The Impacts of Drought on Southwest Tribal Economies

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Research Impact Statement: The results of this study show that drought has significant and negative impacts on tribal economies in the US Southwest.

ABSTRACT: Drought negatively impacts agricultural productivity, often causing reduced crop yields and damage to pasture and rangelands. Droughts are particularly concerning for Native American reservations in the arid US Southwest, as agricultural production on the reservations provides an important economic base. This study evaluates the impacts of drought on the cattle and hay sectors and resulting economic impacts on tribal communities in Arizona, Nevada, New Mexico, and Utah. Panel data analysis is used to estimate the impacts of drought, assessed using the Palmer Drought Severity Index (PDSI), on reservation cattle inventory and hay yields. Then, the supply-driven social accounting matrix approach is used to quantify the total economic impacts on tribal economies given hypothetical drought scenarios. Results show that drought impacts cattle production more than hay/forage production. Each additional year of drought reduces cattle inventory by 1.9% in the following year. Further, for every unit decrease in PDSI each year, cattle inventory and hay yields decline by 0.3% and 0.4%, respectively. The drought scenarios examined result in hefty economic losses for large reservations area such as the Uintah and Ouray Reservation, Navajo Nation, and Tohono O'odham Nation. To alleviate the negative impacts of drought on reservation economies, hurdles which limit tribal ability to mitigate and adapt to drought and climate change impacts should be addressed.

(**KEYWORDS:** drought; Indian reservations; economic impacts; cattle; hay.)

INTRODUCTION

Climate change and the accompanying drought has become increasingly concerning in the U.S. and world-wide. Both have negative impacts on agricultural sectors and food security (Hatfield et al., 2011; Fisher et al., 2012; Kuwayama et al., 2019). Drought, in particular, often leads to heavy crop losses, damage to pasture/range, and reduced plant growth. Drought is especially concerning for Native American reservations in the arid southwestern U.S. For example, approximately 93% of the area where Navajo Nation—the largest Indian reservation in the U.S.—is located, experienced abnormally dry conditions in 2020, and 58% experienced severe drought or worse (U.S Drought Monitor, 2021). Indian reservations and Native Americans in general, regardless of location, are plagued by poverty levels above the U.S. average of 11.8% (Akee et al., 2015; Davis et al., 2016; U.S. Census Bureau, 2020a, 2020b). Additionally, agriculture represents an important source of livelihood among tribal communities (Deol and Colby, 2018) and the share of jobs in agriculture, forestry, and mining on many reservations exceeds the U.S. national average of 1.8% (U.S. Census Bureau, 2020a, 2020b). Thus, tribal communities are particularly vulnerable to the negative impacts of climate change and drought.

Threat to the viability of tribal economies is only one of the negative impacts of climate change and drought on the well-being of Native Americans. A life closely connected to the natural environment is a part of Native American culture, and climate change and drought affects their ability to maintain certain traditions. Lynn et al. (2013) describes in detail the negative impacts of climate change on traditional foods used in traditional diets or as a part of spiritual ceremonies. Drought also negatively impacts the health of tribal communities through higher microbial contamination of public water, spring flooding, damaged underground drinking water lines, and higher heat exposure during outdoor ceremonies (Doyle et al., 2013). Cozzetto et al. (2013) discuss a variety of factors that increase tribal vulnerability to the impacts of climate change, as well as examples of how reservations across different regions, including the southwest, are impacted.

As climate change and drought have the potential to threaten the well-being of tribal communities in multiple ways, it's important that tribes can prevent or mitigate the impacts of drought. However, tribes face challenges that limit their ability to mitigate drought or exacerbate their vulnerability to drought (Redsteer et al., 2013). First, many tribes face unsettled water rights issues that limit access to water resources (Jacobs et al., 2001). Water rights were reserved to them through the *Winters* doctrine (*Winters* v. *United States*, 1908), but must be claimed and quantified through a settlement or litigation process, which can be lengthy and complex. Even if they succeed in securing their water rights, they may lack funding to build the infrastructure needed to exercise their rights (Cozzetto et al., 2013). In addition to that, tribes have limited authority when it comes to preventing the pollution of the water resources outside their reservation area, which affects the quality of the water on the reservation (Cozzetto et al., 2013, Chief et al., 2016). Another issue that tribes experience is a lack of labor and financial resources to monitor weather, soil, and vegetation conditions, identify the onset of drought, and take action to prevent or mitigate damaging drought impacts (Knutson et al., 2007; Redsteer et al., 2013). Understanding the impacts of drought on agricultural production and overall tribal economies can support adoption of policies that will improve the ability of tribes to monitor, prepare for, and respond to droughts.

Several studies have examined the economic impacts of drought on agricultural sectors (Diersen and Taylor, 2003; Wheaton et al., 2008; Pérez and Hurlé, 2009; Dellal and McCarl, 2010; Bauman et al., 2013). However, few studies examine the economic impacts of drought on tribal communities, and particularly those that are vulnerable to drought due to their location in the arid southwest and their reliance on agriculture for subsistence and cultural traditions. For example, Knutson et al. (2007) estimated that livestock producers in the Hualapai Tribe lost $1.6 million between 2001 and 2007 because of a 30% herd reduction brought on by a 50% loss in grazing efficiency due to drought.

The current study aims to fill the gap by estimating the impacts of drought on the productivity of selected agricultural sectors, as well as overall impacts to tribal economies in southwestern U.S. Additionally, we employ an approach to overcoming a lack of agricultural data on the tribal level which may prove useful in the presence of data unavailability for other studies. In this study we focus on the cattle and hay sectors since cattle and hay production are among the major agricultural activities in the studied region. For example, livestock sales on Navajo Nation are 21% of all agricultural sales, and cattle and calves are the second most important livestock group after sheep and lamb (USDA NASS, 2019). Also, livestock is a traditional source of livelihood and plays a significant role in many tribal economies, including Navajo Nation, San Carlos Apache, White Mountain Apache, Hopi, Uintah and Ouray, and Tohono O'odham Nation (Redsteer et al., 2013).

Nania et al. (2014) provide examples of how climate change and drought impact livestock production in the southwest, focusing on Navajo Nation. They describe how drought impacts availability and rangeland quality, water, and livestock health, as well as what factors make this region more vulnerable to drought and what adaptation and mitigation strategies can be implemented. The objective of this study is to understand how drought impacts productivity in the cattle and hay sectors in Indian reservation areas of the arid southwest, as well as how the associated reduced output affects activity in other sectors to demonstrate the economic significance of drought for economically disadvantaged tribal communities.

