Drought Risk Assessment - Kentucky

Introduction

Kentucky is perceived as a "water-rich" state with an average annual rainfall of 45 to 50 inches and abundant groundwater and surface water resources. However, Kentucky can experience extended periods of dry weather ranging from relatively short-duration single-season events to multi-year events.

Drought is a natural and recurring climatic feature but unlike other natural disasters it is not a distinct event that has a clearly defined beginning and end. Rather it is often the result of the interactions between various complex physical and social factors that are difficult to quantify or predict. Ultimately drought is manifest as an amount or distribution of moisture that is not sufficient to meet the needs of society or the environment and can result from both natural events that decrease supply and from human activities that increase the demand for water.

The impacts to the environment, economy and human health and safety caused by droughts underscore a need to move toward a proactive approach to drought planning and management. The risk of these potential impacts depends on the types of water demands, how these demands are met and the availability of water supplies necessary to meet these demands. This risk assessment provides information to support actions intended to reduce drought risk in Kentucky and aid in identifying *mitigation* actions that can be taken to reduce the impacts of future droughts.

This Risk Assessment was completed with consultations from various valued advisors including those from Kentucky Climate Center at WKU, Kentucky Rural Water Association, US Geological Survey, Kentucky Department of Agriculture, Kentucky Farm Bureau's Water Management Working Group and the Kentucky Water Resources Board.

Type and Location of the Drought Hazard – the nature of drought

Kentucky has experienced five significant drought periods in the past 20 years: 1988, 1999- 2000 and 2007-2008, 2010 and 2012. Each of these droughts brought hardships and inflicted various types of damage to Kentuckians, especially the agricultural sector. These droughts also have individual "personalities" in terms of where they struck, how intense they became, how long they lasted and what damage was done. But these droughts also share common features that distinguish them from normal dry periods:

1. Intensity

Drought develops only after a significant length of time with abnormally low precipitation, often combined with abnormally high temperatures. This combination of climatic anomalies results in an environment that stresses plants and animals, makes uncomfortable the lives of people living with water shortages, and can sometimes cause structural damage such as shifting foundations and ruptured water lines.

2. Duration

Kentucky has some level of dry spell in some location in nearly all years. Dry "spells" are termed to reflect a short-duration event most commonly noticed during the hot days of summer, or the warming days of spring. Dry spells are not droughts, but they are always a precursor to droughts. Unfortunately, and this is especially true for agriculture, a persistent dry spell may cause substantial damage early on in drought development; long before water shortages and problems with public water supplies emerge. Thus, one of the most difficult aspects of dealing with the drought hazard is the ability to accurately distinguish when a dry spell transitions into drought. Given the difficulty of this task it is prudent for citizens and officials alike to adopt a proactive approach to lessen the adverse impacts of drought when it invariably occurs.

3. Timing

Dry spells can occur at any time and so frequently that it is easy to become complacent and assume that rain is just around the corner, because it usually is. When a dry spell lingers and tends toward drought the consequences are determined partly by the timing of drought emergence. Spring droughts can delay the refilling of water supply lakes, accelerate water loss from soils by rapidly growing plants, reduce hay production and storage, and in general make us more vulnerable to even mild summer drought. Summer drought development is most damaging to agricultural interests, reducing crop development and yields and often placing hardships on livestock producers when ponds dry up or pastures fail to keep up with animal grazing demands. Droughts that intensify into the fall generally begin to affect the dependability of sources of drinking water, both surface and groundwater. Historically, most communities in Kentucky will experience water shortages during the fall droughts when low flows and low lake levels result from weeks or months of decreased runoff and baseflow in rivers and streams. Late fall and winter droughts can affect recharge of groundwater and delay or prevent the filing of lakes that typically draw down during summer when evaporation and plant water use (evapotranspiration, or ET) rates exceed rainfall. Severe late fall droughts are not as common in Kentucky and are usually a continuation and often the tail end of a summer drought. However, when a late fall drought develops and persists throughout the winter, serious water supply issues can occur in rivers, lakes and wells. Severe persistent winter droughts increase vulnerability to droughts that may develop the following spring or summer. Past droughts, especially in the 1980s, have forced communities to enter emergency water restrictions as late (early) as January or February due to lingering winter drought. More recently, the fall/winter drought of 2016 caused hardships for livestock producers in several south-central and eastern Kentucky counties as water sources became depleted and pastures senesced, forcing producers to begin feeding stored hay much sooner than normal. That same year, several water supplies in eastern and southeast Kentucky implemented drought response actions that persisted into January of the next year.

Defining Drought, Drought Response and Drought Mitigation

There is not a single definition of drought to succinctly describe the progressive nature of drought development. Most often drought is defined by a combination of several definitions for increasing drought severity that are based on meteorological, agricultural, hydrological and socioeconomic effects.

Meteorological Drought

Meteorological measurements are generally the first indicators of drought development. This category of drought is often defined by a period of precipitation deficit that is outside of a "normal" range over a defined period of time. The concept of normal is often derived from a 30- year record of daily precipitation measurements at a specific location. Thus, a definition of meteorological drought is regionally-specific and presumably based on a thorough understanding of regional climatology.

Agricultural Drought

Agricultural drought occurs when there is not enough soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought develops at some point after meteorological drought and is identified by linking the characteristics of a meteorological drought to agricultural impacts. This category of drought can develop quite suddenly and is usually the first economic sector to be affected by drought.

Hydrological Drought

Hydrological drought refers to the deficiencies in surface and subsurface water supplies. It is measured as streamflow and as lake, reservoir and groundwater levels. There is a time lag between lack of rain and diminished quantities of water in streams, rivers, reservoirs and aquifers. Therefore, hydrological measurements are not the earliest indicators of drought. Drought will not be reflected in declining subsurface and surface water levels until precipitation is deficient over an extended period of time. Although it is a natural phenomenon, the impacts of hydrological drought are often intensified by human activities and land use.

Socioeconomic Drought

Socioeconomic drought occurs when physical water shortage begins to affect people, individually or collectively. This category of drought is manifested by adverse impacts to the health, well-being and quality of life of the people, or when drought begins to affect the supply and demand of an economic product.

Drought Response

Drought response is the process of taking actions during a drought event to reduce its immediate impacts to the environment or society. The purpose of drought response is to reduce the impacts of drought by making temporary adjustments to normal practices until the threat of drought is relieved by a resumption of normal climatic conditions. Over the long term a focus on drought mitigation will reduce the severity and level of response that must be implemented.

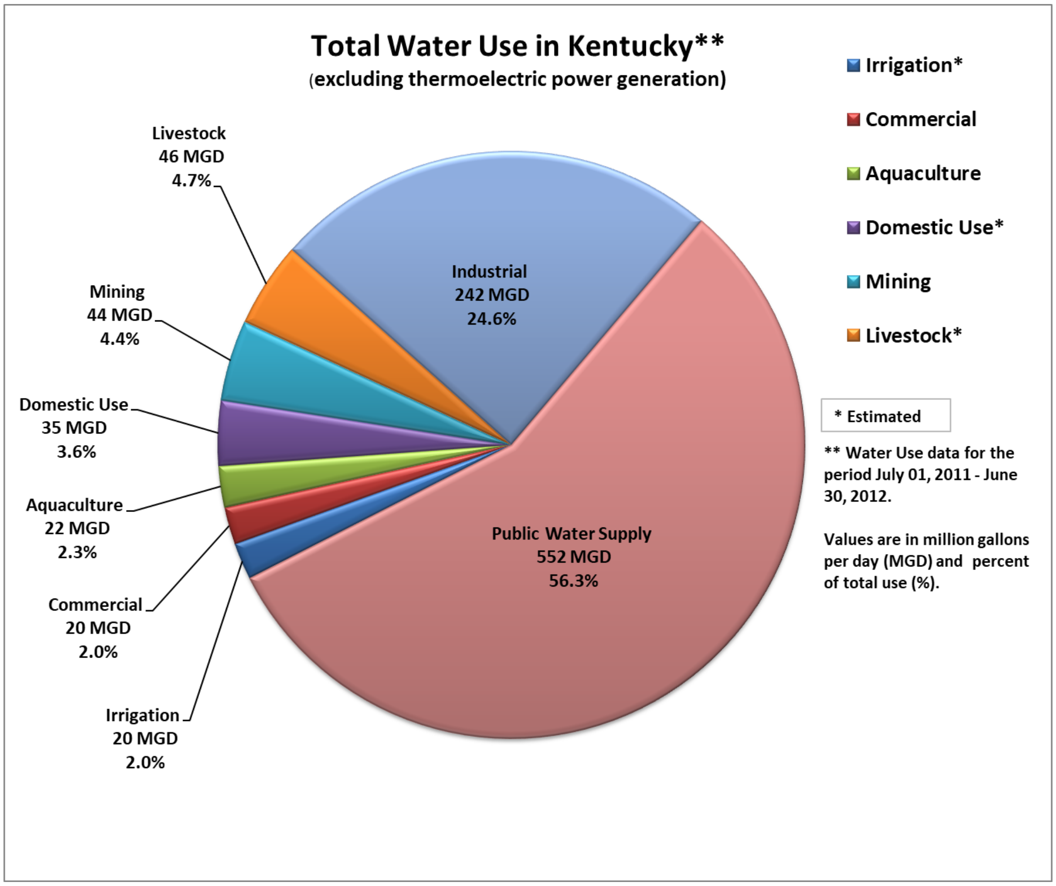
Drought Mitigation

Mitigating drought is the process of taking actions in advance of drought to reduce our long-term risk. The purpose of mitigation and preparedness actions are to reduce the impacts of drought by identifying principal activities, groups or regions most at risk and developing mitigation actions and programs that alter these vulnerabilities.

This assessment can provide data and information that will aid in characterizing and locating the areas and assets most at risk from drought. The focus of this work is on public water supply and agriculture since these water use sectors are vital to Kentucky's human and economic well-being and collectively consume more water than any other water use sector (Figure 1.).

On an annual basis, public water supply withdrawals amount to approximately 550 million gallons per day (MGD), followed by industrial withdrawals, livestock and then several lesser uses. Note that the figure for irrigation (20 MGD) is expressed on an annual basis but typically irrigation will only occur over a period of about three months. The actual water used by irrigation adjusted to a 90-day irrigation season is closer to 80 MGD while the irrigation is actually occurring. Combined, water withdrawn to support irrigation (assuming 80 MGD) and livestock account for about 120 MGD, making agriculture the 3rd largest consumer of water in Kentucky. It should be noted that water used for housed animal operations like dairy or poultry is often supplied by a public water system and is factored into the value for public water supply withdrawals in this assessment.

Figure 1. Water Use (water withdrawn) in Kentucky by sector



Source: Kentucky Division of Water; United States Geological Survey

Methods and Procedures – Drought Hazard, Impacts and Recurrence

The threat that drought poses to Kentucky is difficult to quantify. For purposes of this assessment a standard definition of risk will be adhered to as closely as possible. The data presented in this document will follow the convention that RISK is a product of a defined HAZARD and EXPOSURE. In the context of drought, the hazard is the drought itself but as will be shown later (Table 4.) drought is a broad, regional hazard that over the long-term recurs on a relatively equal frequency across all regions of Kentucky.

A method to quantify drought as a hazard and its associated risk is to evaluate a proxy (surrogate) for drought risk. In this assessment agriculture will be evaluated with respect to monetary losses using Federal Crop Insurance payments (Cause of Loss data), along with exposure : number of poultry houses at risk, number of hog farms at risk, and number of dairy cattle and beef cattle at risk.   For public water systems a drought exposure variable will consist of numbers of affected people, number of hospital and long-term care beds and a cross-over to agriculture with numbers of animals potentially served by each water system.

A summary of the total sales of agricultural commodities published in the UDSA Agricultural Census (2012) gives an indication of what is potentially at risk to some level of drought losses (Table 1.):   commodities with a total sales value of nearly $5,100,000,000 in 2012.

Federal Crop Insurance cause of loss data was chosen for a drought risk proxy because it is one of the few sources of information where damages can be directly attributed to drought. In addition, as of 2016 nearly 90 percent of corn, soybeans, tobacco and wheat acres are enrolled in the federal crop insurance program (Source: USDA Risk Management Agency). This provides a reasonable estimate of the relative impact that drought has had on what is now a nearly 3 billion dollar industry.

