are understandable in a qualitative way but the data underlying the maps are not always clearly accessible. Suggestions included adding the option to view the NADM map in a GIS type interface where you could toggle on and off layers, and adding a map showing local impacts on agriculture.

Users suggested adding the following products and features to the NADM websites:

- Basin delineated time series of drought data, tabular and graphical, similar to what NOAA provides for the US.
- Links to crop forecasts, habitat conditions, remote sensing information.
- Finer streamflow indicators.
- Links to groundwater for irrigation and consumption, forest fire risk, crop stress and recreation.
- Hydrologic analysis for geographic areas that have snow storage that influences drought.

Regarding training and education, one simple suggestion was to add a frequent questions and answers page to each NADM website. Users also suggested it would be helpful if the NADM websites included how-to videos (possibly in the form of embedded YouTube videos) on using the different tools and customizing the information.

Discussion

The 2020 drought summit provided key insights into the realities and needs of practitioners working on drought monitoring, planning and management across Canada, Mexico and the United States. The purpose of the summit was threefold:

1. Convene and connect drought practitioners across Canada, Mexico, and the United States who are tasked with preparing, planning and managing drought.
2. Share experiences, challenges, and innovations in drought monitoring across North America.
3. Formulate recommendations to address information gaps and barriers in access to national and international drought resources and tools, and to improve coordination and communication to better monitor, plan for and respond to drought in North America.

The summit included two keynotes, seven presentations on products and tools from across the countries, thirteen case-study presentations by practitioners (titled "Our Stories"), and five consultations with experts and professionals to discuss the findings of two online surveys conducted by the CEC prior to the summit. These five consultations provided additional qualitative and contextual information about how drought products and tools were being used in North America. This was followed by structured interactive dialog to gather insights into the topics and inform the development of high-level recommendations for improving the drought monitoring products and tools available in North America.

The first and third consultations focused on the NADM and discussed barriers and realities that those designing products and tools need to understand to improve access and use of the NADM. Summit participants discussed the methodology and transparency surrounding the accuracy, applicability, relevance, and scale of analysis available by NADM tools. Also discussed were the role and use of national drought monitors in relation to the NADM, local variance in reporting, and an assessment of what was missing.

The second consultation focused on "Action and Planning" and explored the gaps between knowledge and action in drought response. This focused on drought monitoring timeline needs for daily operations, analyses and forecasts for working with short and long-term drought.

The fourth consultation session focused on "Forms of Drought." From the survey results, participants learned that many respondents were concerned with agricultural and meteorological drought. However, drought also comes in ecological, hydrological and socioeconomic forms, and drought types can interact. North American drought tools and resources were discussed to gain insight into how they may better support responses to all types of drought, and what sort of reports and information may afford new insights to better address drought, its impacts and interaction with other systems. In addition, the unique needs of products and tools for responding to short- and long-term drought were discussed.

The fifth consultation session of the summit focused on "Online Resources of the Future." Participants learned that most drought professionals interact with NADM resources by email subscription or website access. Once inside the NADM and supplementary websites, many professionals turn to geospatial reports and visualizations. Discussion centered around how the navigation and experience of using online products, tools and resources may be improved and what data products or tools are missing from the NADM websites.

The insights acquired during the drought summit presentations and consultations are organized into the following eight discussion areas which then lead to a tabulation of high-level recommendations.

1. Awareness

Today, practitioners turn primarily to national drought monitors and resources which are perceived to be "very" or "extremely useful." A far lesser number of respondents across the three nations find continent-wide resources to be useful to their work. However, presentations and consultations at the trinational drought summit revealed that emerging continent-wide tools and products retain great value and relevance to practitioners, but few are aware of these resources today. These include supplementary websites like NIDIS, NDMC, and newer resources that cover large areas of the continent, like those from the NADM, climateengine.org, and the Tzolkin Mesoamerican Drought Monitor.