METHODS

Reservations of Study

The reservations included in this study are located in the southwest U.S. and include reservations in Utah, Arizona, New Mexico, and Nevada. Table 1 provides a list of the reservations and the counties in which they are located. The total area of each reservation and the reservations' share of each county is also shown. The economic indicators and primary sectors differ for each reservation in terms of poverty levels, unemployment rates, and share of employment in the agriculture, forestry, fishing, and mining sector (see Table 2). However, all currently have poverty levels above the U.S. average of 11.8% (2018), but range widely from 13.8% for the Washoe Tribe to 47% for the San Carlos Apache Reservation (U.S. Census Bureau, 2020b). Also, the unemployment rate is higher among the study reservations than the U.S. average of 5.9% in 2018, ranging from 6.4% on the Hopi Reservation to 34.4% on the White Mountain Apache Reservation (U.S. Census Bureau, 2020b). The share of residents employed in the agriculture, forestry, fishing, and mining sector ranges from 0% on the Moapa River Reservation to 21.4% on the Uintah and Ouray Reservation (U.S. Census Bureau, 2020b).

Data Description

To estimate the impacts of drought on cattle inventory and hay yields we use county-level data (N=34) from 1981 to 2016 (T=36) as reservation specific data is not available or reliable for all reservations. Yearly cattle inventory including calves (head) and hay yield including alfalfa (tons per acre) data were provided by the USDA National Agricultural Statistical Service (USDA NASS, 2020). The range of values for cattle inventory and hay yields in the sample is relatively large—for example, cattle inventory ranges from 100 to 410,000 head. Transformation using natural logarithm reduces the range and thus the transformed data was used in the analysis (ln $Cattle$ and ln $HayYield$). For all reservations the mean cattle inventory was 44,464 head and mean hay yield was 44.4 tons/acre.

Monthly PDSI data on a county-level, compiled by the Cooperative Institute for Climate and Satellites, North Carolina, were collected from the Center for Disease Control and Prevention (CDC, 2018), and they were averaged to obtain yearly PDSI data ($PDSI$). PDSI values are calculated using temperature and precipitation data, and can range from -10 to 10, but typically from -4 to 4, where more negative/positive values represent drier/wetter conditions. During the observed period, continuous dry and wet conditions lasted up to six years. The highest annual average PDSI value across all reservations was 7.4 and the lowest -5.27 indicating times of very dry and very wet conditions in the study area. Figure 1 plots PDSI values over time alongside a) cattle inventory and b) hay yields, to examine possible relationships between these variables.

Table 3 provides a description and summary statistics for the variables used in the analysis. The variables $DryDur$ and $WetDur$ were constructed as counts of the consecutive years where yearly PDSI values were less than -1.9 and greater than 1.9, respectively. PDSI values between -1.9 and 1.9 are considered near normal conditions (National Weather Service, Climate Prediction Center).

Drought Impacts on Cattle Inventory and Hay Yields

In the first step of the analysis, we use panel data analysis to examine the direct impacts of drought on cattle inventory and hay yields. Panel data analysis is applicable, because we observe data for multiple cross-sectional units (N=34 counties) over multiple time periods (T=36 years). For drought impacts on cattle inventory, we estimate the following dynamic panel data model:

$$\ln Cattle_{c,t} = \beta_0 + \gamma \ln Cattle_{c,t-1} + \delta_1 PDSI_{c,t} + \delta_2 DryDur_{c,t-1} + \delta_3 WetDur_{c,t-1} + \beta_1 Trend_t + \upsilon_c + \varepsilon_{c,t} \quad (1)$$

Here, $\ln Cattle_{c,t}$ is the natural log of cattle inventory in county *c* and year *t* and $\ln Cattle_{c,t-1}$ is the natural log of cattle inventory in the previous year. We assume that ranchers maintain some inventory for breeding purposes so there is some dependency between cattle inventory across time periods. Including a lagged dependent variable as a predictor accounts for this dependency, and thus, a dynamic panel data model is estimated to obtain coefficient estimates. $Trend_t$ accounts for changes in cattle inventory over time, and υ_c and $\varepsilon_{c,t}$ are time-invariant and time-variant components of the error term.

To examine drought impacts, the model includes $PDSI_{c,t}$, a PDSI value in county *c* and current year *t*, and $DryDur_{c,t-1}$ and $WetDur_{c,t-1}$, which are counts of consecutive years of dry and wet conditions, respectively, recorded in county *c* in the previous year. It is assumed that dry conditions negatively impact the availability and/or cost of feed, such as hay and private pasture, as well as water. Depending on the drought severity, a rancher may be motivated to cull and sell a portion of their herd earlier than planned, which affects cattle inventory immediately, or in the first year of drought, as measured by the $PDSI_{c,t}$ coefficient in equation (1). However, we assumed that reduced breeding stock due to drought in one year will impact cattle inventory the following year as well, and $DryDur_{c,t-1}$ coefficient measures the lagged effect of drought. Additionally, it measures the negative effect of a long-term drought on cattle inventory, assuming it increases with each additional year of drought. Further, there is likely a non-linear relationship between a change in PDSI and cattle inventory, assuming that neither extremely dry nor wet conditions are optimal for cattle production. A change in PDSI by several units is assumed to affect cattle inventory differently, depending on whether the conditions in the previous year were dry, normal, or wet. Including $DryDur_{c,t-1}$ and $WetDur_{c,t-1}$ variables in equation (1) controls for the conditions in the previous year when estimating the impact of a change in PDSI between two time periods.

To analyze drought impacts on hay yields, we applied the standard panel data model, since there is no dependency between hay yields in consecutive years. We verified this conclusion by estimating the dynamic panel data model which resulted in an insignificant coefficient estimate for the lagged hay yield variable. A Hausman test (Hausman, 1978) was performed to decide between fixed effects and random effects models. We estimated the following model

$$\ln HayYield_{c,t} = \beta_0 + \delta_1 PDSI_{c,t} + \delta_2 DryDur_{c,t-1} + \delta_3 WetDur_{c,t-1} + \\ + \beta_1 Trend_t + \upsilon_c + \varepsilon_{c,t} \quad (2)$$

where $\ln HayYield_{c,t}$ is hay yield in county *c* and time *t*, and the remaining variables are the same as described previously for the cattle model. It is assumed that drought impacts hay yields negatively in the current year, which is captured by the $PDSI_{c,t}$ coefficient, but $DryDur_{c,t-1}$ is also included to capture the potential lagged effect of drought, as well as the effect of drought duration.