Table 1. Value of sales of agricultural commodities in Kentucky

ANIMAL SALES	SALES, $
SPECIALTY ANIMAL TOTALS, (EXCL EQUINE)	119,043,000
SHEEP & GOATS TOTALS, INCL WOOL & MOHAIR & MILK	7,278,000
EQUINE, HORSES & PONIES, OWNED	178,332,000
POULTRY TOTALS, INCL EGGS	1,073,243,000
MILK	194,716,000
HOGS	50,846,000
CATTLE, INCL CALVES	960,486,000
OTHER SALES	202,565,000
TOTAL	**2,786,509,000**
CROP AND PLANT SALES	
VEGETABLE TOTALS, INCL FRESH CUT HERBS, UNDER PROTECTION	1,763,755
VEGETABLE TOTALS, INCL SEEDS & TRANSPLANTS, IN THE OPEN	25,082,000
NURSERY TOTALS	7,338,113
HORTICULTURE	83,096,545
FLORICULTURE TOTALS	16,847,824
FRUIT & TREE NUT TOTALS	5,196,000
WHEAT	156,121,000
TOBACCO	322,329,000
SOYBEANS	749,745,000
CORN	688,409,000
OTHER SALES	224,304,763
TOTAL	**2,280,233,000**
TOTAL SALES: CROPS PLUS ANIMALS	**5,066,742,000**

Source: USDA Census of Agriculture, 2012

Drought Analysis – Palmer Drought Severity Index and Cause of Loss (COL) Data

PDSI and Crop Loss Data are used to develop a chronology of drought. The PDSI serves as the drought index that incorporates soil, precipitation and temperature into a physical description of drought severity. The Cause of Loss data serves as a proxy to link drought impacts to drought severity.

The Palmer Drought Severity Index (PDSI) uses readily available temperature and precipitation data to estimate relative dryness. It is a standardized index that spans -10 (dry) to +10 (wet). It has been reasonably successful at quantifying long-term drought. As it uses temperature data and a physical water balance model, it can capture the basic effect of global warming on drought through changes in potential evapotranspiration.

The PDSI was developed in the 1960s as one of the first attempts to identify droughts using more than just precipitation data. Palmer was tasked with developing a method to incorporate temperature and precipitation data with water balance information to identify droughts in crop-producing regions of the United States. For many years, PDSI was the only operational drought index, and it is still very popular around the world.

The PDSI is calculated using monthly temperature and precipitation data along with information on the water-holding capacity of soils. It takes into account moisture received (precipitation) as well as moisture stored in the soil, accounting for the potential loss of moisture due to temperature influences.

Developed mainly as a way to identify droughts affecting agriculture, it has also been used for identifying and monitoring droughts associated with other types of impacts. PDSI has a timescale of approximately nine months, which leads to a lag in identifying drought conditions based upon simplification of the soil moisture component within the calculations. This lag may be up to several months, which is a drawback when trying to identify a rapidly emerging drought situation. These “flash droughts” can emerge at any time of the year, but have been the most devastating, particularly on agriculture, when they coincide with extreme high temperatures during the summer. Such was the case in past droughts in Kentucky, including droughts in the 1940s, 1960s, 1980s, and most recently in 2007 and 2012.

For purposes of a drought risk assessment the PDSI lends itself very useful due in large part to the relatively long period of record. Current PDSI data available for each climatic division in the U.S. stretches back to 1895, providing more than a century of data to characterize a drought history. For this reason, the PDSI was chosen as the primary indicator to be used in this assessment. The Division of Water has a long history with the PDSI as a drought indicator and for many years it was the only index of drought readily available. Other, more refined indices have emerged in the past two decades, for example the National Drought Mitigation Center’s “Drought Monitor”, NASA’s “GRACE” satellite moisture index and the Standardized Precipitation Index (SPI). These newer tools are superior in smaller spatial and temporal scales and provide a more real-time aspect to drought monitoring. However, the PDSI has proven to be a reliable tool for identifying droughts, especially in retrospect, lending it particularly useful for purposes of this project.

Table 2. PDSI Drought Categories of Moisture Anomaly

PDSI CLASSIFICATIONS	
> 4.00	extremely wet
3.00 to 3.99	very wet
2.00 to 2.99	moderately wet
1.00 to 1.99	wet
0.50 to 0.99	moist spell
0.49 to -0.99	dry spell
-1.00 to -1.99	mild drought
-2.00 to -2.99	moderate drought
-3.00 to -3.99	severe drought
<-4.00	extreme drought

Source: National Oceanic and Atmospheric Association (NOAA)

The PDSI denotes drought severity on a scale of -8 to +8, with any value greater (less) than +4 considered extremely wet and -4 extremely dry.

For purposes of this assessment, moderate drought is reached when at least three consecutive months fall below a PDSI value of -2.0 (Mahmoud, 2014). Drought is considered to persist until the PDSI is once again in a normal (at least zero) range. Severe drought is indicated when PDSI reaches -3.0, and extreme drought is indicated when PDSI fall below -4.0.

As seen in Figure 2 for the period 1905 through the 1950s severe and extreme drought were fairly consistent in recurring about once every five years. Droughts in the 1930s through the 1950s have not been eclipsed and remain benchmarks for extreme drought for purposes of planning for water resources projects. On a statewide basis the most notable drought since the 1950s occurred from 1999 through 2001.

Figure 2. Historic chronology of PDSI drought for the state of Kentucky

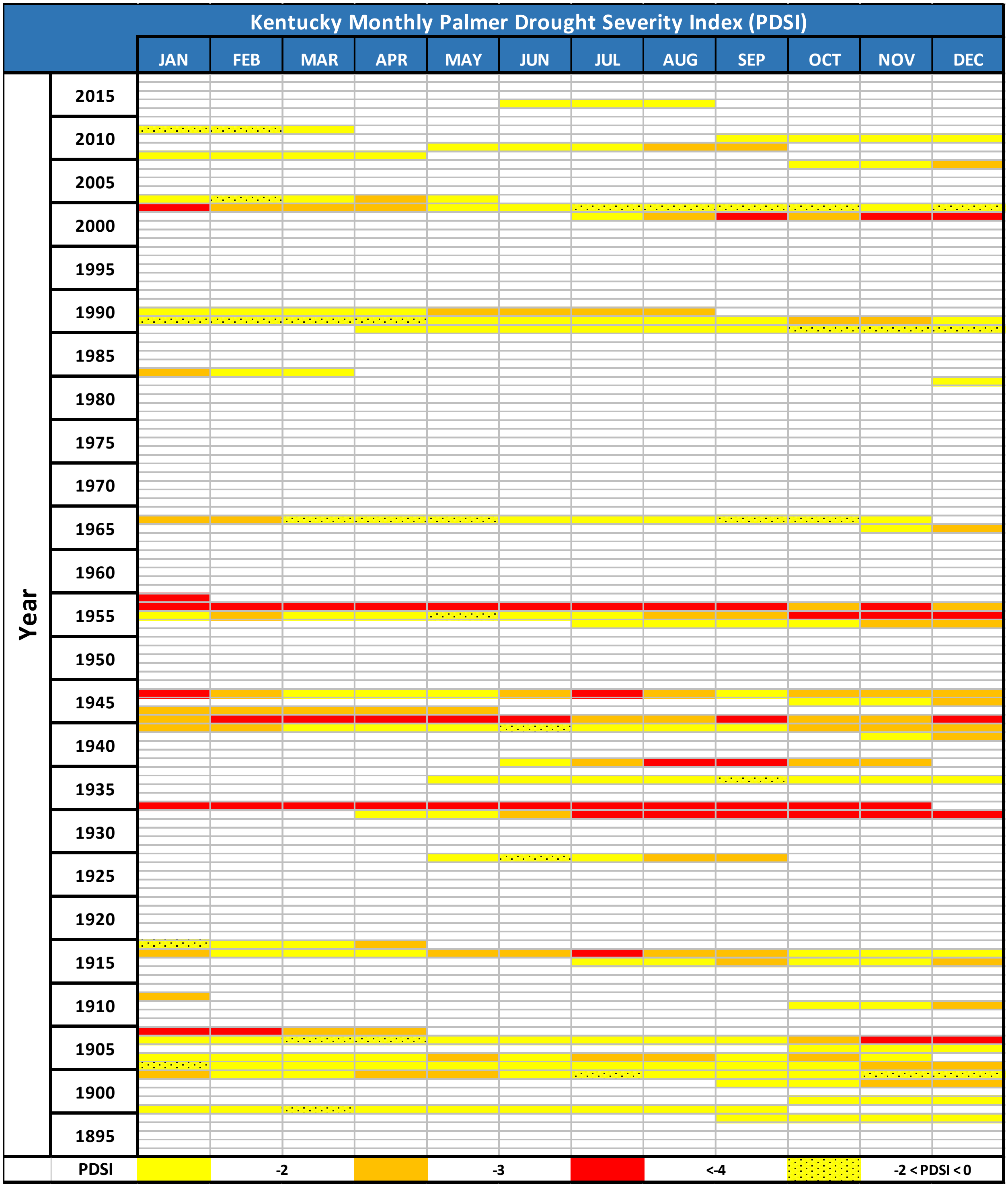


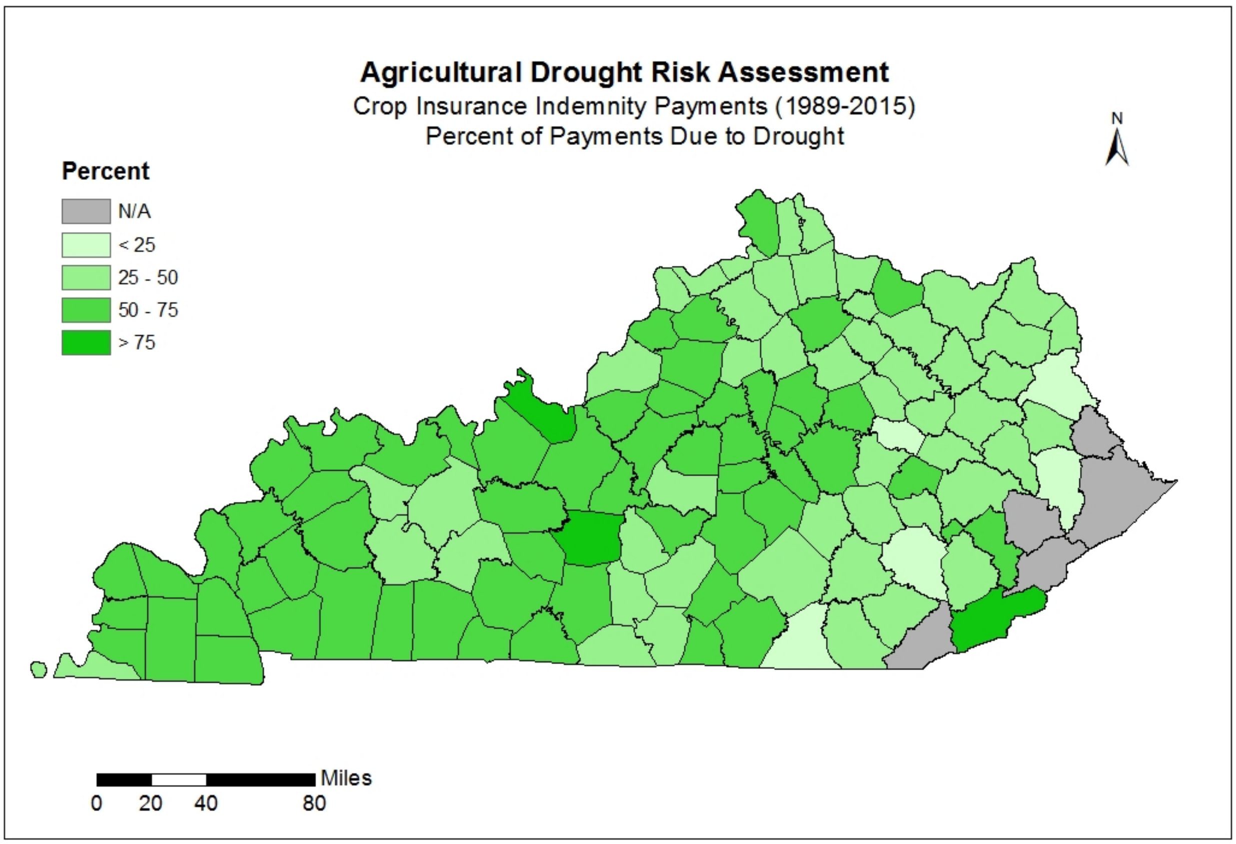
Table 3. Total crop indemnity payments and associated COL