When supplementary products and tools are used, professionals access drought products and tools from websites (45%) or email subscription announcements (32%). Supplementary websites, hosted by individual agencies, may reference or duplicate the same information from the NADM reports in multiple locations. This causes pages to compete actively with one another in online searches, causing confusion, and new professionals and those outside the current drought community who may use drought monitors only occasionally, may not know which tools are most relevant to their work and where to find new products and tools. For example, survey responses and consultations revealed that few people outside of the agricultural, hydrological, water resource, and meteorological professions have heard of or use continental drought resources from NADM in their work.

Increasing the user base for early warning products and tools, improving the awareness of available resources across user groups, and serving new users and sectors outside traditional drought science fields should be a priority. Potential users may be found in sectors like multi-hazard and emergency planning, public health, economic and social development, conservation and natural resource management, state or provincial and subnational governmental bodies, and other entities tasked with understanding and responding to drought or the economies and populations experiencing its impacts.

Further, it is not always clear when a new product or tool is released or updated and what its relevance might be to a practitioner's work. Since few professionals venture outside respective national drought monitor and NADM websites, there is a clear need to *improve the awareness and clarity of NADM online products and tools*.

2. Availability and Navigation

Summit participants and survey respondents using online products and tools noted that resources are scattered and that there are too many primary and secondary drought information websites hosted by an array of agencies and organizations.

Most survey respondents navigate to the NADM website six to twelve times per year and find it to be a useful website, strengthened by the release of monthly reports and forecasts. But some 75% of respondents address short-term drought (lasting from one to six months) at a frequency of only three to five times per decade.

However, in the search for supplementary-scale products and tools to face these drought events, professionals at regional and local levels lack clarity. They also expressed a lack of confidence about which resource they should turn to, and often faced "search engine competition" about which site was most relevant to their situation and needs. The professionals said that once inside the drought monitor websites of the three nations, they felt it was not always clear how to rapidly navigate to reports and make use of emerging powerful tools or download the most beneficial data.

As noted, most users of drought monitoring access these tools and resources online. However, some rural users still face Internet connectivity and bandwidth issues when trying to access data-intensive resources online. This creates a barrier for real-time data analysis and the effective use of emerging powerful data products and tools in remote and rural agricultural areas that are often impacted by drought. Professionals in these areas would like to access smaller-scale maps of specific regions to process the information faster.

Consultation sessions with professionals made clear the urgent need to reduce confusion and the multiplicity of pages, and to provide clear and effective navigation of North American drought tools and products. They suggested that this might take the form of one central website or landing page that could assist users to know what is available and in successfully navigating to drought information products and to the tools that most fit their needs and work. It would also reduce user confusion and search engine competition.

Practitioners desire products that are integrated and rapidly deployable, including ArcGIS-based tools and monthly shapefiles that can actively aid better management and decision-making on short-term drought.

Ensuring selective data downloads, efficient live data analysis, and smaller downloadable files will enable drought practitioners working with limited Internet access to have better access to the tools and resources needed in rural, drought-prone areas. For some practitioners, having a mobile application displaying current drought conditions and push-button notifications when new reports and tools are released would allow better application of products and tools in the field, and would also encourage users to access them more frequently. With these contextual considerations in mind, it is recommended that information providers *improve digital and online drought resources and data availability.*

3. Efficacy

Today, many who access their national-level drought monitors find them to be “very” or “extremely useful”; however, in comments and consultations it became clear that there are opportunities to improve the confidence of users who use these national data sources as well as the continent-wide drought monitoring resources.

Most practitioners work predominately on short-term and novel forms of drought, which require shorter timescales for response, informed by frequent reporting. Current drought monitors and resources deemed “extremely useful” by drought practitioners offer data that are easily accessible and can be interpreted at appropriate scales.

Reporting variances remain between local conditions and regional drought reports. This causes local practitioners to have concerns about the dependability and efficacy of drought reports. Practitioners quite reasonably desire products and tools that assist near-term forecasting, that better forecast drought types and impacts across their region, that offer reliable weekly or bimonthly reports with satellite information, and present indicators relevant to local conditions. A lack of clarity remains in national and continental drought report methodology, in the indices, in the level of uncertainty, and even in the calculations. Thus, it is logical that professionals, both observers and active participants, desire to improve the timeliness, dependability, scale, and availability of information in drought reports.