Economic Impacts of Drought

Estimated coefficients for the impacts of drought on cattle inventory and hay yields from equations (1) and (2), i.e., panel data analysis, were used to calculate cattle and hay production losses under specified drought scenarios. We then calculated the dollar value of those losses for each reservation, which represent the direct impacts of drought on the cattle and hay sectors, needed for the subsequent economic impact analysis. Cattle inventory and hay production data for each reservation are needed to calculate direct impacts. Since these data are not available, we use county level data where each reservation is located and estimate the reservation's share of the cattle and hay production within each county in proportion to the reservations share of the county (acres). As agricultural sectors on the reservation interact with sectors outside the reservation, the use of county level data is intuitive, and results can be viewed as regional. Obtained county-level estimates of cattle inventory and hay production for each reservation are then summed up to obtain total reservation area estimates. These estimates may be higher or lower than the true values for each reservation area, but overall, they represent a fair approximation to the unobserved data.

Due to linkages between economic activities, reduced production in the cattle and hay sectors will indirectly reduce production in other sectors, which have a backward or forward relationship to the cattle and hay sectors. Sectors that provide inputs to cattle and hay production represent backward linkages, while sectors that purchase outputs from cattle and hay production represent forward linkages. For example, labor, machinery, feed, insurance, and veterinary services are inputs to cattle production and the demand for these inputs decreases if herd sizes are reduced due to drought. In turn, if cattle production is reduced, there will be fewer cattle to sell into the food system and meat production will decrease as well. The sum of the impacts on these sectors are indirect impacts of the drought (drought will likely affect some of these sectors directly as well, but the analysis of the overall impact of drought on all sectors is beyond the scope of this study). In addition, employee compensation within affected sectors will decrease and resulting reduced household spending will affect additional sectors throughout the local economy. This effect as well as reduced tax revenues due to all effects represent induced impacts of reduced cattle and hay production in the region due to drought. The sum of direct, indirect, and induced impacts is the total economic impact of drought.

To estimate indirect and induced impacts of the reduced cattle and hay output due to drought, we use a supply-driven social accounting matrix (SDSAM) approach, which is described in detail in Kim et al. (2017). The social accounting matrix (SAM) captures all economic relationships in a region (including transactions among sectors, government, and households), and the supply-driven approach to economic impact analysis estimates impacts due to an initial change on the supply side. The social accounting matrix and data is taken from IMPLAN (IMpact analysis for PLANning) and is modified to calculate the supply-driven impacts.

RESULTS AND DISCUSSION

Drought Impacts on Cattle Inventory and Hay Yields

Table 4 reports results of the models in equations (1) and (2). Both models show that drought affects cattle inventory and hay yields significantly, but differently. Focusing on the cattle model first, a one unit decrease in PDSI (i.e. a change towards drier conditions) is associated with 0.3% reduction in cattle inventory, as expected. Further, the negative and significant coefficient for $DryDur_{t-1}$ means that drought, defined as PDSI < -1.9, has a lingering negative effect on cattle inventory. A one-year drought is associated with a 1.9% decrease in cattle inventory in the year following the drought, and the overall impact of a particular drought increases with drought length. In summary, changes in PDSI and drought duration (i.e., consecutive years of PDSI < -1.9) have a significant impact on cattle inventory, and both need to be considered in the overall impacts of drought on the cattle sector.

As with cattle, a one unit decrease in PDSI is associated with a 0.4% decrease in hay yields. However, the coefficient for $DryDur_{t-1}$ is insignificant. This means that even if PDSI decreases below -1.9, hay yields are only affected negatively in the drought year and not in subsequent years, unless the drought continues. On the other hand, the positive and significant coefficient for $WetDur_{t-1}$ means that wet conditions (PDSI > 1.9) in the past year, as well as the duration of the wet conditions, affects hay yields positively.

Direct Impacts of Drought on the Cattle and Hay Sectors

Table 5 provides an overview of the defined, hypothetical drought scenarios and their impacts in terms of percentage change in cattle inventory and hay yields. The scenarios are worded similarly to allow comparison. However, since results of the cattle model show that drought duration (defined as PDSI < -1.9) matters, the scenario related to the cattle inventory ends with a return to pre-drought conditions at time *t*. The overall impact on cattle inventory at the end of the drought is approximately $d * \delta_2$, where d is duration of drought in years and δ_2 is the coefficient estimate for the drought duration (for simplicity, we assume that the effect of PDSI changes at the beginning and the end of the drought cancels out).

For hay, only the change in PDSI affects yields and the drought duration does not matter. The overall impact on hay yield is $x * \delta_1$, where x is the change in PDSI in units and δ_1 is the coefficient estimate for the PDSI. The percentage changes in cattle inventory and hay yields given the drought scenarios, as reported in Table 4, represent changes on a county-level. However, they represent an appropriate estimate of average impacts on Indian reservations, located in the counties included in the econometric analysis. It's assumed that precipitation and temperature (used in the calculation of PDSI) in the counties considered in the analysis are similar to those on the reservation(s) in those counties. Another important note is that although the estimated economic impacts reported on the following pages are based on the simplified and very specific drought scenarios in Table 4, the calculated impacts can be scaled up or down in proportion to any percentage changes in cattle inventory and hay yield.

Finally, we calculated the production losses and dollar value of the losses (i.e. direct impacts) in cattle and hay sectors for each Indian reservation. In addition to cattle inventory and hay yield data, additional data—value of cattle ($/head, state level), value of hay ($/ton, state level), and hay production (acres harvested, county level)—were obtained from USDA NASS (2020). To calculate losses, we used actual cattle and hay prices, which were observed in the year for which the IMPLAN dataset was available. Usually, reductions of agricultural supplies due to drought leads to increased pricing, which partially offsets the losses due to drought. However, our calculations do not account for this, which means that the direct impacts are partially overestimated.

Table 6 provides a summary of the calculated direct impacts of drought on the cattle and hay sectors (based on the drought scenarios in Table 5) in the studied reservations, grouped by state (primary state for Navajo Nation). Note that although the estimated cattle inventory losses are greater for the Uintah and Ouray Reservation area compared to those for the Navajo Nation area, the estimated dollar value of cattle losses is lower. This is due to the lower cattle prices used to calculate impacts for the Uintah and Ouray Reservation area ($1,180/head in UT in 2017; $1,390/head and $1,530/head in AZ and NM, respectively, in 2016).