YEAR	CAUSE OF LOSS (ALL CROPS)							TOTAL
YEAR	DROUGHT	COLD	WET	HAIL/OTHER	FIRE	BIOLOGICAL	PRICE/YIELD	TOTAL
	Indemnity (dollars) Paid							
1989	192,147	38,255	3,518,987	204,453	74,168	111,255	0	4,139,265
1990	2,715,246	161,534	1,249,472	201,085	8,721	100,306	0	4,436,364
1991	3,164,185	26,973	2,083,236	1,280,250	76,863	500,633	0	7,132,140
1992	35,258	107,982	1,988,617	240,554	108,580	257,092	0	2,738,083
1993	1,960,726	51,730	578,486	129,689	51,342	329,472	579,399	3,680,844
1994	697,902	29,848	266,207	624,488	25,736	77,939	0	1,722,120
1995	2,382,551	16,735	3,416,365	264,958	206,536	822,981	0	7,110,126
1996	1,177,658	655,055	2,840,659	927,130	121,699	1,816,126	0	7,538,327
1997	7,740,111	2,651,284	4,139,576	269,595	59,597	605,070	19,303	15,484,536
1998	14,700,624	564,714	9,708,420	444,502	178,386	728,319	291,919	26,616,884
1999	43,487,995	696,612	1,016,631	759,818	252,609	1,069,776	6,106,770	53,390,211
2000	7,742,607	1,014,255	3,328,791	3,650,602	359,695	1,035,620	3,976,995	21,108,565
2001	1,531,185	253,803	4,095,029	844,232	222,676	387,942	1,666,138	9,001,005
2002	22,224,557	234,923	5,352,324	452,585	148,582	1,203,061	871,648	30,487,680
2003	447,566	423,583	17,190,197	2,101,339	56,713	445,725	33,260	20,698,383
2004	531,529	53,998	20,465,210	1,019,938	62,305	934,933	1,139,026	24,206,939
2005	12,493,552	193,664	5,068,181	713,336	7,639	1,187,035	261,140	19,924,547
2006	822,297	836,398	9,282,254	1,696,564	506,034	831,173	59,021	14,033,741
2007	68,752,245	9,550,870	3,891,318	1,173,250	46,362	454,185	27,050,172	110,918,402
2008	62,766,301	571,350	7,573,663	2,130,279	17,063	485,710	40,750,412	114,294,778
2009	310,624	1,764,493	55,149,124	1,306,321	1,273,853	2,786,194	10,155,026	72,745,635
2010	79,694,773	188,569	49,175,575	3,810,616	316,795	2,152,299	2,995,986	138,334,613
2011	48,117,307	271,733	45,914,142	2,626,448	24,677	983,101	2,238,014	100,175,422
2012	455,753,821	7,784,853	2,119,625	4,165,878	25,249	836,521	20,010,696	490,696,643
2013	609,363	956,561	53,422,414	4,454,567	41,731	530,434	2,365,082	62,380,152
2014	50,883,390	10,205,374	28,453,227	13,443,996	2,520,570	8,200,243	27,147,306	140,854,107
2015	2,731,120	1,257,368	88,613,527	5,169,743	769,429	589,797	1,154,675	100,285,659
TOTAL	893,666,641	40,562,517	429,901,257	54,106,215	7,563,610	29,462,943	148,871,989	1,604,135,172

Cause of loss data is available for the years 1948 to present. However, the percent of cropped acres insured remained relatively minor until the mid to late 1980s. Total indemnity payments from 1948 to 2015 equaled $1,697,906,301, and $1,604,135,172 from 1989 to 2015. Nearly 94 percent of crop loss indemnity payments have occurred since 1989 in Kentucky.

Cause of loss data attributes a specific cause to claim of damage to an insured crop and provides 29 different types of causes. For this assessment six categories were created (Table 3.) to combine related COL items for analysis: Drought, Cold, Wet, Hail/Other, Fire, Biological Damage and Price/Yield Protection. As shown in Table 3 drought (drought, heat, failed irrigation systems and hot wind) account for almost $900,000,000 of the 1.6 billion dollars in indemnity payments since 1989, with just over 50 percent attributed to the 2012 drought alone. Figures 3 and 4 present a county assessment of indemnity payments. As would be expected, a majority of crop indemnity payments occur in grain and tobacco producing areas of western and central Kentucky.

Figure 3. County assessment of the percent of crop indemnity attributed to drought



Source: USDA Risk Management Agency

Figure 4. County assessment of crop indemnity payments for all causes of loss

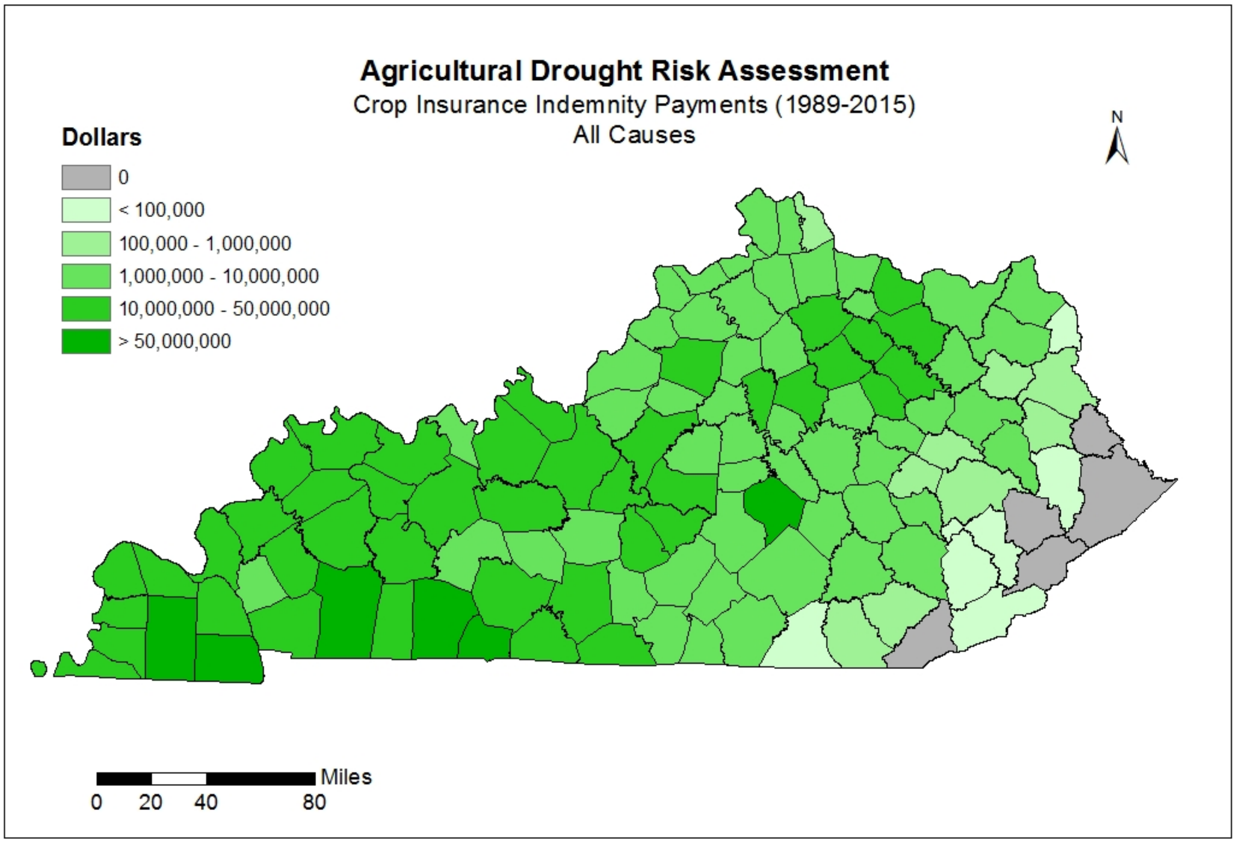


Figure 5. Crop Insurance Indemnity Payments (1989-2015) for Corn, Soybean, Tobacco and Wheat

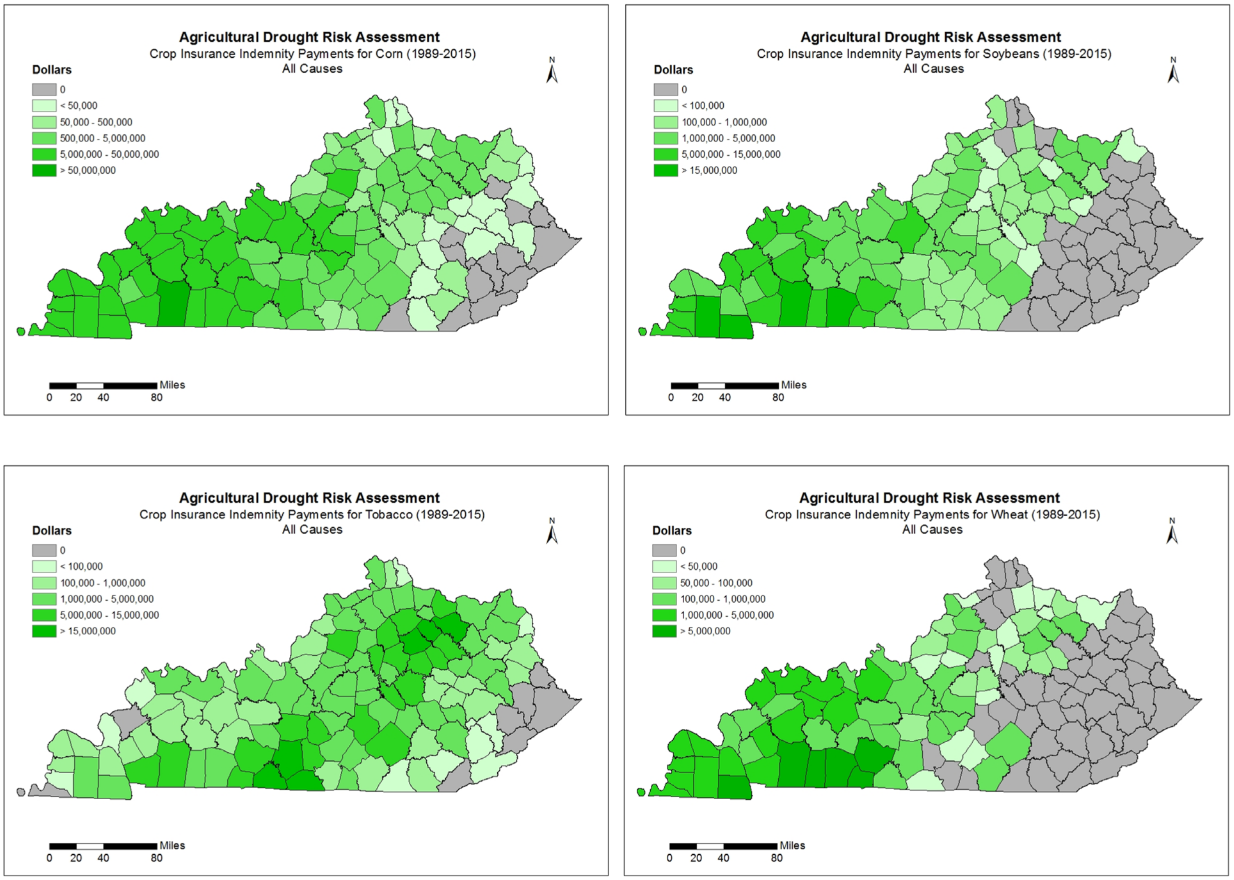
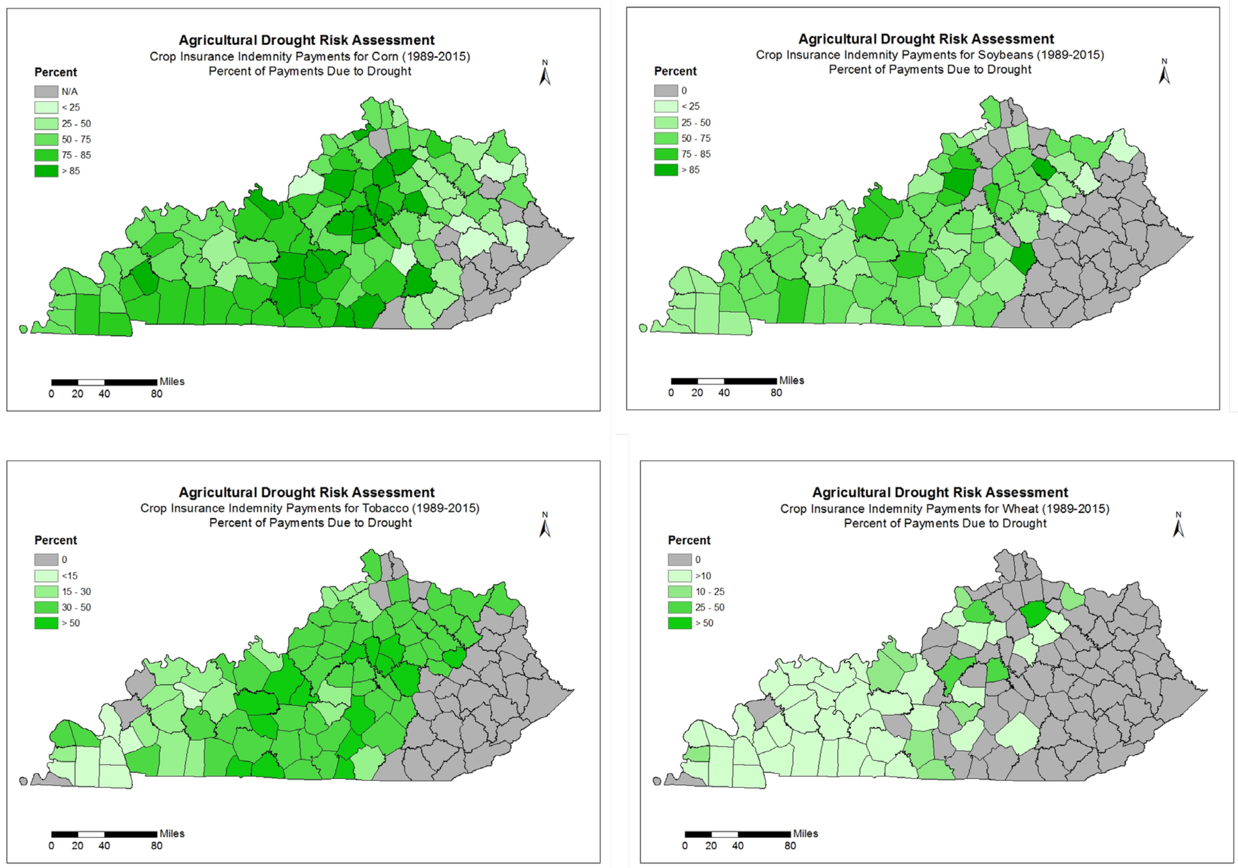