Engaging with uncertainty, current limits of predictability in drought science shape modern drought reporting. Communicating methodology and how uncertainty is engaged in the national drought monitors and the NADM was discussed across consultations. While uncertainty is very difficult to express at a continental scale when using large assemblies of indicators and models, it is not expressed in the NADM or national monitors. Instead, expressing the bounds of uncertainty at regional and local scales was cited as more feasible.

Uncertainty here can be communicated either mathematically or as a description of confidence (high, medium, or low). Drought professionals receive feedback from those they serve when reports are imprecise. Current limits of predictability can be improved, by communicating the bounds of uncertainty more effectively in reports and forecasts.

Furthermore, imprecise or infrequent reports make planning and response more difficult and may hinder professionals from responding effectively to drought conditions, risks, and losses at the local level. Instead, empowering them as local observers to comment on drought forecasts—especially when confusion or inaccuracies are present— could greatly increase the public's confidence in the reliability of drought reports used at the local level.

The Canada Drought Monitor editor and online review tool in ArcMap offers local observers and professionals the ability to comment and mark conditions, variances and discrepancies on live digital drought maps. This offers an emerging example of how products can actively involve local perspectives and better reflect local conditions—greatly improving the efficacy of tools and products.

Lastly, some practitioners would like to have a greater understanding of the data quality, level of certainty and methodology behind the indicators and how reports are made. Professionals felt that having transparency in how the tools function and the ability to give feedback may improve their confidence using the products and tools across the continent.

These key insights from consultations made it clear that frequent reports and forecasts may better serve the needs of practitioners faced with short-term drought. Furthermore, drought reporting and monitoring systems may improve the confidence of users by increasing transparency. This could even include disclosing the level of uncertainty or providing disclaimers about the capacity of the tool or product.

Lastly, engaging local observers so that reports can better reflect local conditions will enhance user confidence and improve the value of drought early warning resources. From these insights, it is clear how products and tools can be shaped, and it is recommended that information sources *improve the efficacy of drought reporting and forecasting***.**

4. Multipurpose Use

One key theme which emerged in the discussions is the need to develop products and tools for diverse users to be employed across drought resilience activities in unique applications. When products or tools for dealing with drought are designed only for specific activities by certain types of users, this may limit a tool's long-term viability, its application by a broad spectrum of users, and ultimately its value to drought resilience professionals.

Drought professionals look to a variety of resources in their work, from the historical record, to real-time observations and models. They need to assess vulnerability to drought, report the current severity of a drought, and develop appropriate policy actions to prepare for or respond to drought. Professionals using North American drought tools and supplemental resources today experience information overload, and simply lack the capacity or time to navigate scattered resources, complex raw data sets and deploy analysis in different drought contexts.

Instead, they would like to be able to find relevant data rapidly, tailor and download information for their regions and for relevant analyses. Experts working in hydrology and integrated water resource management noted the need to integrate drought conditions and their impacts across the entire water balance—an equation that includes monitoring precipitation, evapotranspiration, streamflow, groundwater storage, recharge, runoff and change in storage.

The topic of better defined and more universally recognized drought triggers and thresholds was brought up in the Summit. Triggers and thresholds help determine specific, timely actions by local and regional decision makers, and often are the links between drought impacts and indicator values. While set at state, provincial and local levels, triggers and thresholds often interact with national drought monitors, indicators and reports.

Practitioners in Mexico and the United States desire products and tools that help them set clearer triggers and thresholds so that they can move from early warning to plan activation and response measures more effectively. Currently, the simple and effectively constructed scale of drought conditions used in the United States, hosted by the USDM and NIDIS at <drought.gov>, is cited by professionals as a common multipurpose tool and reference for setting thresholds. Conditions of D2 (Severe Drought) often trigger local and regional drought policy responses across sectors. This scale indicates drought conditions and impacts from D0 (Abnormally Dry) to D4 (Exceptional Drought) and are offered at the local ZIP code level.

