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# Droughts of the twentieth and early twenty-first centuries: Influences on the production of beef and forage in Kentucky, USA

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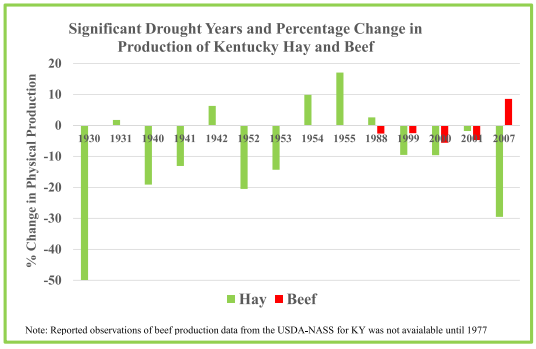
## HIGHLIGHTS

- Six severe droughts in Kentucky since 1930.
- Changes in hay and beef cattle yield, prices, and revenues during severe drought episodes.
- Hay production during severe drought years declined up to 49%.
- Beef cattle sales declined up to 47% during severe drought years.

## GRAPHICAL ABSTRACT

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## ABSTRACT

Drought affects societies world-wide in many different ways. It is a natural hazard that is complex and not well understood and as a result, its impacts are often poorly documented. The purpose of this research is to quantify (in dollars) the impacts of drought on Kentucky's beef and forage (hay) production. Observations suggest that the most important droughts in Kentucky occurred in 1930–31, 1940–42, 1952–55, 1987–88, 1999–2000 and 2007. The total state revenue for these commodities were analyzed during these severe drought years and non-drought years. The research estimated revenue deficit from these severe droughts in Kentucky for these (beef and hay) agricultural commodities. This study is important to the general public as well as planners and policy makers. Proper documentation of drought impacts should help identify drought vulnerabilities and result in better risk management and mitigation.



## 1. Introduction

Agriculture is an important sector in the global and national economies and is vulnerable to inter-annual climatic variability including drought (Tol, 2002; Touchan et al., 2010). Recently, Hartmann et al.

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(2013) noted that, globally, drought frequency and intensity has increased in some regions while decreased in others. A number of studies have investigated and demonstrated important negative impacts of drought on agriculture, including hay and cattle, in the U. S., Canada, Australia, Mexico, France, Turkey, China, Botswana, Ethiopia, and Czech Republic. (e. g., Chipansi et al., 2003; Endfield and Tejedo, 2006; Evangelista et al., 2013; Foran and Stafford Smith, 1991; Gillard and Monypenny, 1990; Hlavinka et al., 2009; Howitt et al., 2015; Ju et al., 2013; Özdoğan, 2011; Rihawi et al., 2007; Trigo et al., 2010; USDA, 2013; van der Velde et al., 2012; Warrick, 1984; and Wheaton et al., 2008). Wheaton et al. (2008) conducted a study focusing historic drought of Canada in 2001 and 2002. They have found water shortages due to drought negatively impacted livestock and hay production. Quebec reported a $55 million loss in soybean and hay production due to drought. Ontario reported a total loss of $435 for corn, soybean, and hay while Nova Scotia reported $44 million loss in various crop production including hay. This study reported 10% (600000) decline in cattle numbers in Alberta. Overall there was $143.4 million loss in 2002 alone and half of this loss occurred in Alberta.

Hlavinka et al. (2009) investigated drought impacts on a number of crops, including hay, in Czech Republic for 1960 through 2000. They have reported significant decline of crop production during drought. A 79% correlation was estimated between drought and hay yield and average yield (3690 kg $ha^{-1}$) departure was estimated as −900 kg $ha^{-1}$. Foran and Stafford Smith (1991) found that, compared to non-drought years, cow death rate can increase up to 5–7 times during drought in Australia. This research also reported weight gain by steers could drop from 204 to 12 kg $ha^{-1}$ and mortality could increase three times, from 1.3 to 4.3%.

In this context, to address future challenges due to drought, the National Integrated Drought Information System (NIDIS) was developed in the United States (U.S.). NIDIS helps drought response by improving monitoring, prediction, risk assessment, and communication. NIDIS is viewed as an accessible drought risk information system that allows users to determine potential drought impacts and provides decision support tools needed to prepare for and mitigate the impacts of drought (The National Integrated Drought Information System Implementation Plan, 2007). This research addresses goals set by NIDIS and aims to document drought impacts and helps in drought mitigation.