Figure 6. Percent of Crop Insurance Indemnity Payments (1989-2015) Attributed to Drought for Corn, Soybean, Tobacco and Wheat



Corn leads all crops in drought susceptibility followed tobacco and soybeans. Wheat rarely attributes drought to indemnifiable damages, tending much more toward problems caused from freezing or excess moisture.

PDSI Analysis

Data for PDSI (1895-2015) for each of four climatic divisions in Kentucky was analyzed to determine each occurrence of at least moderate drought (3 consecutive months where PDSI < -2.0). The number of occurrences were recorded and the number of months < -2.0, < -3.0 and < -4.0 were counted, and noted whether they occurred in May – November (net water consumption months) and December – April (net recharge months). These were then divided by the total number of months < -2.0 determine PDSI severity for each season (consumption or recharge) The results are presented in table 4. Note that in some years and climatic divisions that the more intense PDSI values occur in the consumption months (1899-

1902, 1925, 1936, 1988, 2007, 2012) and most of the rest in the recharge months, with 1930-1931 equally severe in both seasons. This is not unexpected since the PDSI is a slow developing, longer-term index that is not well-suited to detect short term droughts. It is worth noting that the years 1936, 1988, 2007 and 2012 were rapidly developing, intense droughts that did tremendous damage to agriculture with lesser impacts to pubic water supplies. The data supports the observations that the years between 1930 and the late 1950s were generally drought-prone and subject to multi-year droughts and tending to persist much longer than more recent droughts in Kentucky.

Based on table 4 there have been 28 moderate droughts since 1895 with 23 progressing to at least severe drought. There have been 12 regional droughts and 11 statewide droughts. On average Kentucky has experienced a severe drought at least once every 5 years. Severe regional droughts are occurring in some area of Kentucky about once every 10 years , and statewide droughts have recurred on an 11-year interval.

Table 5 summarizes the data further by categorizing and counting years with meeting moderate and severe PDSI thresholds as well as the number of regional (less than 4 climatic divisions reach a severe drought level) and statewide droughts (all climatic divisions reach at least a severe drought level. The data supports the observation that drought incidence and recurrence is very similar between all four climatic divisions.

Table 4. PDSI Analysis of Drought Incidence in Kentucky for all years where moderate drought advanced to severe or extreme

CLIMATE DIVISION	1895	1897	1899-1902	1903-1905	1908	1913-1915	1922	1925	1930-1931	1934	1936	1939-1942	1943-1945	1952-1955	1963-1964	1980-1981	1986-1988	1999-2001	2005	2007	2008	2010	2012
1																							
All Months		0.75	0.67	0.43	0.50	0.78		0.38	0.85		0.58	0.65		0.79	0.56		0.31	0.25		0.50		0.50	0.80
May-Nov		0.50	0.85	0.17	0.50	0.77		0.67	0.86		0.86	0.53		0.79	0.33		0.40	0.33		0.50		0.33	1.00
Dec-Apr		1.00	0.20	0.63	0.50	0.80		0.00	0.83		0.25	0.84		0.73	1.00		0.00	0.25		0.00		1.00	0.00
2																							
All Months		0.50	0.45	0.70		0.61		0.50	0.85	0.17	0.83	0.75	0.63	0.77	0.60	0.25	0.13	0.50		0.20			
May-Nov		0.66	0.47	0.40		0.55		0.50	0.86	0.00	0.83	0.65	0.50	0.68	0.00	0.00	0.20	0.46		0.20			
Dec-Apr		1.00	0.42	1.00		0.71		0.00	0.83	1.00	0.00	0.86	0.75	0.92	1.00	0.25	0.00	0.50		0.00			
3																							
All Months	0.778		0.70		0.60	0.11	0.50		0.95	0.60	0.86	0.70	0.93	0.61	0.25		0.52	0.63	0.71	0.25	0.16		
May-Nov	0.75		0.75		0.33	0.13	0.33		0.93	0.43	0.83	0.82	0.89	0.63	0.00		0.39	0.64	0.33	0.25	0.25		
Dec-Apr	0.8		0.80		1.00	0.00	1.00		1.00	1.00	1.00	0.62	1.00	0.58	0.60		0.80	0.71	1.00	0.00	0.00		
4																							
All Months	0.17		0.41	0.37		0.20		0.33	0.87		0.83	0.63	0.20	0.74		0.14	0.50	0.61	0.57	0.56			
May-Nov	0.50		0.38	0.22		0.20		0.33	0.90		0.83	0.54	0.17	0.69		0.00	0.58	0.55	0.33	0.45			
Dec-Apr	0.00		0.44	0.50		0.17		0.00	1.00		0.00	0.73	0.25	0.83		0.25	0.33	0.71	0.75	0.60			

CLIMATE DIVISION	MINIMUM PDSI FOR THE DROUGHT PERIOD																						
1	-2.03	**-3.19**	**-4.05**	**3.63**	**-3.26**	**-5.35**	-1.28	**-3.81**	**-6.17**	-2.57	**-5.23**	**-5.61**	**-4.62**	**-5.51**	**-4.75**	-2.83	**-3.34**	**-3.19**	-1.93	**-3.66**	-2.12	**-3.60**	**-4.40**
2	-2.46	**-3.08**	**-4.12**	**4.12**	-2.85	**-4.28**	-1.38	**-3.16**	**-6.51**	**-3.04**	**-4.01**	**-5.03**	**-3.97**	**-5.47**	**-3.65**	**-3.22**	**-3.35**	**-4.25**	-2.55	**-3.24**	-2.50	-1.43	-2.38
3	**-4.08**	-2.25	**-5.19**		**-4.41**	**-3.43**	**-3.31**	-2.27	**-7.51**	**-4.35**	**-4.31**	**-4.78**	**-4.93**	**-5.39**	**-3.50**	**-2.48**	**-4.13**	**-5.39**	**-3.80**	**-3.46**	**-3.01**	-2.52	-2.28
4	**-3**	-2.16	**-3.68**	**-3.75**	-2.3	**-3.17**	-1.79	**-3.48**	**-6.47**	-2.72	**-3.53**	**-4.86**	**-3.28**	**-4.89**	-2.55	**-3.49**	**-4.04**	**-4.27**	**-3.57**	**-4.45**		-0.54	-1.99

Table 5. Recurrence intervals for moderate, severe, regional and statewide droughts

CLIMATE DIVISION	Moderate Drought Criteria Met	Recurrence Interval, years	Severe Drought Criteria Met	Recurrence Interval, years	Regional Droughts	Recurrence Interval, years	Statewide Droughts	Recurrence Interval
	Number of Droughts							
1	21	5.8	17	7.1	6	20.2	11	11.0
2	24	5.0	16	7.6	5	24.2	11	11.0
3	20	6.1	18	6.7	7	17.3	11	11.0
4	21	5.8	16	7.6	5	24.2	11	11.0
STATEWIDE	28	4.3	23	5.3	12	10.1	11	11.0

Table 6. Recurrence Intervals and Percent Exceedance of 3-month PDSI

Recurrence Interval, years	3- month PDSI			
	Climate Division 1	Climate Division 2	Climate Division 3	Climate Division 4
60	-5.4	-5.5	-6.3	-5.8
40	-5.2	-5.1	-5.2	-4.5
20	-4.8	-4.1	-4.9	-4.2
10	-4.2	-3.8	-4.3	-3.6
5	-3.2	-3	-3.4	-2.9
2	-1.7	-1.5	-1.8	-1.5
% CHANCE LESS THAN PDSI	%			
-6	0.82	0.82	0.82	0.82
-5	4.1	2.5	4.1	2.5
-4	9.8	6.6	11.5	7.4
-3	25	18	25	17
-2	40	41	41	39

Finally, monthly PDSI values were evaluated to calculate a three-month running average, the length of a “typical” irrigation season. Recurrence intervals and percent chances for each PDSI threshold were calculated from a Weibull plotting position. Based on this data, on average **Kentucky experiences moderate to slightly severe drought about every five years; moderate to somewhat extreme every 10 years, and extreme drought at least every 20**

years. The data also suggest there is an 18-25 percent chance of a severe drought, and a 7-11 percent chance of extreme drought each year, respectively. It is evident that while the recurrence of droughts in the moderate to extreme categories are about the same in all climatic divisions, drought intensity within each category tends to be slightly higher in the west than in the east. This could be a result of climatic factors or an artifact of the PDSI calculations themselves.

Crop Loss Analysis

Table 7. Return Intervals and percent chance of occurrence of drought as a COL

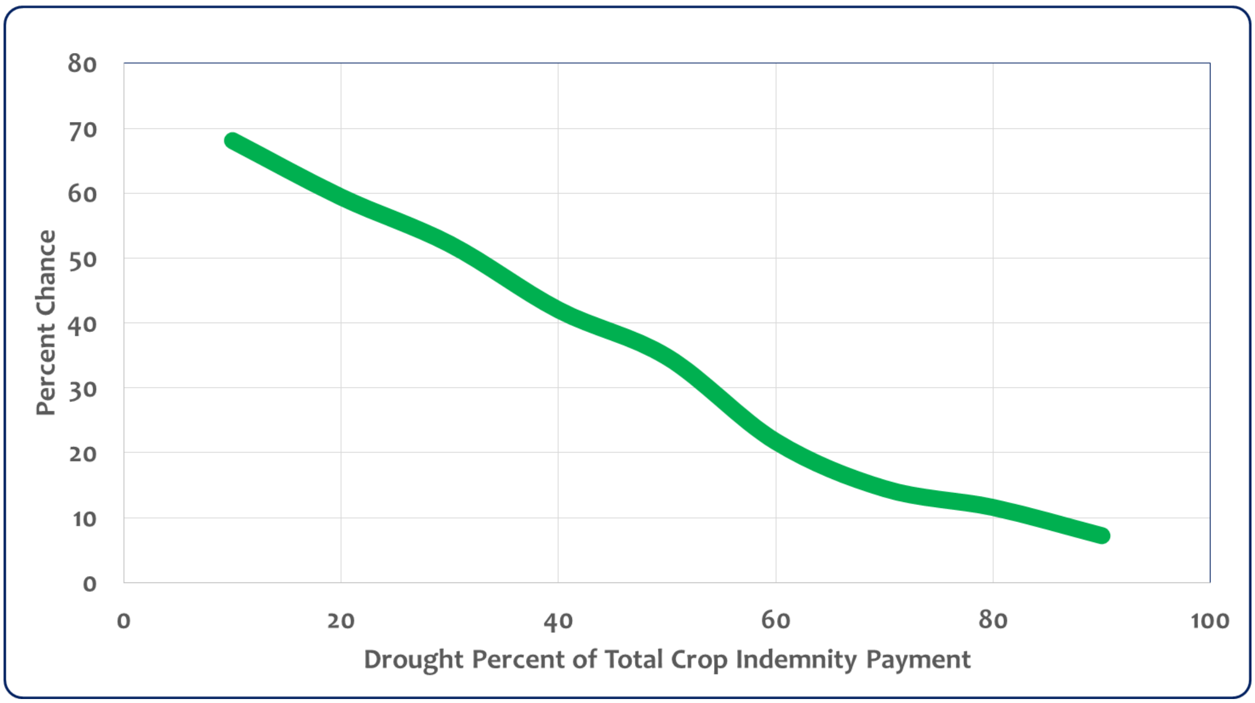
% COL Attributed to Drought[1]	Return Interval	Percent Chance Less Than % COL
%	years	%
90	13.8	7.2
80	8.6	11.6
70	6.9	14.5
60	4.6	21.7
50	2.9	34.8
40	2.4	42.0
30	1.9	52.2
20	1.7	59.4
10	1.5	68.1