The Total Economic Impacts of Drought

Tables 7-8 report the direct, indirect, induced, and total economic impacts of the drought scenarios for the cattle and hay sectors by reservation area. The impacts were calculated either separately for the largest reservations—Uintah and Ouray Reservation Navajo Nation, Tohono O'odham Nation—or they were combined for the smaller reservations in Arizona Nevada, and New Mexico. Specific impacts by sector and type for each reservation area can be found in appendix Tables A1-A6. Overall, the economic impacts of a drought directly impacting the cattle sector (two-year drought) are larger than the impacts on the hay sector (conditions becoming drier by two-unit PDSI decrease) across all studied reservation areas. Backward impacts (i.e., impacts on suppliers to cattle and hay production) range from $0.3 million combined for studied reservations in Nevada to $4.8 million for the Tohono O'odham Nation area for the cattle sector, and from $0.01 million for the Nevada reservations to $0.4 million for the Uintah and Ouray Reservation area for the hay sector. Forward impacts (i.e., impacts on the buyers of cattle and hay production) range from $0.02 million for the Nevada reservations to $1.4 million for the Uintah and Ouray Reservation area for the cattle sector, and from $0 for Nevada reservations to $0.1 million for the Tohono O'odham Nation area for the hay sector. Total economic impacts range from $0.6 million for Nevada reservations to $8.2 million in the Uintah and Ouray Reservation and Navajo Nation areas for the cattle sector, and from $0.02 million for Nevada reservations to $0.7 million for the Uintah and Ouray Reservation area for the hay sector.

Tables 7-8 also report multipliers, which are calculated as total economic impacts divided by direct impacts. A multiplier of *2* means that for every dollar, which is lost directly in the cattle or hay sector, an additional dollar is lost through indirect and induced effects. Among the three largest reservations, multiplier effects are strongest for the Tohono O'odham Nation area. This may be due to the urban character of the counties in which the Tohono O'odham Nation is located. The Navajo Nation and the Uintah and Ouray Reservation are in predominantly rural counties—associated with lower economic activity and weaker ties across sectors within a county.

As previously mentioned, the overall economic impact can be scaled up or down in proportion to the change in the direct impact, which in turn depends on the actual drought scenario (e.g., for one-year drought affecting cattle producers, estimated direct impacts and resulting total economic impacts would be half, holding all other conditions constant). Also, note that the drought affecting cattle ranchers directly impacts hay producers indirectly at the same time, since there is a backward linkage from cattle production to hay production, who supply hay to ranchers. Similarly, drought affecting hay producers directly affects cattle ranchers indirectly, since there is a forward relationship from hay production to cattle production. The impacts in Tables 7-8 represent impacts when these two sectors are affected by drought separately, not considering that they may be affected by drought directly at the same time. Finally, the economic impact analysis conducted here is based on the relationships between sectors and institutions, which are identified on a county level. It is possible that a sector exists in a county, but not on the reservation(s) located in the county.

CONCLUSIONS

This study examined the impacts of drought on the cattle and hay sectors for selected U.S. Indian reservation areas, located in the drought-prone states of Arizona, Nevada, New Mexico, and Utah. First, data for reservation counties was used in the panel data analysis to estimate the effect of changes in PDSI (i.e., temperature and precipitation) on cattle inventory and hay yields. Estimated percentage changes in cattle inventory and hay yields based on defined drought scenarios were used to calculate the direct impacts of drought conditions on the output value of the cattle and hay sectors for each reservation area. Finally, we applied the SDSAM approach to economic impact analysis to estimate total regional impacts of the drought-induced reductions in cattle and hay output.

Study results show that in the year when conditions become drier, hay yields decrease significantly, which results in reduced hay output, declined economic activity in related industries, and economic losses for the tribal economies of the arid southwest. While hay grown in the southwestern U.S. is primarily irrigated, surface and ground water levels may decrease significantly during periods of drought, and negatively impact irrigated crop yields (Elias et al., 2016). The results of the analysis here confirm previous findings.

Cattle producers, as hay buyers, are impacted by drought through reduced hay availability, but also reduced availability and quality of grazing and water resources, and even increased susceptibility to pests (USDA, 2017). These issues may motivate cattle ranchers and producers to cull or sell cattle earlier than planned, which reduces the breeding stock and negatively impacts cattle inventory in the later years as well. As in case of hay, reduced economic activity in cattle sector also leads to significant economic losses for Indian reservations.

We find that a change towards drier conditions impacts hay and cattle productivity differently. Hay producers experience reduction in productivity through reduced hay yields immediately during the year when the conditions become drier, but the yields in the next year are not impacted. On the other hand, if cattle producers respond to drier conditions by reducing cattle inventory, this implies a smaller breeding stock and less cattle production in the year following the drought, i.e. the effect of drought on cattle production is both immediate and lagged. The larger economic contribution of cattle production compared to hay production in the region, coupled with the extended effects of drought on cattle production beyond the year of drought, results in larger estimated economic losses derived from the direct impacts of drought on cattle sector compared to hay sector. Although estimated disruptions in hay production due to drought are smaller, reduced hay availability may have considerable negative consequences for cattle production if it depends heavily on hay for feed as a result of reduced grazing efficiency.

This study is the first to examine the direct impacts of drought on selected agricultural sectors and resulting regional economic impacts, specifically for southwest Indian reservations. However, it is important to highlight the lack of reservation specific data is one of the study limitations. The calculated direct and total economic impacts are based on the estimates of the initial cattle and hay production within each reservation, but they may be larger or smaller than the actual (unobserved) production for a given reservation, which would have an over- or underestimating effect on the calculated impacts. Another limitation is the use of fixed cattle and hay prices in the calculation of the economic impacts, although commodity prices are volatile and respond to events such as droughts. This causes overestimation of the calculated economic impacts. It is unclear whether the underestimation of the impacts due to potentially underestimated cattle and hay production in the reservations is compensated with the overestimation of the impacts due to not accounting for the change in cattle and hay prices during drought. Despite that, our findings represent a fair approximation to the actual impacts.

Study findings show that drought can have significant negative effects on tribal economies by negatively impacting productivity in agricultural sectors, similarly as it does across the U.S. However, the impacts of drought and climate change are more severe for reservations, where agriculture plays an important role in tribal economies and is a source of subsistence in many communities, and where the ability of tribal governments to respond to drought is limited. As a result, these impacts likely exacerbate unemployment and poverty issues on the reservations. Our findings show that it is important that the tribes can monitor drought, as well as identify and implement actions for climate change and drought adaptation and mitigation. For them to do so successfully, financial, and human resources as well as collaboration with researchers, policy makers, state and local governments and stakeholders may be critical (Knutson et al., 2007; Redsteer et al., 2013; Chief et al., 2016). Agricultural producers specifically may benefit from training and tools to recognize the onset of a drought, learn about different strategies to respond to drought and their implications, as well as access to financial assistance needed to implement these strategies (Knutson et al., 2007). Finally, allowing reservations access to their water resources by simplifying the water rights settlement process and providing financial support to build the necessary infrastructure can help alleviate the drought and its negative impact on reservation economies.

APPENDIX

Table A1. Economic impacts of drought, Uintah and Ouray Reservation Area, 2017 data.

