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**Research Report:**

**The Economic Impacts of Drought on Navajo Nation**

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**Abstract:** Drought negatively impacts productivity in the agricultural sectors. Drought is particularly concerning in the arid Southwest, where agriculture plays an important role in the economies and traditions of Native American peoples. The objective of this study is to evaluate the impacts of drought on primary agricultural sectors for Navajo Nation, specifically cattle and hay production, applying panel data analysis, as well as the resulting total economic impacts applying the supply-driven social accounting matrix analysis. Study results show that drought has a larger impact on cattle production than hay production on Navajo Nation, resulting in total economic losses of \$8.2 million and \$0.4 million for the cattle and hay sectors, respectively.

**Key words:** Drought, Navajo Nation, Economic impacts, Cattle, Hay, PDSI

## **1 Introduction**

Climate change and accompanying drought negatively impacts the productivity of agricultural sectors by causing crop losses, damage to pasture/range, and reduced plant growth (Hatfield et al., 2011; Kuwayama et al., 2018). In the U.S., they are particularly concerning in the arid Southwest (SW), where agriculture represents an important part of the economies, as well as the culture and traditions of tribal communities (Deol and Colby, 2018; Redsteer et al., 2013). As tribal communities are also plagued by poverty levels above the U.S. average (Davis, Roscigno, and Wilson, 2016; U.S. Census Bureau, 2020), they are particularly vulnerable to the negative impacts of climate change and drought.

The objective of this study is to estimate the impacts of drought on cattle and hay production, as well as the overall economy of Navajo Nation, the largest Indian reservation in the U.S. Table 1 shows that poverty and unemployment rates on Navajo Nation are at least three times greater than the U.S. average, while median household income is less than half the U.S. average. At the same time, livestock contributes significantly to the economy and food security on Navajo Nation (Redsteer et al., 2013). Livestock sales represent around 21% of all agricultural sales on Navajo Nation, and cattle and calves make up roughly 19% of all livestock inventory, which come second after sheep and lamb (USDA NASS, 2020a). Further, hay is the most important crop, as hay and haylage represent roughly 67% of all crop acreage (USDA NASS, 2020a). Thus, drought may have a significant impact on cattle and hay productivity, and thus, may represent a serious threat to the well-being of the Navajo Nation communities.

## **2 Literature Review**

Few studies examine the impacts of droughts on native American tribes in the U.S. Knutson, Hayes, and Svoboda (2007) found that livestock producers in the Hualapai Tribe lost

approximately \$1.6 million between 2001 and 2007 due to drought, as a result of reduced grazing, feed, and water availability, which led to herd reduction. Nania et al. (2014) provided examples of climate change and drought impacts on livestock production on Navajo Nation, as well as other parts of Southwestern U.S. They describe how drought impacts the availability and quality of forage rangeland, water, and livestock health, what factors make this region more vulnerable to drought, and what adaptation and mitigation strategies can be implemented. Cozzetto et al. (2013) identify the impacts of climate change on ranching and agriculture to tribal communities.

Several studies examined the economic impacts of drought on agricultural sectors (e.g. Diersen and Taylor, 2003; Pérez and Hurlé, 2009; Dellal and McCarl, 2010; Bauman et al., 2013; Howitt et al., 2014). However, none examine the economic impacts of drought specifically on tribal communities, this study aims to fill this gap. We examine the severity of drought impacts on agriculture on Navajo Nation to highlight the importance of assisting tribes with preparation and response to drought, as well as addressing issues that exacerbate their vulnerability to drought.

### **3 Methods**

#### *3.1 Data*

Yearly cattle inventory including calves (head) and hay yield including alfalfa (tons per acre) data were collected from USDA National Agricultural Statistical Service (USDA NASS, 2020b). These variables were transformed using the natural logarithm. Monthly PDSI data, compiled using temperature and precipitation data by the Cooperative Institute for Climate and Satellites – North Carolina (CICS-NC), were obtained from the Center for Disease Control and Prevention (CDC, 2018), and yearly averages were calculated. PDSI values can range from -10 to 10,

typically from -4 to 4, where more negative/positive values represent drier/wetter conditions. Variables *DryDur* and *WetDur* were constructed as counts of consecutive years when yearly PDSI values were less than -1.9 and more than 1.9, respectively (values between -1.9 and 1.9 are considered “near normal” condition, according to the National Weather Service, Climate Prediction Center). The data spanned the period 1981 to 2016 (T=36) and included all counties with Native American reservations in Arizona, New Mexico, Nevada, and Utah (N=34). Table 2 provides an overview of variables and summary statistics.

### *3.2 Drought Impacts on Cattle Inventory and Hay Yield*

First, we apply panel data analysis to examine the direct impacts of drought on the cattle inventory and hay yields. We use current PDSI values, lagged duration of dry conditions, lagged duration of wet conditions, and trend as predictors in models for both cattle inventory and hay yields. For cattle inventory model, we also include lagged cattle inventory (i.e. dependent variable) as a predictor, as there is some dependency between cattle inventory in adjacent time periods since ranch managers need to maintain inventory for breeding purposes and dairy production.

### *3.3 Economic Impacts of Drought*

After estimating the impacts of drought on cattle inventory and hay yields, we calculate the dollar value of the cattle and hay output losses under specified drought scenarios for Navajo Nation. These dollar values represent the direct impacts of drought on the cattle and hay sectors. Estimated direct impacts are used for the estimation of the total economic impacts of drought. Reduced production in cattle and hay sectors due to drought will result in reduced production in other sectors, which either sell inputs to the cattle and hay sectors (e.g. feed, seeds, labor, veterinary services), or purchase outputs from the cattle and hay sectors (e.g. food processing).