[1]Cause of Loss (COL) as a percent of total indemnity payments

Return intervals and percent chances of drought as a percent of total indemnity payments were calculated using a similar Weibull plotting position on the percent of drought COL versus total payments each year since 1948. **Results show that drought has been 90 percent or more of the total indemnity payments on a 14-year recurrence interval, or a 7 percent chance in any year. Drought is at least 50 percent of all indemnity payments at a recurrence interval of 3 years, or about 35 percent chance each year.**

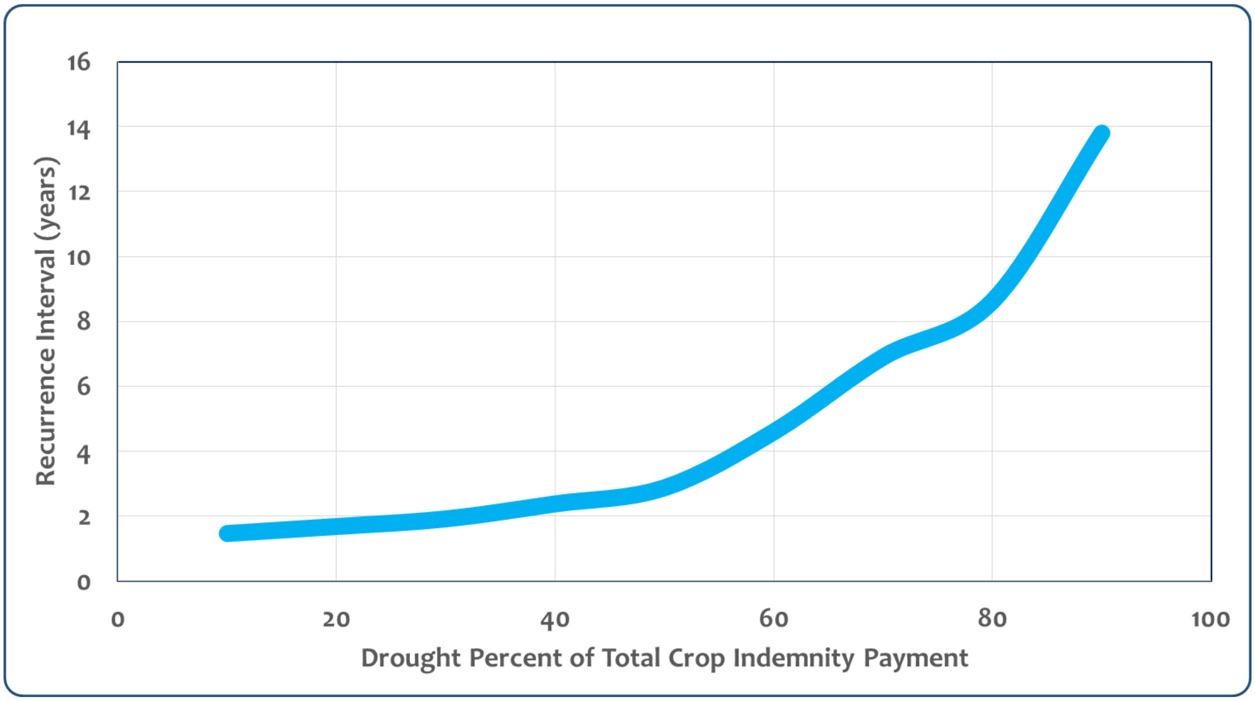
Combining the results from tables 6 and 7 the following relationships can be approximated: when drought makes up 90 percent or more of crop indemnity cause of loss, the three-month PDSI had reached at least a minimum of -4.2. Similarly, for 80 percent drought PDSI had reached a -4.0, for 70 percent drought -3.1 and 50 percent drought when PDSI had reached -2.0. This may be of some use in predicting what level of crop damage each year might be expected from drought with the knowledge that a majority of droughts progress to severe or worse once the threshold for moderate drought is reached.

Figure 7. Percent chance of drought indemnity exceeding a percent of total crop indemnity



Figures 8 and 9 present generalized relationships from table 7 in a graphical presentation demonstrating the likelihood, based on historical data, that a certain percentage of crop indemnity will attribute COL to drought. For example, figure 8 shows there is about a 40 percent chance that annual crop indemnity payments will attribute at least 40 percent of the causes of loss to drought. Similar visual relationships are presented in Figure 9 for recurrence intervals for percent drought as a cause of loss.

Figure 8. Recurrence intervals for drought indemnity exceeding a percent of total crop indemnity



Drought Risk Assessment Results

Methods

Public Water Supply Scoring

Primary Source Score- Created by taking a system's main source and assigning a score (from 1 to 3 with 3 being the least vulnerable) based on how drought vulnerable that source. Stream flow variabilities, lake characteristics, historical documents, and the systems demand compared to the size of the source, were taken into consideration. Sources that have experienced issues in the past or have the potential to experience a shortage in a moderate drought were given a high-risk score (1 or 1.5). Sources that have the potential to experience a shortage in a significant drought were given a moderate risk score (2 or 2.5). Sources that are essentially drought invulnerable were given a low risk score (3). Systems that purchase water were scored based upon the score of the system(s) the water is purchased from.

All Sources Score- Created by taking into account all the sources that a system uses. This includes stream/rivers used for a pump store, secondary wells, etc. Systems were then scored using the same criteria as used above.

Supply Score- Created by taking the All Sources score and also including management into the scoring. This including interconnections with other systems proactiveness of system staff, city officials, etc. in previous droughts or current planning. Systems that have a source score of 3 were not scored on management.

Leakage Loss- Percent leakage loss is one of two factors that go into creating the infrastructure score. Percent leakage loss was calculated using numbers found in WRIS and SDWIS MORs. Percent leakage loss is the percent of treated water produced by a system that is unaccounted for. This can be caused by several things including leakage from pipes, slow running meters, and theft. For this analysis, it is being assumed that a large portion of the unaccounted-for water is due to leakage from pipes.

Distribution Lines 3 Inches or Less- Calculated using the miles of 3" lines or less in a system divided by the total miles of lines in a system.

Public Water System Hazard – Is calculated by averaging the Supply Vulnerability Score and the Infrastructure Score, which is the average of Leakage Loss and 3-inch Lines. The score is weighted for Supply Vulnerability.

County Hazard Level for Public Water Systems – Scores for all systems that are in a given county were weighted based upon the number of people that system serves in that county and then averaged to produce the County Hazard Level.

*It should be noted that with all water system maps, systems that purchase 100% of their water from another system were merged with that system and assigned scores for primary source equal to that of the seller.

Soil Hazard Mapping

The soil hazard score was created by assigning every soil in the state with a hazard score. The soils were defined using the 87 different NRCS Soil Surveys that encompass the state. While many soils share the same name from survey to survey, the characteristics can very slightly which result in 2,900 unique soils for the state. To determine the drought hazard for each soil, 3 criteria were used: Infiltration, Water Movement, and Water Supply. Each criterion then consisted of two different soil properties that are rated in each soil survey: Infiltration (Slope and Hydrologic Soil Groups), Water Movement (Drainage Class and Ksat), and Water Supply (Available Water Supply in Profile and Depth to Restrictive Layer). Each of the six properties was then scored on a scale of 0 to 5 with 0 being the most drought vulnerable.

The average score of the two soil properties was used to calculate the score for each of the three criteria. The scores of the three criteria were then averaged to calculate the drought risk score for that soil. The scales for the soil properties were determined using NRCS rankings:

Table 8. Six soil moisture variables used to develop a soil drought hazard 24assessment

Slope:	Score	Saturated Hydraulic Conductivity (Ksat)	Score
0-3%	5	Very High	5
3-8%	4	High	4
8-16%	3	Moderately High	3
16-30%	2	Moderately Low	2
30-60%	1	Low	1
>60%	0	Very Low	0
Hydrologic Soil Group:	**Score**	**Available Water Supply in Profile**	**Score**
A or A/D	5	Very High	5
B or B/D	3.33	High	3.75
C or C/D	1.67	Moderate	2.5
D	0	Low	1.25
		Very Low	0
Drainage Class:	**Score**	**Depth to Restrictive Layer**	**Score**
Very Poorly or Poorly Drained	5	>80”	5
Somewhat Poorly Drained	4	60-80”	3.75
Moderately Well Drained	3	40-60”	2.5
Well Drained	2	20-40”	1.25
Somewhat Excessively Drained	1	<20”	0
Excessively Drained	0		

Hazard Level for All Soils Used for Crops (Figure 25)

The map was created in ArcMap by laying the Soil Drought Hazard map on top of the 2011 National Land Cover Data (NLCD) map and then clipping the NLCD layer to leave only the areas designated as “crop”, leaving only the soils that overlay the crop areas.

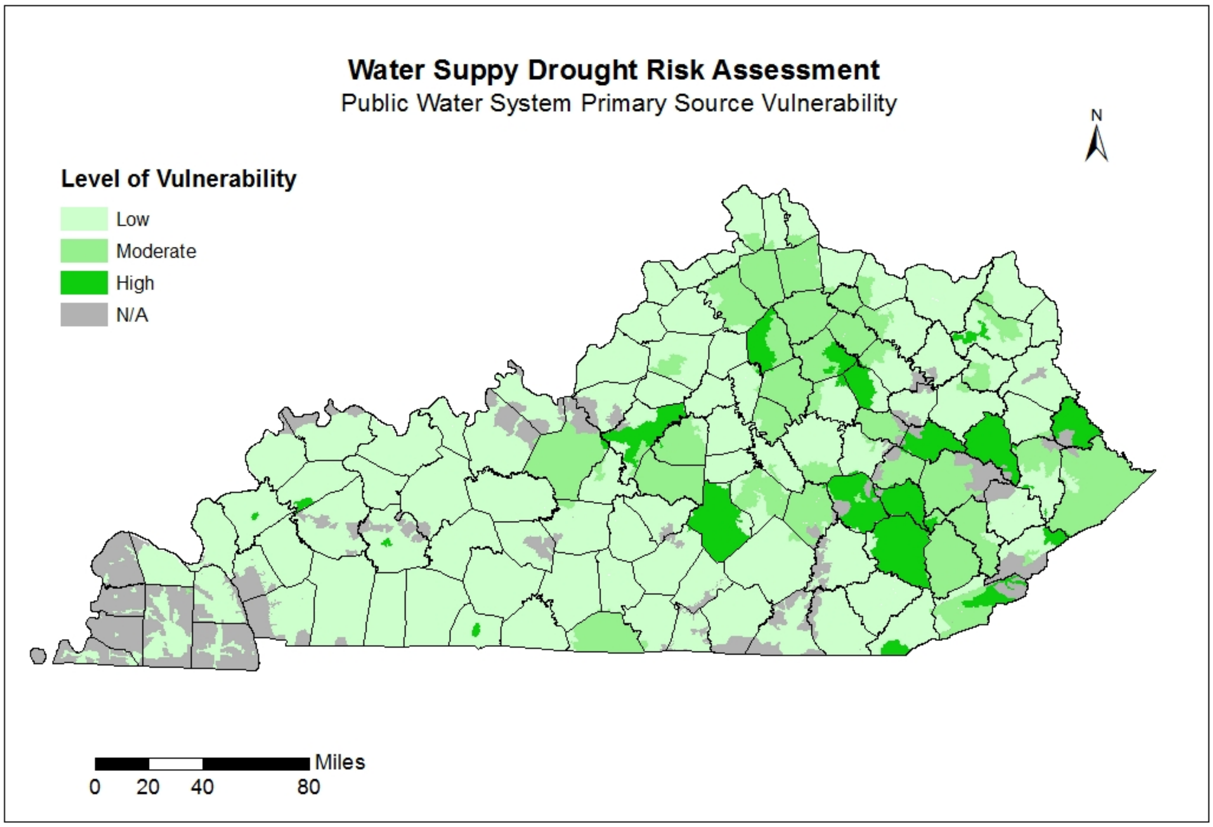
Hazard Level for All Soils Used for Pasture/Hay (Figure 24)

The map was created in ArcMap by laying the Soil Drought Hazard map on top of the 2011 National Land Cover Data (NLCD) map and then clipping the NLCD layer to leave only the areas designated as “pasture” and “hay”, leaving only the soils that overlay these areas.