	Cattle sector (million $)			Hay sector (million $)		
	Backward	Forward	Total	Backward	Forward	Total
Direct impact	**-**	**-**	**3.243**	**-**	**-**	**0.257**
Impact on output by sector (indirect)	1.142	1.384	2.526	0.108	0.014	0.122
Ag forest & hunting	0.065	0.011	0.076	0.007	0.002	0.009
Hay	0.092	0.005	0.097	n/a	n/a	n/a
Cattle ranching	n/a	n/a	n/a	0.000	0.007	0.008
Other livestock	-	-	-	-	-	-
Mining	0.041	0.000	0.041	0.007	0.000	0.007
Utility	-	-	-	-	-	-
Construction	0.034	0.000	0.034	0.003	0.000	0.004
Manufacturing	0.035	0.027	0.062	0.002	0.001	0.002
Slaughtering	0.000	1.338	1.338	0.000	0.004	0.004
Wholesale	0.225	0.000	0.225	0.008	0.000	0.008
Other retail	0.043	0.000	0.043	0.007	0.000	0.007
Food retail	0.008	0.000	0.009	0.001	0.000	0.001
Transportation	0.096	0.000	0.096	0.004	0.000	0.004
FIRE[1]	0.429	0.000	0.429	0.062	0.000	0.062
Government	0.075	0.000	0.075	0.006	0.000	0.006
Impact on value added (indirect)	1.571	0.002	1.572	0.181	0.000	0.182
Employment compensation	0.449	0.000	0.449	0.107	0.000	0.107

Proprietary income	-0.233	0.000	-0.233	-0.016	0.000	-0.016
Other property income	1.290	0.000	1.290	0.090	0.000	0.090
Indirect business taxes	0.065	0.000	0.066	0.000	0.000	0.000
Impact on household (HH) income (induced)	0.706	0.005	0.711	0.117	0.001	0.118
Low income HH (up to 35k)	0.091	0.003	0.094	0.014	0.000	0.014
Medium income HH (35k-100k)	0.388	0.002	0.390	0.068	0.000	0.069
High income HH (over 100k)	0.226	0.001	0.227	0.035	0.000	0.035
State revenue (induced)	0.190	0.001	0.191	0.015	0.000	0.016
Indirect + induced impact	3.608	1.392	**5.000**	0.421	0.015	**0.436**
Total regional impact			**8.243**			**0.693**
Multiplier			**2.54**			**2.70**

Notes: [1] Finance, Insurance, Real estate, and Education

Economic impacts were estimated using 2017 IMPLAN data for Duchesne, Grand, Uintah, and Wasatch counties in Utah.

Table A2. Economic impacts of drought, Navajo Nation Area, 2016 data.

	Cattle sector (million $)			Hay sector (million $)		
	Backward	Forward	Total	Backward	Forward	Total
Direct impact	-	-	**3.502**	-	-	**0.111**
Impact on output by sector (indirect)	1.310	1.119	2.429	0.060	0.047	0.107
Ag forest & hunting	0.107	0.006	0.114	0.004	0.001	0.006
Hay	0.027	0.004	0.031	n/a	n/a	n/a
Cattle ranching	n/a	n/a	n/a	0.000	0.014	0.014

Other livestock	0.005	0.012	0.017	0.000	0.000	0.000
Mining	0.016	0.000	0.016	0.001	0.001	0.003
Utility	0.062	0.000	0.063	0.004	0.001	0.005
Construction	0.024	0.001	0.025	0.001	0.006	0.007
Manufacturing	0.081	0.018	0.098	0.002	0.016	0.018
Slaughtering	0.000	1.069	1.069	0.000	0.000	0.000
Wholesale	0.240	0.000	0.241	0.003	0.000	0.004
Other retail	0.042	0.000	0.043	0.003	0.000	0.004
Food retail	0.007	0.000	0.008	0.001	0.000	0.001
Transportation	0.110	0.000	0.111	0.002	0.000	0.002
FIRE[1]	0.490	0.000	0.491	0.033	0.004	0.037
Government	0.097	0.007	0.104	0.005	0.002	0.007
Impact on value added (indirect)	1.398	0.001	1.400	0.084	0.004	0.089
Employment compensation	0.408	0.000	0.408	0.062	0.003	0.065
Proprietary income	0.001	0.000	0.001	-0.002	0.000	-0.002
Other property income	0.923	0.000	0.923	0.021	0.001	0.022
Indirect business taxes	0.067	0.000	0.067	0.003	0.001	0.004
Impact on household (HH) income (induced)	0.736	0.004	0.740	0.063	0.007	0.069
Low income HH (up to 35k)	0.132	0.002	0.134	0.011	0.002	0.013
Medium income HH (35k-100k)	0.388	0.001	0.390	0.036	0.003	0.039
High income HH (over 100k)	0.215	0.001	0.216	0.016	0.001	0.017
State revenue (induced)	0.140	0.001	0.141	0.007	0.004	0.012
Indirect + induced impact	3.584	1.126	**4.709**	0.214	0.063	**0.276**

Total regional impact			**8.212**			**0.387**
Multiplier			**2.34**			**3.49**

Notes: [1] Finance, Insurance, Real estate, and Education

Economic impacts were estimated using 2016 IMPLAN data for Apache, Coconino, and Navajo counties in Arizona, and Cibola, McKinley, Rio Arriba, San Juan, and Sandoval counties in New Mexico.

Table A3. Economic impacts of drought, Tohono O'odham Nation Area, 2016 data.

	Cattle sector (million $)			Hay sector (million $)		
	Backward	Forward	Total	Backward	Forward	Total
Direct impact	**-**	**-**	**1.805**	**-**	**-**	**0.089**
Impact on output by sector (indirect)	1.907	0.740	2.647	0.104	0.082	0.186
Ag forest & hunting	0.050	0.004	0.054	0.004	0.002	0.005
Hay	0.045	0.002	0.047	n/a	n/a	n/a
Cattle ranching	n/a	n/a	n/a	0.000	0.009	0.009
Other livestock	0.001	0.010	0.011	0.000	0.000	0.000
Mining	0.004	0.001	0.005	0.000	0.000	0.001
Utility	0.050	0.001	0.051	0.004	0.001	0.005
Construction	0.036	0.001	0.038	0.002	0.012	0.014
Manufacturing	0.107	0.012	0.120	0.004	0.032	0.036
Slaughtering	0.001	0.702	0.703	0.000	0.003	0.003
Wholesale	0.265	0.001	0.266	0.007	0.001	0.008
Other retail	0.085	0.001	0.087	0.005	0.002	0.007
Food retail	0.014	0.001	0.015	0.001	0.000	0.001
Transportation	0.127	0.001	0.128	0.004	0.001	0.005