The sum of these impacts are the indirect impacts of drought. In addition, employee compensation within affected sectors will decrease and resulting reductions in household spending will affect additional sectors throughout the local economy. This effect combined with reduced tax revenues represent induced impacts. The sum of direct, indirect, and induced impacts are the total economic impacts. Indirect, induced, and total effects are estimated using supply-driven social accounting matrix analysis (Kim, 2015; Kim et al., 2017).

## **4 Results**

### *4.1 Drought Impacts on Cattle Inventory and Hay Yield*

Results of the econometric analysis confirm that drought affects cattle inventory and hay yields negatively, but differently. First, a unit decrease in PDSI (i.e. a change towards drier conditions) is associated with 0.3% reduction in cattle inventory and 0.4% reduction in hay yields in the same year when the conditions become drier. Drought also has a long-term negative effect on cattle inventory, but not on hay yield. Each year of drought, such that PDSI is below -1.9, is associated with 1.86% decrease in cattle inventory in the following year.

### *4.2 Direct and Total Economic Impacts of Drought*

Since we find that drought affects cattle and hay production differently, we defined a specific drought scenario for each. The drought scenarios and associated impacts on cattle inventory and hay yields in terms of percentage change are reported in Table 3. We used these percentage changes to calculate cattle and hay output losses on Navajo Nation and associated dollar values, i.e. direct impacts of drought on cattle and hay sectors on Navajo Nation. The direct impacts and resulting indirect, induced, and total economic impacts are reported in Table 4.

Two-year drought reduces output of cattle sector directly by estimated \$3.5 million on Navajo Nation. Decrease in PDSI by 2 units reduces output of hay sector directly by \$0.1

million. Total economic impacts of drought on Navajo Nation are \$8.2 million and \$0.4 million for the cattle and hay sectors, respectively. Estimated impacts are larger for cattle production since drought affects cattle production in the long run, and cattle production is more prominent in the region. It is also important to mention that the drought affecting cattle production also indirectly affects hay production, and vice versa. The impacts reported in Table 4 represent impacts when these two sectors are affected by drought separately, not taking into account that they are likely affected by drought directly at the same time.

## **5 Conclusions**

This study examined the direct impacts of drought on cattle and hay production, as well as the resulting total economic impacts on Navajo Nation. Cattle inventory and hay yields decrease significantly in the same year when the conditions become drier. In addition, there is a lagged effect of drought on cattle inventory, but not hay yields. Cattle producers are impacted by drought through reduced availability and/or higher cost of feed, grazing, and water, which may motivate them to cull or sell cattle earlier than planned. This reduces the breeding stock and thus affects cattle inventory in the years following the drought. Although estimated disruptions in hay production due to drought are smaller, reduced hay availability may have large negative consequences for cattle production if it depends heavily on hay for feed as a result of reduced grazing efficiency. Overall, reduced cattle and hay production results in lower economic activity in related sectors and large economic losses throughout the region.

In conclusion, droughts represent a serious threat to the tribal economies, where agriculture plays an important role. Our results highlight the need for education and policy to improve the ability of reservations to monitor drought and implement actions for drought adaptation and mitigation. Financial and human resources as well as collaboration with

researchers, policy makers, state and local governments, and other stakeholders may be critical (Knutson, Hayes, and Svoboda, 2007; Redsteer et al., 2013; Chief, Meadow, and Whyte, 2016).

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**Table 1.** Selected Economic Indicators

Region	Population below poverty level (%)	Employment in agriculture, forestry, fishing/hunting, and mining (%)	Unemployment rate (%)	Median household income (\$)
Navajo Nation	39.5	3.5	18.1	27,361
U.S.	11.8	1.8	5.9	64,324

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

**Table 2.** Summary Statistics

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

Notes: Data collected over T=36 years (1981-2016) and N=34 counties. Cattle inventory and hay yield data not observed for some years/counties.

Dry and wet duration constructed as the number of consecutive years such that PDSI<-1.9 and PDSI>1.9, respectively.

**Table 3.** Drought Scenarios and Impacts on Navajo Nation Cattle Inventory and Hay Yields

Model	Scenario description	Total impact at <i>t</i>
Cattle	2-year drought: PDSI decreases below -1.9 and stays the same for two years, then increases back to the pre-drought level	-3.72%
Hay	PDSI decreases by 2 units	-0.87%

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

**Table 4.** Economic Impacts of Drought on Navajo Nation Cattle and Hay Sectors

	Cattle sector (million \$)			Hay sector (million \$)		
	Backward	Forward	Total	Backward	Forward	Total
<b><i>Direct impact (cattle/hay sector)</i></b>	-	-	<b>3.502</b>	-	-	<b>0.111</b>
<i>Impact on sectors (indirect)</i>	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	-	-	-
Cattle ranching	-	-	-	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 <sup>1</sup>	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
<i>Impact on VA (indirect)</i>	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
<i>Impact on HH income (induced)</i>	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
<i>State revenue (induced)</i>	0.140	0.001	0.141	0.007	0.004	0.012
<b><i>Indirect + induced impact</i></b>	3.584	1.126	<b>4.709</b>	0.214	0.063	<b>0.276</b>
<b><i>Total regional impact</i></b>			<b>8.212</b>			<b>0.387</b>

Notes: <sup>1</sup> Finance, Insurance, Real Estate, and Education