Public Water System Risk Assessment

Water Supply Source Assessment

Figure 9. Vulnerability of primary sources of water for Kentucky public water systems

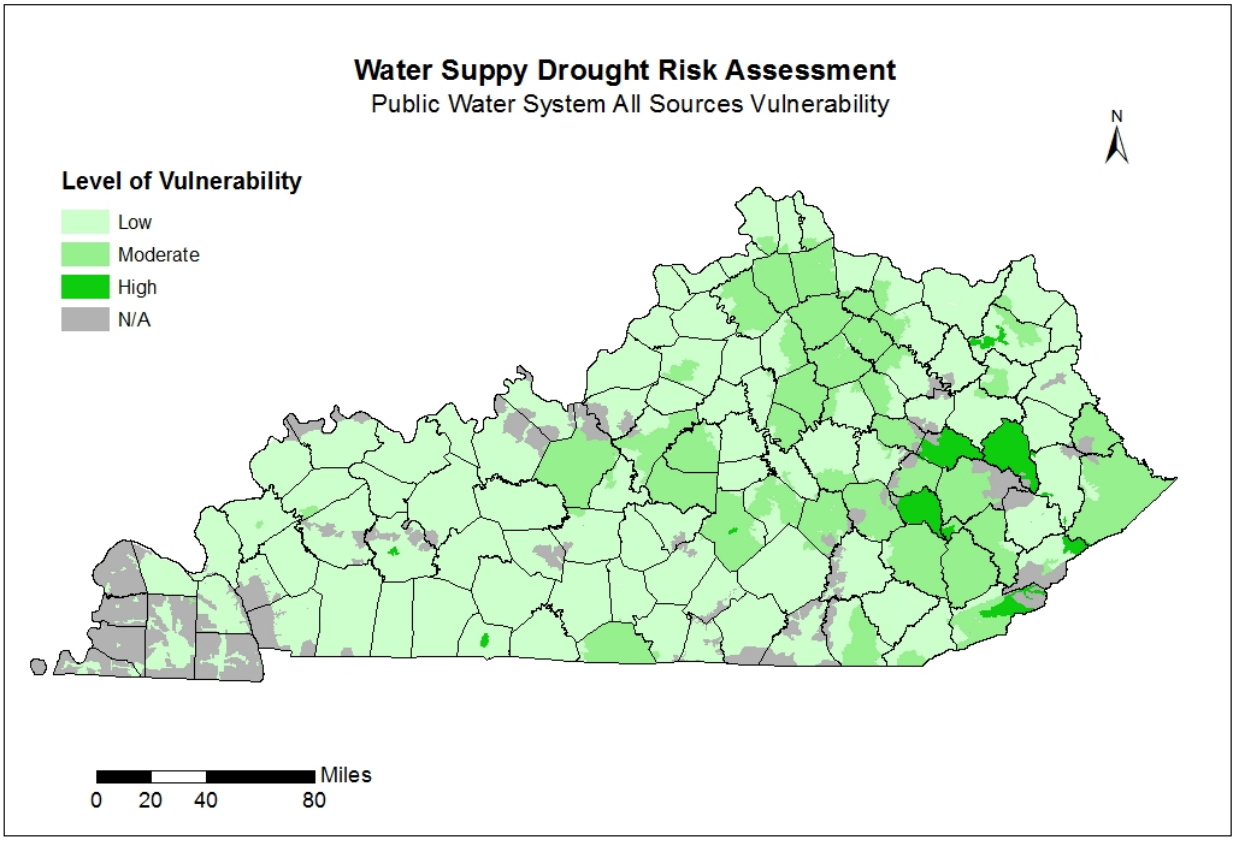


Shaded areas denote water service areas determined by constructing polygons from water line layers in ArcMap.

* Areas not served by a public water system are labeled as N/A

*Primary Source refers to only the MAIN source used by the water system

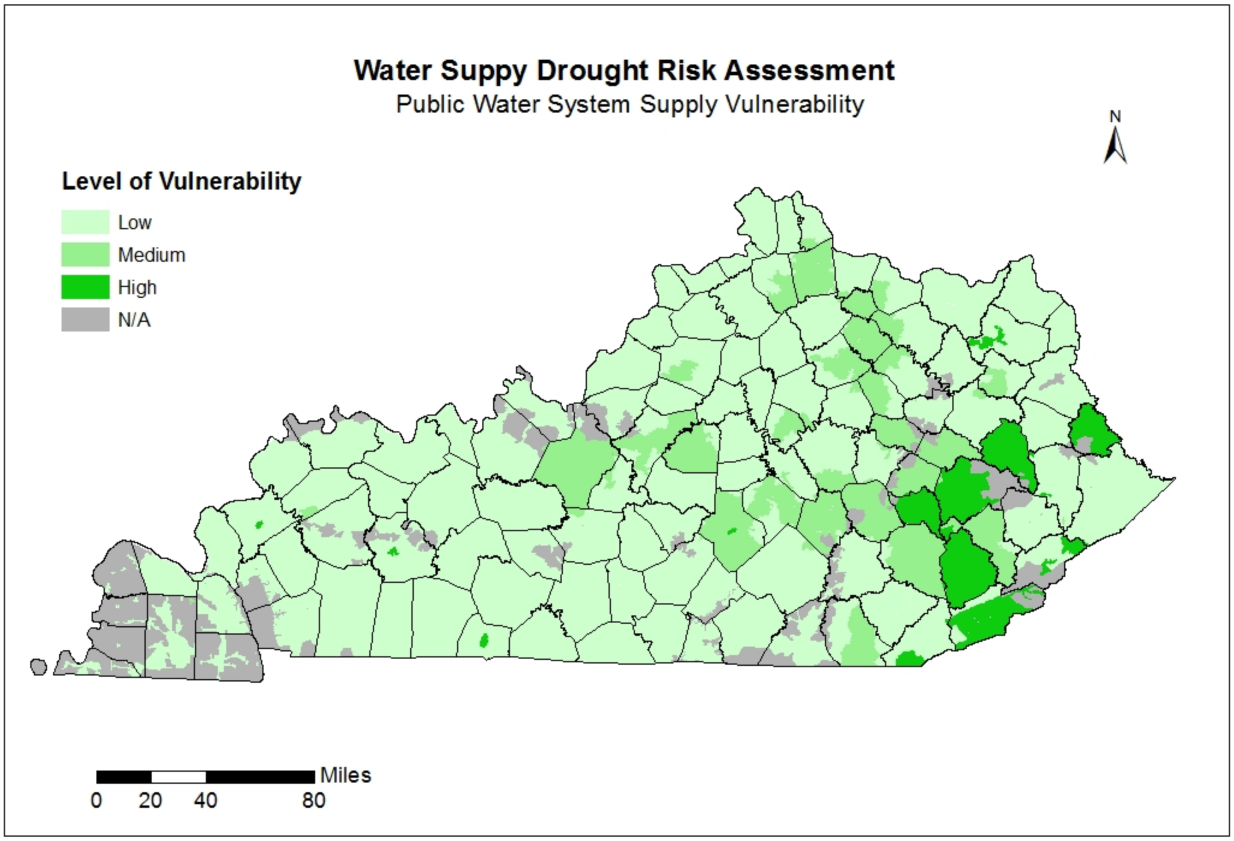
Figure 10. Vulnerability of public water systems when alternate and backup sources are included



*Shaded areas denote water service areas determined by constructing polygons from water line layers in ArcMap.

* Areas not served by a public water system are labeled as N/A

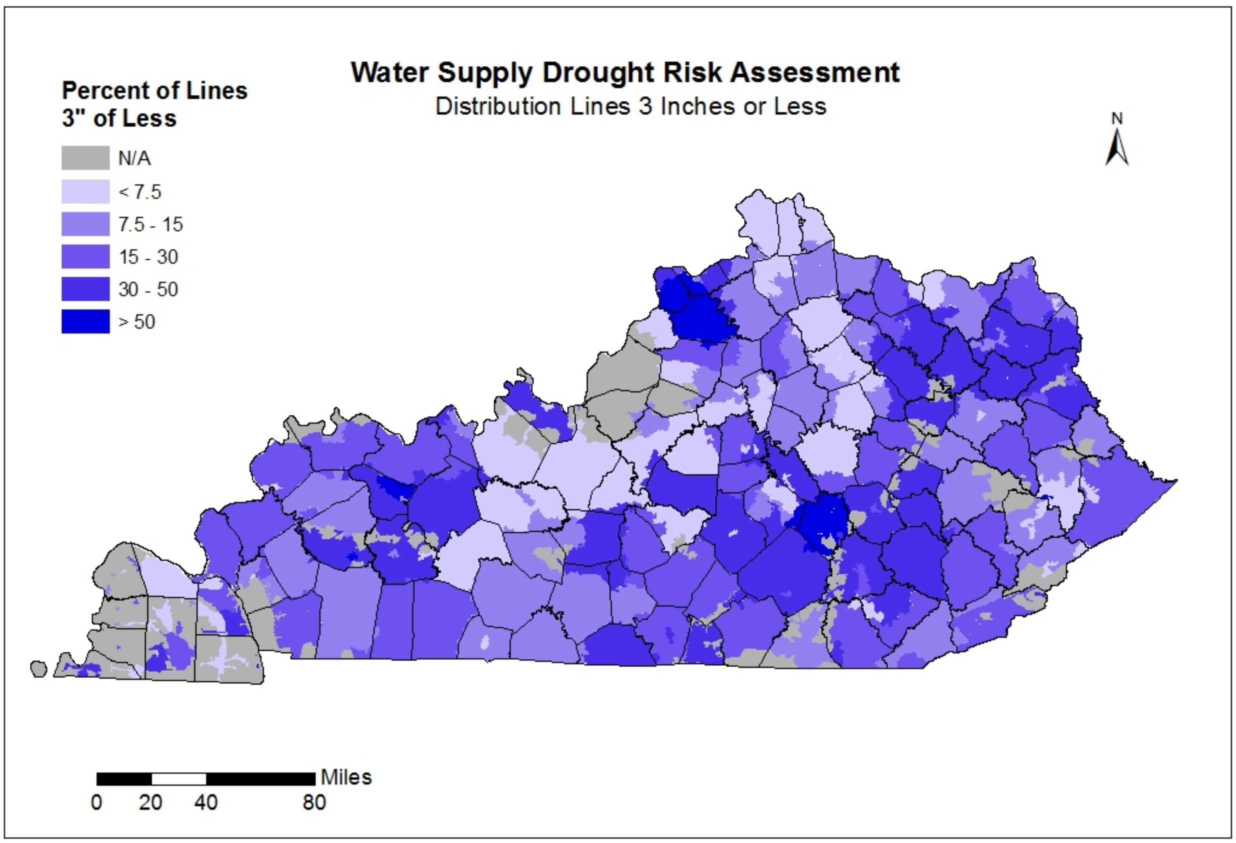
Figure 11. Combined vulnerability score for public water systems with interconnections, emergency sources and drought management included



Shaded areas denote water service areas determined by constructing polygons from water line layers in ArcMap.

