Economic Impacts of Drought on Southwestern Tribal Economies

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SW Drought Impact Assessments

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Background

- Negative impacts of drought on agriculture
  - Hatfield et al., 2011; Fisher et al., 2012; Kuwayama et al., 2019
  - Crop losses, damage to pasture/range, reduced plant growth
  - Particularly concerning in arid Southwest

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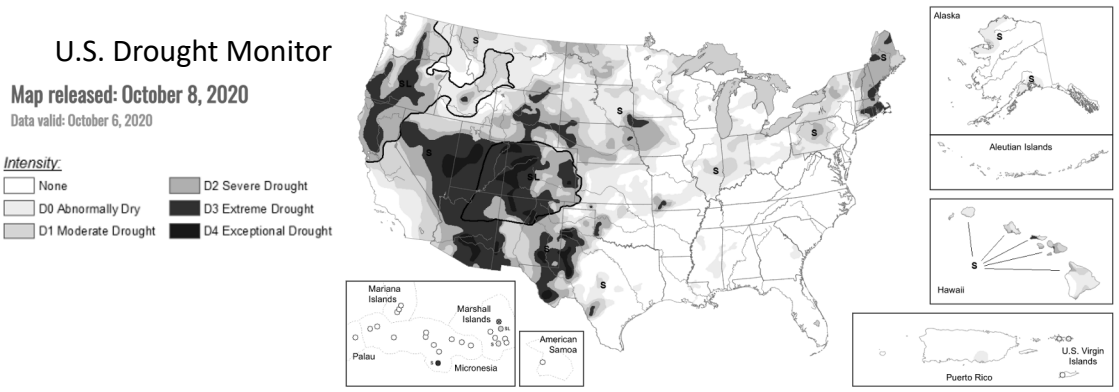
Background



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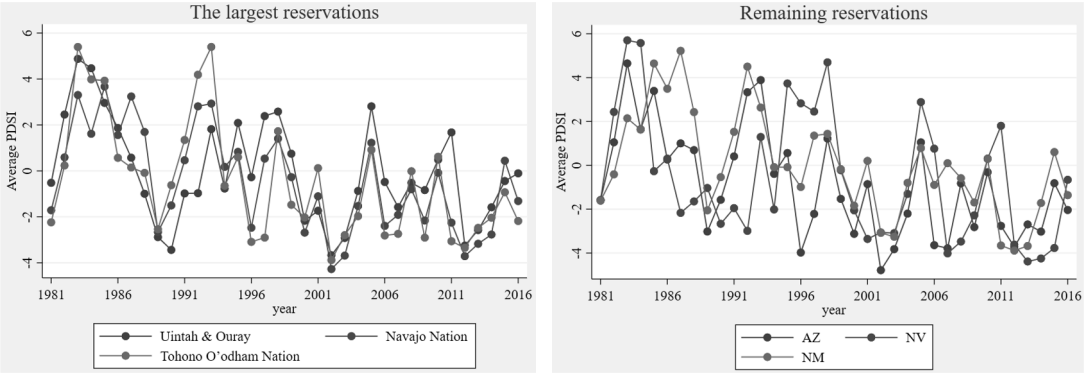
Drought on the Reservations



- Plots contain Palmer Drought Severity Index (PDSI) averaged across counties where a reservation is located
  - PDSI is constructed using temperature and precipitation data
  - PDSI ranges: 0 = normal conditions; >0 = wet conditions; <0 = dry conditions

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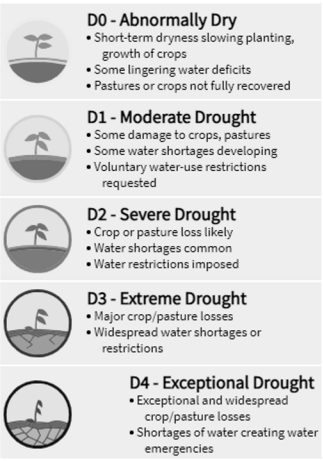
Percent Area in Drought

Drought Intensity	Area*	% Area in Drought		
		2012	2016	2020
Abnormally dry or worse (D0-D4)	Navajo Nation	93	77	92
	Tohono O'odham Nation	100	95	47
	Uintah & Ouray	96	48	91
	Remaining tribes AZ	99	88	67
	Remaining tribes NV	99	82	80
	Remaining tribes NM	97	72	81
Severe drought or worse (D2-D4)	Navajo Nation	47	0	57
	Tohono O'odham Nation	76	2	35
	Uintah & Ouray	62	2	42
	Remaining tribes AZ	61	0	46
	Remaining tribes NV	64	52	27
	Remaining tribes NM	54	0	33