FIRE[1]	1.029	0.001	1.031	0.068	0.017	0.085
Government	0.091	0.001	0.092	0.005	0.002	0.007
Impact on value added (indirect)	1.557	0.004	1.561	0.093	0.013	0.106
Employment compensation	0.673	0.001	0.674	0.056	0.008	0.065
Proprietary income	0.416	0.001	0.417	0.016	0.001	0.017
Other property income	0.384	0.001	0.384	0.016	0.002	0.018
Indirect business taxes	0.084	0.001	0.085	0.004	0.002	0.006
Impact on household (HH) income (induced)	1.196	0.014	1.210	0.075	0.017	0.092
Low income HH (up to 35k)	0.146	0.007	0.153	0.009	0.005	0.015
Medium income HH (35k-100k)	0.576	0.005	0.580	0.038	0.009	0.047
High income HH (over 100k)	0.475	0.002	0.477	0.027	0.003	0.031
State revenue (induced)	0.182	0.004	0.186	0.010	0.007	0.017
Indirect + induced impact	4.841	0.762	**5.604**	0.282	0.119	**0.401**
Total regional impact			**7.408**			**0.490**
Multiplier			**4.11**			**5.51**

Notes: [1] Finance, Insurance, Real estate, and Education

Economic impacts were estimated using 2016 IMPLAN data for Maricopa, Pima, and Pinal counties in Arizona.

Table A4. Combined economic impacts of drought, other Arizona reservations, 2016 data.

	Cattle sector (million $)			Hay sector (million $)		
	Backward	Forward	Total	Backward	Forward	Total
Direct impact	**-**	**-**	**1.684**	**-**	**-**	**0.030**

Impact on output by sector (indirect)	0.426	0.301	0.727	0.009	0.007	0.016
Ag forest & hunting	0.045	0.002	0.047	0.001	0.001	0.002
Hay	0.026	0.002	0.028	n/a	n/a	n/a
Cattle ranching	n/a	n/a	n/a	0.000	0.004	0.004
Other livestock	0.002	0.003	0.005	0.000	0.000	0.000
Mining	0.002	0.000	0.002	0.000	0.000	0.000
Utility	0.011	0.000	0.011	0.000	0.000	0.000
Construction	0.010	0.000	0.010	0.000	0.000	0.001
Manufacturing	0.007	0.005	0.012	0.000	0.002	0.002
Slaughtering	0.000	0.288	0.288	0.000	0.000	0.000
Wholesale	0.042	0.000	0.042	0.000	0.000	0.000
Other retail	0.020	0.000	0.020	0.001	0.000	0.001
Food retail	0.004	0.000	0.004	0.000	0.000	0.000
Transportation	0.035	0.000	0.035	0.000	0.000	0.000
FIRE[1]	0.185	0.000	0.185	0.005	0.000	0.005
Government	0.040	0.000	0.040	0.001	0.000	0.001
Impact on value added (indirect)	0.569	0.000	0.570	0.016	0.000	0.016
Employment compensation	0.148	0.000	0.149	0.009	0.000	0.009
Proprietary income	0.217	0.000	0.217	0.005	0.000	0.005
Other property income	0.192	0.000	0.192	0.002	0.000	0.002
Indirect business taxes	0.012	0.000	0.012	0.000	0.000	0.000
Impact on household (HH) income (induced)	0.438	0.001	0.440	0.014	0.000	0.014

Low income HH (up to 35k)	0.076	0.001	0.076	0.002	0.000	0.003
Medium income HH (35k-100k)	0.242	0.000	0.242	0.008	0.000	0.008
High income HH (over 100k)	0.121	0.000	0.121	0.003	0.000	0.003
State revenue (induced)	0.058	0.000	0.058	0.002	0.000	0.002
Indirect + induced impact	1.491	0.303	**1.794**	0.040	0.008	**0.048**
Total regional impact			**3.478**			**0.078**
Multiplier			**2.07**			**2.61**

Notes: Economic impacts combined for Hopi Res., San Carlos Apache Indian Res., and White Mountain Apache Indian Res. for cattle sector, and San Carlos Apache Indian Res. and White Mountain Apache Indian Res. for hay sector. Economic impacts were estimated using 2016 IMPLAN data for Apache, Coconino, Gila, Graham, Pinal, and Navajo counties in Arizona.

[1] Finance, Insurance, Real estate, and Education

Table A5. Combined economic impacts of drought, Nevada reservations, 2016 data.

	Cattle sector (million $)			Hay sector (million $)		
	Backward	Forward	Total	Backward	Forward	Total
Direct impact	**-**	**-**	**0.264**	**-**	**-**	**0.005**
Impact on output by sector (indirect)	0.110	0.018	0.127	0.003	0.000	0.003
Ag forest & hunting	0.003	0.000	0.003	0.000	0.000	0.000
Hay	0.006	0.000	0.007	n/a	n/a	n/a
Cattle ranching	n/a	n/a	n/a	0.000	0.000	0.000
Other livestock	0.000	0.000	0.001	0.000	0.000	0.000
Mining	0.000	0.000	0.000	0.000	0.000	0.000
Utility	0.002	0.000	0.002	0.000	0.000	0.000

Construction	0.002	0.000	0.002	0.000	0.000	0.000
Manufacturing	0.002	0.001	0.002	0.000	0.000	0.000
Slaughtering	0.000	0.016	0.016	0.000	0.000	0.000
Wholesale	0.024	0.000	0.024	0.000	0.000	0.000
Other retail	0.005	0.000	0.005	0.000	0.000	0.000
Food retail	0.001	0.000	0.001	0.000	0.000	0.000
Transportation	0.008	0.000	0.008	0.000	0.000	0.000
FIRE[1]	0.050	0.000	0.050	0.002	0.000	0.002
Government	0.006	0.000	0.006	0.000	0.000	0.000
Impact on value added (indirect)	0.105	0.000	0.105	0.004	0.000	0.004
Employment compensation	0.048	0.000	0.048	0.004	0.000	0.004
Proprietary income	-0.011	0.000	-0.011	0.000	0.000	0.000
Other property income	0.060	0.000	0.060	0.001	0.000	0.001
Indirect business taxes	0.008	0.000	0.009	0.000	0.000	0.000
Impact on household (HH) income (induced)	0.079	0.000	0.079	0.004	0.000	0.004
Low income HH (up to 35k)	0.009	0.000	0.009	0.000	0.000	0.000
Medium income HH (35k-100k)	0.042	0.000	0.042	0.002	0.000	0.002
High income HH (over 100k)	0.028	0.000	0.028	0.001	0.000	0.001
State revenue (induced)	0.013	0.000	0.013	0.000	0.000	0.000
Indirect + induced impact	0.307	0.018	**0.325**	0.011	0.000	**0.011**
Total regional impact			**0.589**			**0.017**
Multiplier			**2.23**			**3.15**

Notes: Economic impacts combined for Washoe Tribe, Duck Valley Indian Res., Pyramid Lake Indian Res., Goshute Res. for cattle sector and hay sector. Economic impacts were estimated using 2016 IMPLAN data for Douglas, Elko, Lyon, Storey, Washoe, and White Pine counties in Nevada.