Water Supply Infrastructure Assessment

Figure 12. Percent of three inch or less water lines as indicators of potential water distribution problems during drought



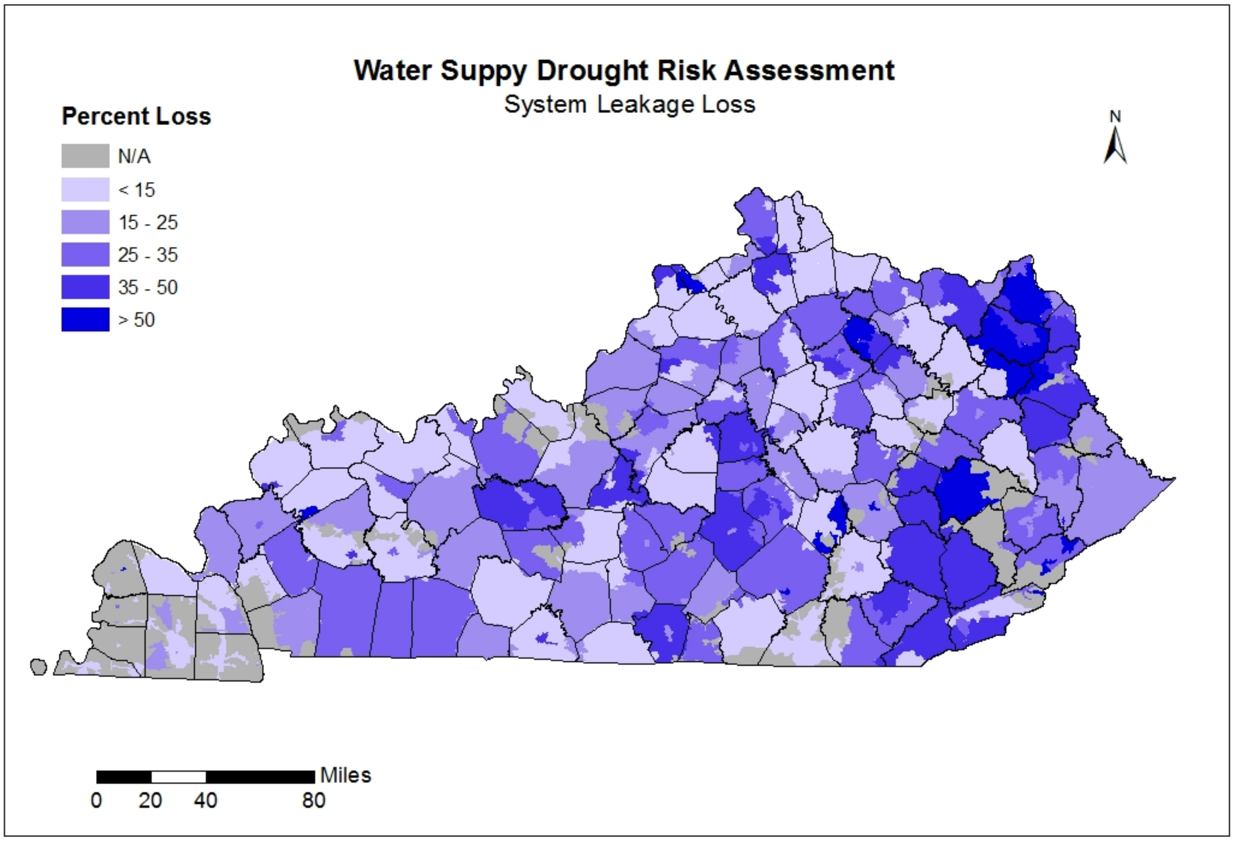
Shaded areas denote water service areas determined by constructing polygons from water line layers in ArcMap.

* N/A areas are either not served by a public water system or data was not available

The percent of water lines 3 inches or less is one of two factors that create the

infrastructure score. During droughts, when demand becomes greater than the amount the system can produce, customers supplied by smaller lines will be impacted first. Systems with a higher percentage of 3 inch lines have a higher number of customers that could be impacted during periods of high usage, or limited supply.

Figure 13. Percent Unaccounted- for water as an indicator of drought vulnerability of a water system



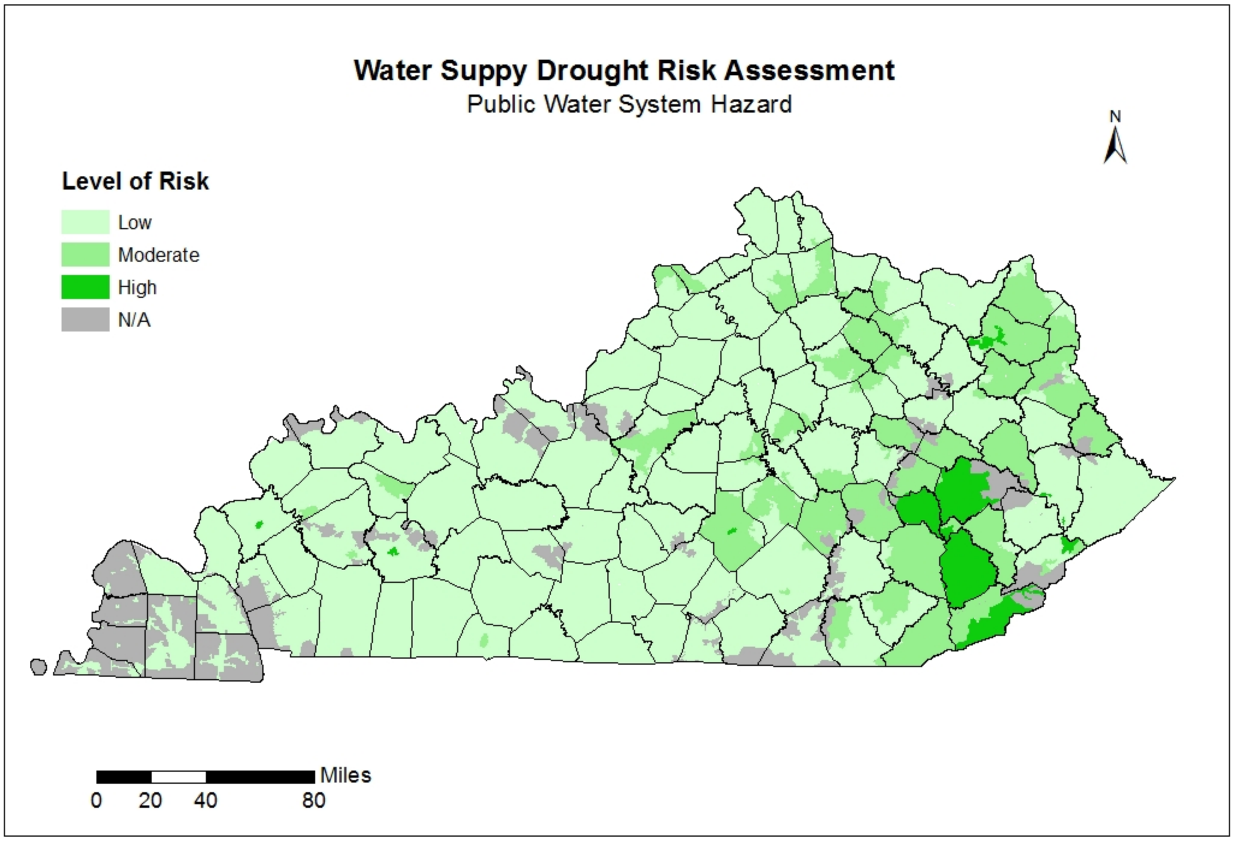
*Shaded areas denote water service areas determined by constructing polygons from water line layers in ArcMap.

* N/A areas are either not served by a public water system or data was not available

*Systems with a high leakage loss are more vulnerable to drought when a portion of the water being withdrawn from the source is lost. Experience has shown that certain systems that experience low availability during drought often are losing more water than the drought restriction savings required by water withdrawal permits. Leakage losses also reduce the effectiveness of conservation efforts since those efforts will only impact the percentage of water making it to the customers.

Water Supply Final Assessment –Public Water Supply Drought Hazard

Figure 14. Overall public water system scores considering available sources and infrastructure issues

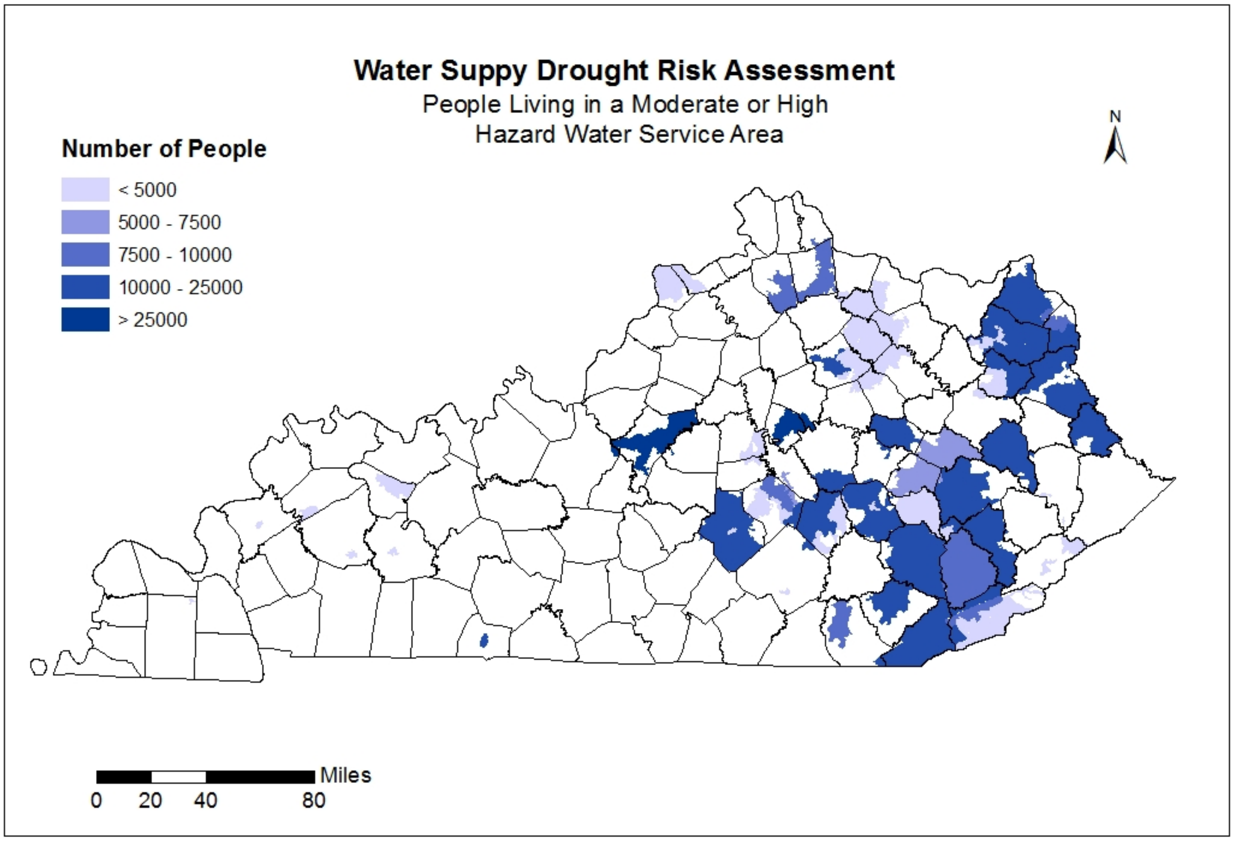


*Shaded areas denote water service areas determined by constructing polygons from water line layers in ArcMap.

*Systems with a good source can become drought vulnerable because of poor infrastructure. Poor infrastructure, when combined with a system that already has a drought vulnerable source, makes a bad situation even worse. There are also examples of systems that improved their drought hazard score with good infrastructure scores by doing an excellent job keeping leakage loss to a minimum.

Water Supply Final Assessment – Public Water Supply Risk

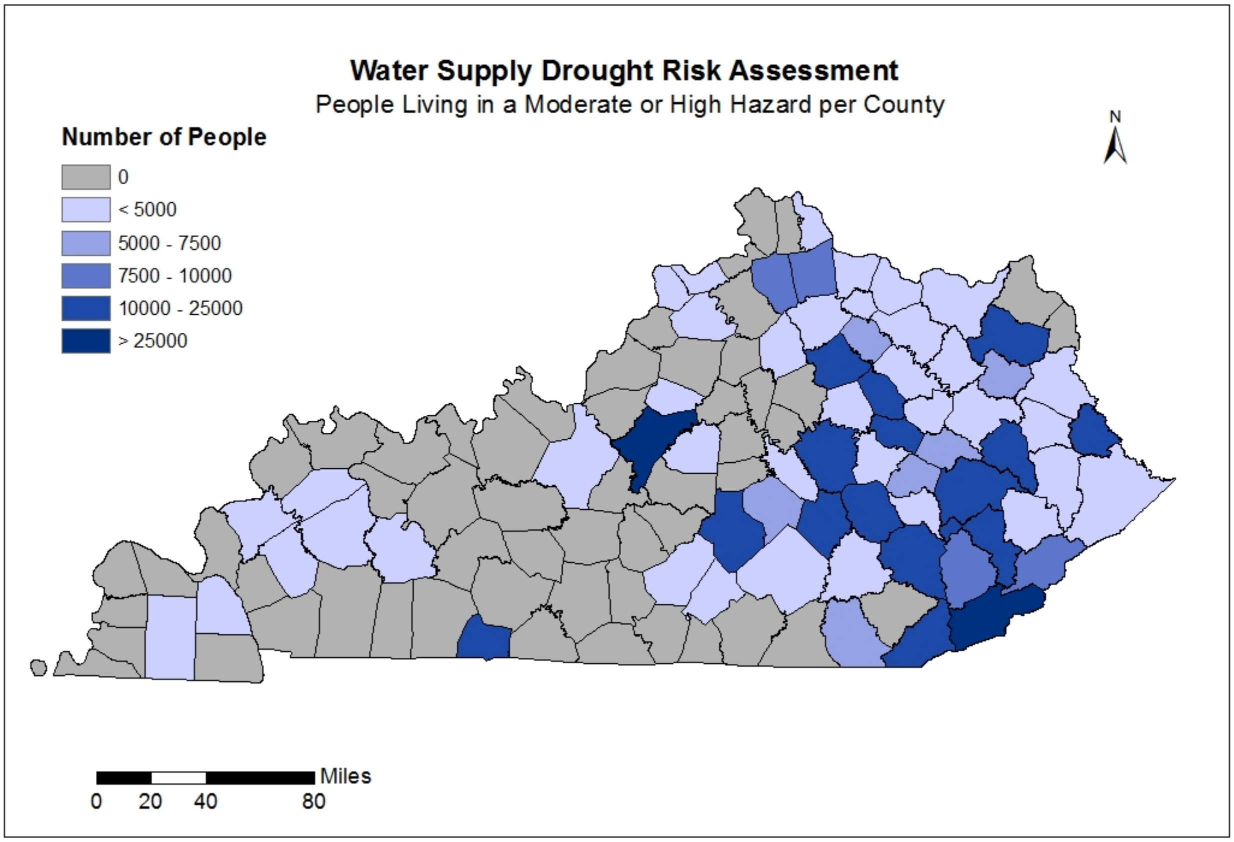
Figure 15. Water supply risk as number of people served by moderate or high drought hazard water systems



*Shaded areas denote water service areas determined by constructing polygons from water line layers in ArcMap.