For example, in Canada, the British Columbia River Forecast Centre and Drought Information Portal offers a case study in how a data product is used at the interface of drought conditions, water resources management, and provincial water regulation. In that province, indices capturing early season forecast and drought season core indicator thresholds are set forth in the drought response plan. When drought reports and conditions reflected in the portal indicate that critical environmental flow thresholds (CEFTs) have been reached, regulatory actions and protections for ecological flows and fisheries are administered.

Early monitoring systems and tools should involve many data sets, users, and uses to ensure that tools can be used to accurately inform drought resilience activities. For their use in analysis and to allow early warning resources to be used most effectively to build drought resilience, drought information tools should be selective by region and scale. Furthermore, drought information products and tools should support the development of thresholds and triggers, and be able to rapidly create tailor-made maps, downloads and analyses to meet user needs across drought resilience workstreams. Lastly, drought events, both short- and long-term, need to be understood in how they interact with other changes, including long-term industrial uses, urban development, land-use changes, and climate change.

The versatility and value of future products and tools for drought can be strengthened by developing drought monitoring that integrates all the above factors and transmits those insights into user interfaces to be used across applications by drought practitioners. With the use of early warning products and tools to further drought resilience efforts, it is recommended that information sources *create multipurpose products and tools*.

5. Gaps and Lags

In sparsely populated areas—notably mountainous regions, rural agricultural areas, or the Arctic—remote sensing density and data gaps make accurate reporting and development or use of early warning systems difficult:

- Major improvements have been made in remote sensing of drought in the past 40 years, especially in environmental and vegetation remote sensing, but gaps in systemic monitoring and lags in data collection remain, causing blind spots for practitioners and delaying responses to short-term drought. This impacts effective monitoring of drought's social, economic, ecological and health impacts, or of documenting novel forms of drought, land use change, development, and human activity.
- Sufficient density of weather station placements remains a challenge for drought early warning systems and, too often, high spatial resolution data does not reflect nuances of local drought conditions. This leads to regional assessments with local inaccuracies and missing nuances which make early warning systems less reliable for rural drought practitioners.

Improving the density of sensors and remote sensing accuracy through expanded local observer networks, agricultural range monitoring, and transboundary monitoring initiatives may address gaps present today and improve the value of early warning systems for regional users. Engaging new sets of remote sensing data, open- and cross-sector data sets, may improve the sensitivity and accuracy of future early warning systems. There are emerging opportunities for integrating indicators that capture drought occurrence and impacts more accurately across systems (namely social, health and ecology). This increasing array of blended and composite indices, paired with open data approaches, offers an area for future collaboration and innovation in drought early warning systems.

Currently, 22% of practitioners surveyed incorporate local and Indigenous knowledge into their work, acknowledging the value of traditional and local ecological knowledge and its ability to provide a major opportunity to address gaps and provide foundational understandings of drought conditions, environmental change, potential impacts, preparedness, and response, but may not know where to begin.

Tribal and rural practitioners today may participate as observers in the drought reporting process, but respect for effective recognition and integration of local and Indigenous knowledge into drought early warning systems remains localized and underdeveloped. Trust, relationship building, understanding protocol and desires of Indigenous Nations to protect their tribal sovereignty and data, are cited as areas for meaningful improvement in the role they can play in addressing gaps in early warning systems and building drought resilience. With local observations and insights in mind, it is recommended agencies and drought monitors *address gaps in data and delays in reporting*.

6. Work Across Boundaries

Many summit participants shared their knowledge that drought conditions and impacts often cross political and watershed boundaries. Survey respondents and summit participants alike noted that there is currently a large array of tools and products available but hampered by poor coordination and cooperation among various groups and jurisdictions. Drought tools and products should reflect the transboundary reality of drought on the ground and provide a central resource for the multisectoral, multi-stakeholder and collaborative responses necessary to effectively address modern short- and long-term droughts. Consultations with professionals retold the fundamental value of established and trusted relationships, open communication, and coordination across jurisdictions *before* drought and emergency events occur.