One of the goals of NIDIS Implementation Plan is to provide a plan for educating those affected by drought, about drought occurrences and associated impacts (NIDIS, 2007). Others include, establishing a successful integrated national drought monitoring and forecasting system; focusing on impact mitigation and predictive capabilities; creating a drought early warning system that is accurately able to supply timely and integrated information on drought conditions at a relevant spatial scale to help with decisions that will minimize economic, social, and environmental loss; and to provide interactive delivery systems that are standard and comprehensible. NIDIS Implementation Plan identified that there is core gaps in our knowledge about economic impacts of drought and highlighted the importance of and need for systematic efforts of determining drought impacts (NIDIS, 2007; Schubert et al., 2007). A subsequent update of NIDIS objectives called for providing a framework for public awareness and education about droughts, impacts, and preparedness (Climate Program Office, 2016).

We suggest that a passive approach to drought management will only increase vulnerability and thus, proactive strategies to mitigate drought impacts need to be developed in various regions of the world. In this vein, as outlined by NIDIS, the U.S. Drought Monitor and the U.S. Seasonal Drought Outlook are helpful tools in monitoring drought, however, a comprehensive federal drought policy needs to be implemented. An important component of policy development and implementation is the historical record of past droughts and the assessment of impacts of droughts, which include economic assessments based on agricultural yield and production.

The present paper contributes to this goal by studying historical droughts in Kentucky and their economic impacts on forage (hay in this case) and beef production. Although this study is set in Kentucky, the approach and results could be useful for similar studies conducted for other regions of the U.S. and the world. In addition, the current study is a continuation of our previous research on this topic. In the past, we assessed drought impacts on corn (Craft et al., 2013) and soybean (Craft et al., 2015).

There is a lack of systematic data collection and analysis of drought impacts within the United States. Data on drought-related relief payments, revenue losses due to water shortage, ecological impacts, impacts of wildfires, reduced hydropower production, mental health visits during drought periods, and agricultural yield losses, among many others, need to be collected. Since a centralized collection of these data does not exist, economic and social costs due to drought are often underestimated. Moreover, effective drought research efforts need to be made by the government, private entities, and universities to accelerate the development of a centralized drought response plan. Historical climate data, water supply and storage capabilities, drought indices, and GIS modeling framework need to be utilized and expanded to fill information gaps (Western Governors' Association, 2004). Also, because of the geographic variability of drought, local impacts are often overlooked compared to statewide averages (Hayes et al., 2002). Proper quantification of impacts will improve understanding of economic losses that can occur from drought at local and regional levels. The research presented here helps to fill some of these gaps by collecting agricultural data, documenting drought impacts, and determining financial costs due to droughts.

The purpose of this research, hence, is to assess the financial impacts of droughts on Kentucky's beef and forage (hay) production. This included an estimation of gross revenue losses to the beef cattle and forage sectors of Kentucky. This study did not attempt to develop an econometric model. It rather provided a baseline estimates of revenue losses from beef and hay production due to the droughts during the late twentieth and early twenty-first centuries.

State of Kentucky relies on its agricultural revenues, and droughts can cause severe revenue deficits. It is important to quantify the impacts of drought on Kentucky's agriculture so that planners and policy makers can make effective decisions. Kentucky's hay production is valued at over $680 million (USDA NASS, 2015) and ranks 5th in the nation with a production of over 6316 million tons annually (USDA NASS, 2007). Kentucky has over 91,400 livestock farms, is ranked 14th in the United States for all cattle inventory, and 8th in beef cattle inventory (Kentucky Department of Agriculture, 2008). Drought has great potential to have adverse impacts on the revenues of these agricultural industries. Quantifying impacts of past droughts on Kentucky's agriculture will help decrease drought vulnerability in the future.

## 2. Background

Since drought affects many different sectors, Wilhite and Glantz (1985) identified four different types of droughts. These include meteorological, hydrological, agricultural, and socioeconomic droughts. Meteorological drought is defined by the degree of dryness (in comparison to an average amount) and the length of the dry period. Hydrological droughts are defined by the "effects of periods of precipitation shortfall on surface or subsurface water supply" (Dracup et al., 1980, p. 299). Hydrological drought can reduce lake levels, groundwater, reservoirs, and streamflow (Heim, 2002). Examples of hydrological drought can be found in Wen et al. (2011), Shaban (2009), and Jones and Lister (1998).

Agricultural drought combines meteorological and hydrological drought characteristics to determine agricultural impacts. It focuses on the lack of precipitation, evapotranspiration rates, and soil moisture content, among others. High temperatures, low relative humidity, and desiccating winds can also contribute to the impacts of an agricultural drought (Heim, 2002). Assessment of agricultural drought is specific