[1] Finance, Insurance, Real estate, and Education

Table A6. Combined economic impacts of drought, New Mexico reservations, 2018 data.

	Cattle sector (million $)			Hay sector (million $)		
	Backward	Forward	Total	Backward	Forward	Total
Direct impact	**-**	**-**	**0.691**	**-**	**-**	**0.010**
Impact on output by sector (indirect)	0.192	0.105	0.297	0.008	0.010	0.018
Ag forest & hunting	0.007	0.000	0.008	0.000	0.000	0.000
Hay	0.001	0.000	0.002	n/a	n/a	n/a
Cattle ranching	n/a	n/a	n/a	0.000	0.000	0.000
Other livestock	0.000	0.001	0.001	0.000	0.000	0.000
Mining	0.001	0.000	0.001	0.000	0.000	0.000
Utility	0.004	0.000	0.004	0.000	0.000	0.000
Construction	0.002	0.000	0.002	0.000	0.001	0.001
Manufacturing	0.008	0.002	0.010	0.000	0.004	0.004
Slaughtering	0.000	0.101	0.101	0.000	0.000	0.000
Wholesale	0.030	0.000	0.030	0.001	0.000	0.001
Other retail	0.008	0.000	0.008	0.000	0.000	0.001
Food retail	0.001	0.000	0.001	0.000	0.000	0.000
Transportation	0.014	0.000	0.014	0.000	0.000	0.000
FIRE[1]	0.099	0.000	0.099	0.006	0.003	0.009

Government	0.016	0.000	0.016	0.000	0.001	0.001
Impact on value added (indirect)	0.415	0.000	0.416	0.010	0.004	0.014
Employment compensation	0.087	0.000	0.087	0.009	0.003	0.011
Proprietary income	-0.038	0.000	-0.038	0.000	0.000	0.000
Other property income	0.362	0.000	0.362	0.002	0.001	0.003
Indirect business taxes	0.004	0.000	0.004	-0.001	0.000	0.000
Impact on household (HH) income (induced)	0.162	0.001	0.162	0.008	0.005	0.013
Low income HH (up to 35k)	0.038	0.000	0.038	0.001	0.002	0.003
Medium income HH (35k-100k)	0.084	0.000	0.084	0.004	0.003	0.007
High income HH (over 100k)	0.040	0.000	0.040	0.002	0.001	0.003
State revenue (induced)	0.019	0.000	0.019	0.000	0.001	0.001
Indirect + induced impact	0.788	0.106	**0.894**	0.025	0.021	**0.046**
Total regional impact			**1.585**			**0.056**
Multiplier			**2.29**			**5.52**

Notes: Economic impacts combined for Acoma Indian Res., Jicarilla Apache Nation, Laguna Pueblo, Mescalero Apache Res., and Zuni Indian Res. for cattle sector, and Acoma Indian Reservation, Laguna Pueblo, and Pueblo of Isleta for hay sector. Economic impacts were estimated using 2018 IMPLAN data for Bernalillo, Catron, Cibola, Lincoln, McKinley, Otero, Rio Arriba, Sandoval, Socorro, and Valencia counties in New Mexico.

[1] Finance, Insurance, Real estate, and Education

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Table 1. Indian reservation, total area, and county location.

Reservation	Area (mi^2)	State and counties (% share of county area by reservation)
Hopi	2,533	AZ – Coconino (5%), Navajo (17%)
Navajo Nation	23,965	AZ – Apache (61%), Coconino (27%), Navajo (40%); NM – Cibola (5%), McKinley (43%), Rio Arriba (.04%), San Juan (60%), Sandoval (4%); UT – San Juan (25%)
San Carlos	2,926	AZ – Gila (21%), Graham (37%), Pinal (4%)
Tohono O'odham	4,454	AZ – Maricopa (2%), Pima (42%), Pinal (8%)
White Mountain	2,631	AZ – Apache (7%), Gila (17%), Navajo (10%)
Duck Valley	453	NV – Elko (1%); ID – Owyhee (3%)
Goshute	188	NV – White Pine (1%); UT – Juab (2%), Tooele (.04%)
Moapa River	111	NV – Clark (1%)
Pyramid Lake	730	NV – Lyon (.02%), Storey (0.25%), Washoe (11%)
Washoe	139	NV – Douglas (19%)
Acoma Pueblo	596	NM – Catron (.23%), Cibola (11%), Socorro (1%)
Jicarilla Apache	1,162	NM – Rio Arriba (20%)
Laguna Pueblo	784	NM – Bernalillo (7%), Cibola (11%), Sandoval (3%), Valencia (9%)
Mescalero Apache	720	NM – Lincoln (.01%), Otero (11%)
Pueblo of Isleta	179	NM – Bernalillo (15%)
Zuni Pueblo	705	NM – Catron (.01%), Cibola (4%), McKinley (9%)
Uintah and Ouray	6,728	UT – Duchesne (89%), Grand (9%), Uintah (64%), Wasatch (53%)

Table 2. Selected economic indicators by reservation (2018).

Reservation	Population below poverty level (%)	Employment in agriculture, forestry, fishing/hunting, and mining (%)	Unemployment rate (%)
Hopi	36.8	0.6	6.4
Navajo	39.5	3.5	18.1
San Carlos	47.0	5.4	30.4
Tohono O'odham	46.3	1.8	28.8
White Mountain	43.2	2.8	34.4
Duck Valley	36.2	9.5	18.4
Goshute	33.6	1.9	25.7
Moapa River	24.8	0.0	14.2
Pyramid Lake	19.0	6.5	18.7
Washoe	13.8	1.1	10.0
Acoma	21.7	3.4	17.8
Jicarilla Apache	27.3	3.8	18.6
Laguna Pueblo	27.0	3.2	21.3
Mescalero Apache	32.4	2.5	20.4
Pueblo of Isleta	26.6	2.0	13.0
Zuni	34.5	1.6	22.0
Uintah and Ouray	14.5	21.4	7.7
U.S. Total	11.8	1.8	5.9

Source: U.S. Census Bureau, 2014-2018 American Community Survey 5-Year Estimates

Table 3. 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 yield, incl. alfalfa (ton/acre)	972	4.44	1.58	0.90	10.00
$\ln HayYield$	Natural log of hay yield	972	1.43	0.35	-0.11	2.30
$PDSI$	PDSI value	1,224	-0.34	2.61	-5.27	7.40
$DryDur$	Consecutive dry years, if PDSI<-1.9	1,224	0.57	1.03	0.00	6.00
$WetDur$	Consecutive wet years, if PDSI>1.9	1,224	0.43	1.03	0.00	6.00

Notes: Data for T=36 years (1981-2016) and N=34 counties, reservation share only.