*Area = counties where each tribe is located (county-level data available)

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Importance of Agriculture on SW Tribes

- Agriculture an important source of livelihood (Deol and Colby, 2018)
  - Share of jobs in agricultural and mining industry above U.S. average at 1.8%
  - Poverty levels among Native Americans above U.S. average at 11.8% (e.g. 39% on Navajo Nation and 47% on San Carlos Apache Res.)
- Agriculture also important to native culture and traditions
- 2017 Census of Agriculture (USDA NASS, 2019)
  - **Navajo Nation**: 16,000 farms, 16 million acres of land in farms (90% of all reservation land), $88 million market value of agricultural products sold
  - **Tohono O'odham**: 159 farms, 2.6 million acres of land in farms (91% of all reservation land), $8 million market value of agricultural products sold

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Importance of Cattle and Hay Production

- Livestock production is a significant part of the economy for SW tribes and part of traditional culture (Redsteer et al., 2013)
  - E.g., livestock sales on Navajo Nation make up 21% of all agricultural sales, cattle and calves are second most important after sheep and lamb (USDA NASS, 2019)

	% of Total Agricultural Sales in State		% of State Production for Reservation Counties	
State	**Cattle**	**Other Crops and Hay**	**Cattle Inventory**	**Hay & Alfalfa Acres**
Arizona	17%	10%	66%	56%
Nevada	37%	34%	50%	30%
New Mexico	24%	6%	15%	37%
Utah	21%	15%	13%	16%

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Drought Impacts on Livestock Production

- Potential climate change impacts on production (Nania et al., 2014)
  - Reduction of forage availability and quality
  - Invasive species thriving on Navajo Nation
  - Reduced water availability for livestock
  - Negative effects on livestock health
- Economic impacts on the Hualapai Tribe (AZ) (Knutson et al., 2007)
  - $1.6 million losses for livestock producers between 2001-2007
  - Herd reduced by 30% in 2001-2002, grazing reduced by 50% in 2004-2007

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Tribal Challenges in Drought Management

- Redsteer et al., 2013
  - Water rights settlement and ability to exercise of rights
  - Insufficient resources and expertise to monitor drought and climatic conditions
  - Pollution of water resources occurring outside tribal area
  - Conflict management and collaboration with federal and local governments and other stakeholders

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Research Questions

1. What is the impact of drought on agricultural sectors on southwest reservations?
   - Sectors selected for the study: cattle, hay
2. What is the overall economic impact of drought on southwest tribal economies?
   - Total impact due to drought affecting cattle and hay sectors directly

- Past studies examined total economic impacts of drought on agricultural sectors, but not in tribal economies specifically
  - E.g. Pérez and Hurlé, 2009; Bauman et al., 2013; Howitt et al., 2014

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Data

- County-level data for reservation counties (N=34)
  - Counties in Arizona, Nevada, New Mexico, Utah
  - Reservation areas of each county only
- Period: 1981-2016 (T=36)

- Cattle inventory, including calves – USDA NASS
- Hay yields, including alfalfa – USDA NASS
- Palmer Drought Severity Index (PDSI) – Cooperative Institute for Climate and Satellites, North Carolina
  - Compiled using temperature and precipitation data
  - Range from -10 (very dry conditions) to +10 (very wet conditions), typically -4 to +4

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Summary Statistics

Variable	Definition (Measurement)	Obs.	Mean	St. dev.	Min	Max
$Cattle$	Cattle inventory, incl. calves (head)	1,194	44,464	55,099	100	410,000
$\ln Cattle$	Natural log of cattle inventory	1,194	10.20	1.09	4.61	12.92
$HayYield$	Hay yields, incl. alfalfa (ton/acre)	972	4.44	1.58	0.90	10.00
$\ln HayYield$	Natural log of hay yields	972	1.43	0.35	-0.11	2.30
$PDSI$	PDSI value	1,224	-0.34	2.61	-5.27	7.40
$DryDur$	Duration of dry conditions (count of consecutive years, if PDSI<-1.9)	1,224	0.57	1.03	0.00	6.00
$WetDur$	Duration of wet conditions (count of consecutive years, if PDSI>1.9)	1,224	0.43	1.03	0.00	6.00

Notes: PDSI between -1.9 and 1.9 is considered "near normal" condition, according to the National Weather Service, Climate Prediction Center.