Many turn to the same national and continental-wide drought early warning tools and products that provide improved observation, reporting, and coordination. Products and tools that are easy to find, that are interoperable and dependable across international and watershed boundaries have the potential to increase regional awareness of drought severity, cascading impacts and the complex coordination necessary to monitor, prepare, manage and respond to drought events.

Current ad hoc efforts between Tribal Nations and US states and collaborations along the international borders by Canada, Mexico, and the United States offer promise in the efficacy of drought tools. Efforts like the USDA Climate Hubs and the Drought Learning Network offer platforms for collaborative learning and responses to drought across political and watershed boundaries. With the transboundary nature and large footprint of drought in mind, and needs for effective coordination, it is recommended that agencies responsible for designing early warning systems *create tools and resources that support multi-sectoral and transboundary drought coordination*.

7. Training and Support

In order to support the six discussion areas above, training of North American drought practitioners in the use of the tools and products, the majority of which are digital and web-based, will further improve access and use. There is strong interest from professionals, across drought subfields and regions, to learn more about drought early warning resources and use them better. However, there are many barriers. Professionals cite limited time to learn new tools and there can be difficulties of access and having the resources necessary to complete professional development opportunities for a new resource. Worse, high turnover rates in staffing at agencies and organizations can nullify advantages that would seem to be gained by offering in-person training when the newly trained personnel leave. This leads to an inhibited uptake of new products and tools. Lastly, scientific jargon or field-specific differences in terminology in manuals and online technical support documentation, or poor translations of these, can render products and resources nearly incomprehensible, even for a resource that may prove invaluable to a drought professional with adequate training and support.

If practitioners are to use powerful products and tools effectively, then ongoing support and service to understand, navigate, and successfully utilize a new resource is required. Modern stand-alone learning resources and peer-to-peer learning networks have been recognized as effective tools in professional development, especially with evolving digital tools. Successful online tutorials and educational resources may include videos, user and troubleshooting guide blogs, documented answers to Frequently Asked Questions (FAQs), and chat support. More frequent workshops, when feasible, could provide demonstration and training on the use of new products. Other opportunities include routine monthly notifications of releases of new tools and educational resources.

Engaging available drought learning and professional development networks and associations may afford educational opportunities for drought professionals. Making professional continuing education credits available would further incentivize the use of educational materials and utilization of products and tools. Lastly, changes in product use must be reflected in improvements in the tools and creation learning resources as they are utilized for new purposes. Translating and defining terms and using clear language can make tools readily accessible to users across the sectors and fields relating to drought and its impacts. With current resources available and the needs of drought professionals in mind, it is recommended that managers and agencies responsible for designing early warning systems *develop training materials and support peer-to-peer networks*.

8. Enabling Policy and Resources

Currently, efforts to build products and tools are spread across multiple agencies in the three nations in North America. Funding constraints can limit effective national and multilateral collaboration for building products and tools, as well as response efforts and effective event planning at the scale and transboundary footprint of droughts. This leads to efforts that are isolated and insufficient to deal with drought events at the scale and frequency of those today and those in the decades to come.

Forward-looking policy and adequate resources are needed to catalyze development efforts for products and tools that will be appropriate for collaboratively monitoring and responding to drought risk across the continent. Strong collaboration, trust in products and tools, and communication before drought events and disasters occur, are cited as important to effective disaster response coordination.

Given the direction, capacity, and necessary resources, continent-level and national collaborations are possible in multi-stakeholder transboundary and trinational approaches to modernize drought early monitoring systems that serve North America. With continent-wide coordination and efforts to improve the widespread use of early warning systems now being reviewed, it is recommended that national agencies and respective governments *make resources and the necessary policy available to enable effective collaboration in drought early warning systems*.

Recommendations

Consultations and presentations with drought professionals at the trinational drought summit, in step with CEC surveys, offer a novel assessment of current realities and the needs of drought practitioners. From these observations and insights, eight thematic high-level recommendations are provided in the table below. Each recommendation is distinct but remains interconnected to the broader function of an improved drought early warning system in North America. For each recommendation, a series of strategic actions are suggested, based on the engagement and input of professionals. These actions provide pathways to actions intended to ensure that the drought early warning systems of tomorrow are accessible, responsive, and effective for the user, and will improve the resilience of the communities and sectors that they serve.