Table 4. Panel data model estimation results.

Dependent variable	$\ln Cattle_t$		$\ln HayYield_t$	
Independent variables	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 χ^2	65510.06***		19.93***	
Arrelano-Bond AR(1) test p-value[a]	0.003***		-	
Arrelano-Bond AR(2) test p-value[a]	0.373		-	
Hansen test p-value[b]	0.226		-	
Hausman test p-value	-		0.445	

Notes: Dynamic panel data model estimated with cattle data, random effects model estimated with hay data. Asterisks ***,**,* denote significance at 1%, 5%, and 10% level, respectively.

[a] These tests examine autocorrelation in the error term of the first order, AR(1), and second order, AR(2). The null hypothesis assumes autocorrelation is not present. The model is correctly specified if the null is rejected for the AR(1) test and not rejected for the AR(2) test.

[b] This test examines whether the instruments used during the estimation are valid. The null hypothesis assumes the instruments are valid and uncorrelated with model residuals.

Table 5. Drought impacts on cattle inventory and hay yields.

Model	Period	Conditions	Impact
Cattle	*t-3*	Near normal	0%
	t-2	PDSI decrease by 2 units below -1.9	-0.54%
	t-1	PDSI same as in *t-2*	-1.86%
	t	PDSI increase by 2 units to pre-drought level	-1.32%
		Total impact	-3.72%
Hay	*t-3*	Near normal	0%
	t-2	PDSI decrease by 2 units below -1.9	-0.87%
	t-1	PDSI same as in *t-2*	0%
		Total impact	-0.87%

Notes: Scenario impact represents percentage change in the cattle inventory (head) or hay yields (tons/acre) based on the results of cattle and hay models, respectively.

Table 6. Direct impacts of drought on reservation cattle and hay sectors.

Group # & reservation area	State(s) located	Loss in cattle inventory (head)	Loss in cattle value ($)	Loss in hay production (tons)	Loss in hay value ($)
#1 Uintah and Ouray[b]	UT	2,748	3,242,800	1,917	256,900
#2 Navajo[a,1]	AZ, NM	2,438	3,502,300	674	110,900
#2 Tohono O'odham[a]	AZ	1,298	1,804,700	584	88,800
#2 San Carlos Apache[a]	AZ	708	983,800	194	29,500
#2 White Mountain Apache[a]	AZ	253	351,600	2	300
#2 Hopi[a]	AZ	251	348,300	0	0
#3 Washoe Tribe[a]	NV	69	100,500	28	4,200
#3 Duck Valley[a,2]	NV	61	88,900	3	500
#3 Pyramid Lake[a]	NV	42	61,100	0	0
#3 Goshute[a,1]	NV	9	13,700	4	600
#4 Laguna Pueblo[c]	NM	152	199,200	31	7,600
#4 Jicarilla Apache[c]	NM	125	163,300	0	0
#4 Zuni[c]	NM	102	133,900	0	0
#4 Acoma[c]	NM	82	107,900	3	600
#4 Mescalero Apache[c]	NM	66	86,400	0	0
#4 Pueblo of Isleta[c]	NM	0	0	8	1,900

Notes: [a,b,c] denote that the impacts were calculated using 2016, 2017, or 2018 data, respectively. The year was determined based on the availability of the IMPLAN dataset used for the economic impact analysis. Cattle and hay value losses are rounded to the nearest $100.

[1] Direct impacts do not include counties in Utah, due to unavailability of the Utah 2016 IMPLAN dataset.

[2] Direct impacts do not include counties in Idaho, due to the unavailability of the Idaho 2016 IMPLAN dataset.

Table 7. Economic impacts of drought (million $), cattle sector.

Reservation Area(s)	Direct	Indirect		Induced		Total	Multiplier
		Backward	Forward	Backward	Forward		
Navajo[a]	3.502	2.708	1.120	0.876	0.005	8.212	2.34
Tohono O'odham[a]	1.805	3.464	0.744	1.378	0.018	7.408	4.11
Uintah and Ouray[b]	3.243	2.713	1.385	0.896	0.007	8.243	2.54
Remaining Arizona[a,1]	1.684	0.995	0.302	0.496	0.001	3.478	2.07
Remaining Nevada[a,2]	0.264	0.214	0.018	0.092	0.000	0.589	2.23
Remaining New Mexico[c,3]	0.691	0.607	0.105	0.181	0.001	1.585	2.29

Notes: Superscripts *a, b, c* denote that the 2016, 2017, 2018 IMPLAN dataset, respectively, was used to estimate economic impacts.

[1] Economic impacts combined for the Hopi Res., San Carlos Apache Indian Res., and White Mountain Apache Indian Res.

[2] Economic impacts combined for the Washoe Tribe, Duck Valley Indian Res., Pyramid Lake Indian Res., and Goshute Res.

[3] Economic impacts combined for the Acoma Indian Res., Jicarilla Apache Nation, Laguna Pueblo, Mescalero Apache Res., and Zuni Indian Res.

Table 8. Economic impacts of drought (million $), hay sector.

Reservation Area(s)	Direct	Indirect		Induced		Total	Multiplier
		Backward	Forward	Backward	Forward		
Navajo[a]	0.111	0.144	0.052	0.070	0.011	0.387	3.49
Tohono O'odham[a]	0.089	0.197	0.095	0.085	0.024	0.490	5.51
Uintah and Ouray[b]	0.257	0.289	0.014	0.132	0.001	0.693	2.70
Remaining Arizona[a,1]	0.030	0.025	0.007	0.016	0.001	0.078	2.61
Remaining Nevada[a,2]	0.005	0.007	0.000	0.004	0.000	0.017	3.15
Remaining New Mexico[c,3]	0.010	0.018	0.014	0.007	0.007	0.056	5.52

Notes: Superscripts *a, b, c* denote that the 2016, 2017, 2018 IMPLAN dataset, respectively, was used to estimate economic impacts.

[1] Economic impacts combined for the San Carlos Apache Indian Res. and White Mountain Apache Indian Res.

[2] Economic impacts combined for the Washoe Tribe, Duck Valley Indian Res., Pyramid Lake Indian Res., and Goshute Res.

[3] Economic impacts combined for the Acoma Indian Reservation, Laguna Pueblo, and Pueblo of Isleta.

Figure 1. PDSI compared to a) cattle inventory and b) hay yields in the study area, 1981-2016.

Notes: PDSI value, cattle inventory, and hay yields are averages across reservations by year.