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Methodology

- Cattle – dynamic panel data analysis:
- $\ln Cattle_{c,t} = \beta_0 + \gamma \ln Cattle_{c,t-1} + \delta_1 PDSI_{c,t} + \delta_2 DryDur_{c,t-1} + \delta_3 WetDur_{c,t-1} + \beta_1 Trend_t + \upsilon_c + \varepsilon_{c,t}$

- Hay – panel data analysis (random effects):
- $\ln HayYield_{c,t} = \beta_0 + \delta_1 PDSI_{c,t} + \delta_2 DryDur_{c,t-1} + \delta_3 WetDur_{c,t-1} + \beta_1 Trend_t + \upsilon_c + \varepsilon_{c,t}$

- Total economic impacts: supply-driven social accounting matrix, IMPLAN data

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Results: Panel Data Models

	$\ln Cattle_t$		$\ln HayYield_t$	
	Coefficient	St. Error	Coefficient	St. Error
$\ln Cattle_{t-1}$	0.721***	0.102	-	-
$PDSI_t$	0.003*	0.002	0.004*	0.002
$DryDur_{t-1}$	-0.019**	0.007	-0.006	0.007
$WetDur_{t-1}$	-0.002	0.010	0.013**	0.005
Constant	8.939**	3.705	2.016	1.387
$Trend_t$	-0.003**	0.001	0.000	0.001
Number of obs.	1155		950	
Wald $\chi^2(5)$	196.49***		19.93***	

Notes: ***,**,* denote significance at 1%, 5%, and 10% level, respectively.

One unit decrease in PDSI:
- cattle inventory -0.3%
- hay yield -0.4%

One year of drought in the past:
- cattle inventory -1.9%
- hay yield no impact

Lagged impact of drought on cattle inventory, not on hay yields.

These results used to calculate impacts of drought scenarios.

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Results: Drought Scenarios

Model	Scenario Description	Total Impact at *t*
Cattle	2-year drought: normal at *t-3*, PDSI decrease at *t-2* and stays the same at *t-1*, PDSI increase back up at *t*	-3.72%
Hay	Normal or dry at *t-1*, PDSI decrease by 2 units at *t*	-0.87%

These scenarios were used to calculate:

1. **Decrease in output** in a) cattle and b) hay sectors on each reservation
2. $ value of losses in a) cattle production and b) hay production on each reservation => **direct impacts of drought** on a) cattle and b) hay sectors
3. $ value of total economic losses for each reservation => **total economic impacts of drought**, driven by direct impacts in a) cattle and b) hay sectors

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Results: Drought Impacts

	Cattle Sector (Million $)	Hay Sector (Million $)
	Uintah & Ouray	
Direct impact	3.243	0.257
Total impact	8.243	0.693
	Navajo Nation	
Direct impact	3.502	0.111
Total impact	8.212	0.387
	Tohono O'odham Nation	
Direct impact	1.805	0.089
Total impact	7.408	0.490

	Cattle Sector (Million $)	Hay Sector* (Million $)
	Remaining combined, Arizona (a)	
Direct impact	1.684	0.030
Total impact	3.478	0.078
	Remaining combined, Nevada (b)	
Direct impact	0.264	0.005
Total impact	0.589	0.017
	Remaining combined, New Mexico (c)	
Direct impact	0.691	0.010
Total impact	1.585	0.056

(a) Hopi, San Carlos*, White Mountain*; (b) Duck Valley*, Goshute*, Pyramid Lake, Washoe Tribe*;
(c) Acoma*, Jicarilla Apache, Laguna Pueblo*, Mescalero Apache, Zuni

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Summary

- Droughts negatively impact cattle inventory and hay yields immediately in the same year conditions become drier
- Also, there is lagged effect of drought for cattle inventory, but not for hay yields
  - Reduced breeding stock results in smaller cattle inventory in the following years
- Large economic impacts of drought for reservations
  - Direct losses larger in the cattle sector, resulting in larger total economic impacts compared to the hay sector

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Conclusions

- Droughts represent a serious threat to the tribal economies
- Need to improve ability of tribal governments and producers to monitor, prepare for, and respond to droughts:
  - Resources and training to recognize onset of drought
  - Develop and implement strategies for drought adaptation and mitigation
  - Water rights settlement and financial support to build infrastructure
  - Collaboration with researchers, policy makers, local/state governments

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