Table 1. Recommendations from the 2020 Trinational Drought Summit

No.	Recommendations	Actions
1	**Improve awareness and clarity of North American online drought resources**	a. Create a communications strategy to improve the visibility of current and emerging NADM products and tools. b. Partner with professional organizations, across drought relevant sectors, to improve awareness of NADM tools, products and new innovations in drought early warning systems. Engagement tools include recorded webinars, infographics, and stand-alone introductory videos and resources, distributed across networks.
2	**Improve online drought resources and data availability**	a. Create one portal to house and navigate NADM, CDM, MSM and USDM tools and products. b. Conduct user assessments on the barriers to use and the underutilization of the NADM and other national drought monitor tools. c. Consult users in the design of new drought monitoring resources. Consider co-design principles, employ commonly used language and be inclusive of the many users, sectors and systems affected by drought. d. Improve navigation and user controls of online drought data products. Provide a refined search function, the ability to select discrete geography and scale, and the ability to select and download specific maps, data sets, and code. e. Ensure that online and mobile tools and products can be used as cached, offline and with limited or varied internet bandwidths, to ensure drought practitioners with limited computing capacity receive vital early warnings and access to resources. f. Ensure code and data are open source and able to work across regions, applications, operating systems, and code languages. g. Develop and optimize mobile applications for users in the field who are engaged in drought monitoring, assessment, planning and real-time observations. h. Consider push button notifications for newly released reports and major changes in drought conditions.

Table 1 continued…

3	**Improve the efficacy of drought reporting and forecasting**	**a.** Increase the frequency of forecasts and data updates. When possible, pursue monthly, bi-monthly or weekly products. **b.** Ensure early warning systems can address gaps and disparities between regional climate reports and local conditions through observer and editor networks that allow observations and comments on current conditions and drought monitor reports. **c.** Provide access to data and indicator methodology in reports. **d.** Communicate the accuracy and level of certainty in data products and tools. Consider measures of confidence, convergence, and data quality.
4	**Create multipurpose drought resilience tools**	a. Develop and promote multisector data products and tools that integrate drought assessment, planning and management. b. Build tools that allow drought report interaction with thresholds and triggers for action. Ensure that common thresholds use clear language devoid of scientific jargon and are methodologically defensible. c. Allow for the incorporation of data sets and types.
5	**Address gaps in data and delays in reporting**	a. Identify data gaps, inadequate monitoring and observation, and source of delays in data processing and reporting. b. Explore technological and resource solutions, including artificial intelligence, to address gaps and delays in data processing and drought reporting. Consider real-time sensors and automation of drought calculations. c. Identify strategic opportunities for improved instrumentation in remote areas. d. Mobilize local and traditional knowledge into conventional drought monitoring and reporting systems while promoting Tribal Sovereignty and data sovereignty. d. Engage and expand citizen science and local observation networks for drought.
6	**Create tools and resources that support multi-sectoral drought coordination**	a. Ensure tools and resources promote inclusive, frequent, and effective collaboration in drought management between jurisdictions, languages, watersheds, and stakeholders. b. Support regional and transboundary drought dashboards to improve the interface of drought monitoring, data analysis, and decision-making. c. Promote stronger provincial or state participation in remote and northern areas.
7	**Develop training and support peer-to-peer networks**	a. Develop and implement a communications strategy to improve the awareness and use of core NADM and national drought monitors' resources. b. Develop clear and concise topical online instructional videos on the use of NADM and national drought monitors. c. Make educational material available to learning networks to improve NADM and national drought monitoring communities of practice. d. Provide online support resources such as FAQs, help contacts and bug reporting on NADM and national drought monitor websites.
8	**Create enabling policy and resources for collaboration in early warning systems**	a. Establish mechanisms for long-term trinational coordination of drought management and response. b. Provide resources for trinational and transboundary early warning systems joint task forces. c. Establish funding for larger NADM teams to build new and improved data products and tools which increase the effectiveness and efficiency of drought monitoring management and response.