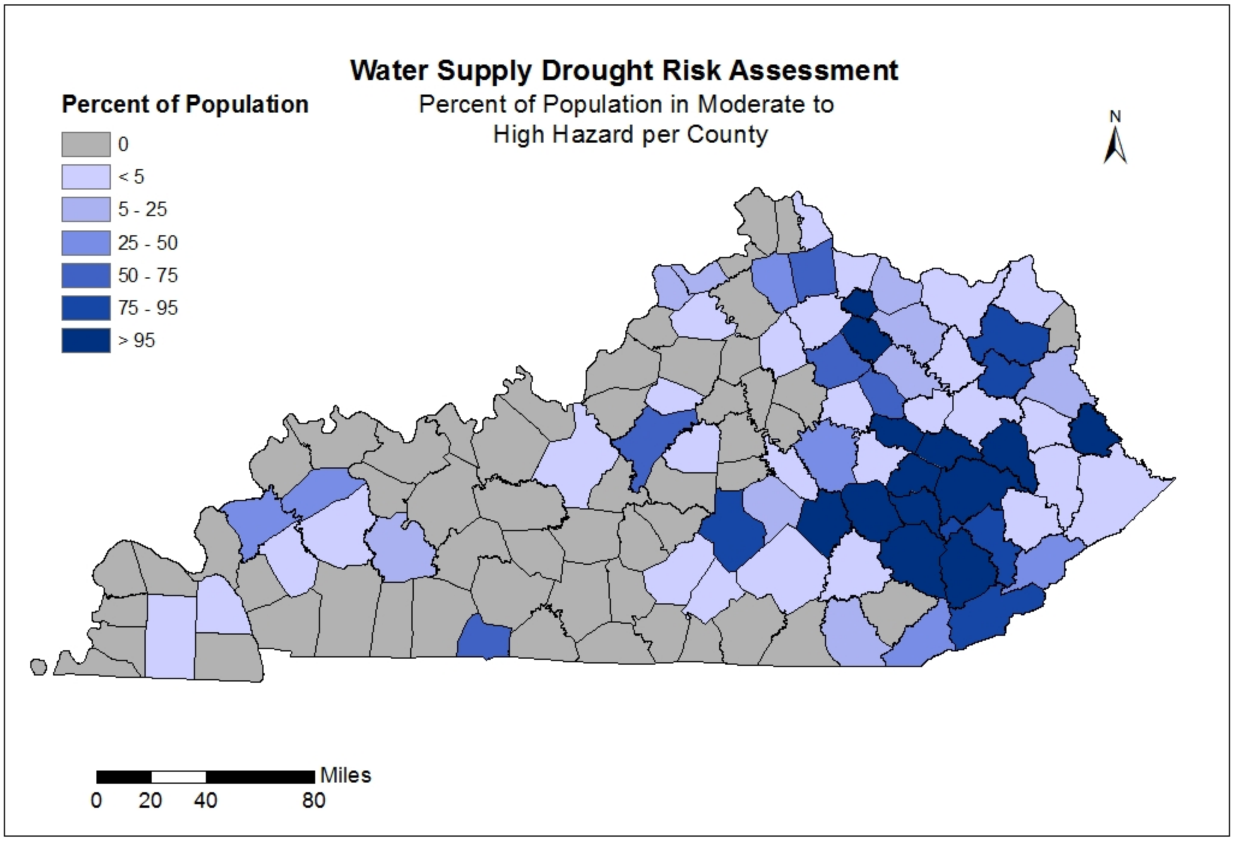
*White areas indicate that the area has no public water system lines or is a low hazard water service area.

Figure 16. Water supply risk as number of people by county



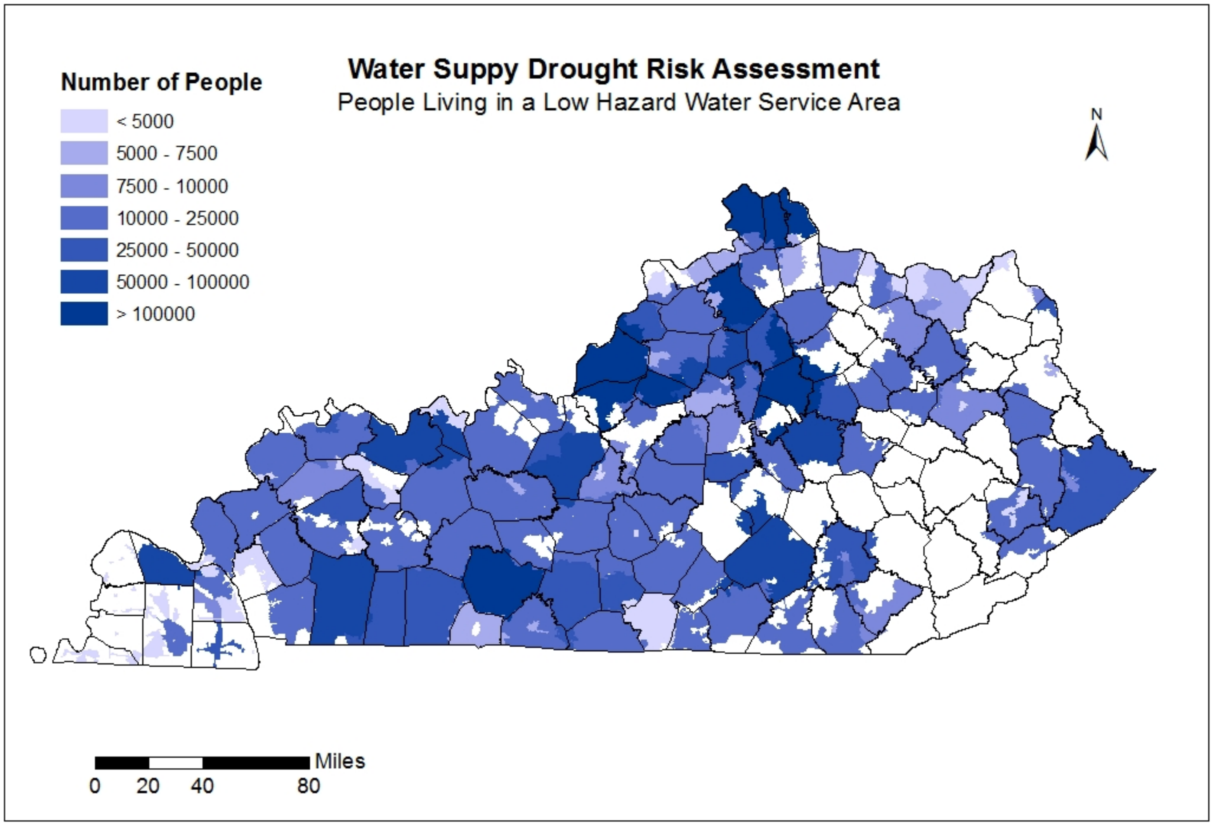
Most Kentuckians living in areas with high risk for Public Water systems are found in the eastern and southeastern third of the state. Water system hazard scores in eastern Kentucky suffer form both supply deficiencies (surface sources are mainly headwaters and there is a lack of reliable ground water sources). Problems associated with large leakage losses or other unaccounted for water stresses these systems both operationally and financially. The results of this risk assessment should highlight the need for focused investment in eastern Kentucky to alleviate some this this drought risk.

Figure 17. Water supply risk as percent of population in each county served by moderate or high drought hazard water systems.



Viewing high risk counties with an emphasis on the percent of resident populations in high hazard water service areas gives an even clearer vision of where the most pressing water supply drought issues exist.

Figure 18. Populations served by water systems with low drought hazard



*Shaded areas denote water service areas determined by constructing polygons from water line layers in ArcMap.

*White areas indicate that the area has no public water system lines or is a moderate or high hazard water service area

Figure 19. Populations served by water systems with low drought hazard by county

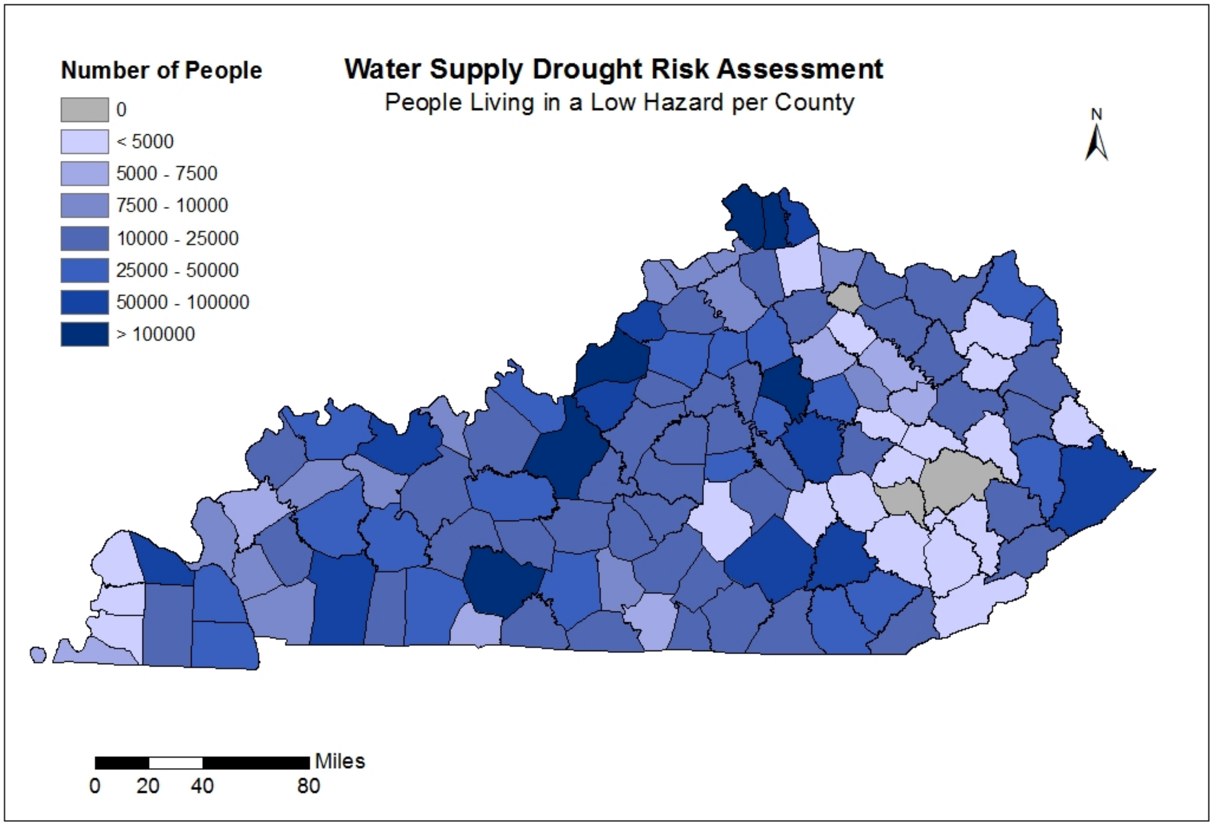


Figure 20. Numbers of Hospitals and Long-term care facilities (by numbers of beds) as indicators of human health risks

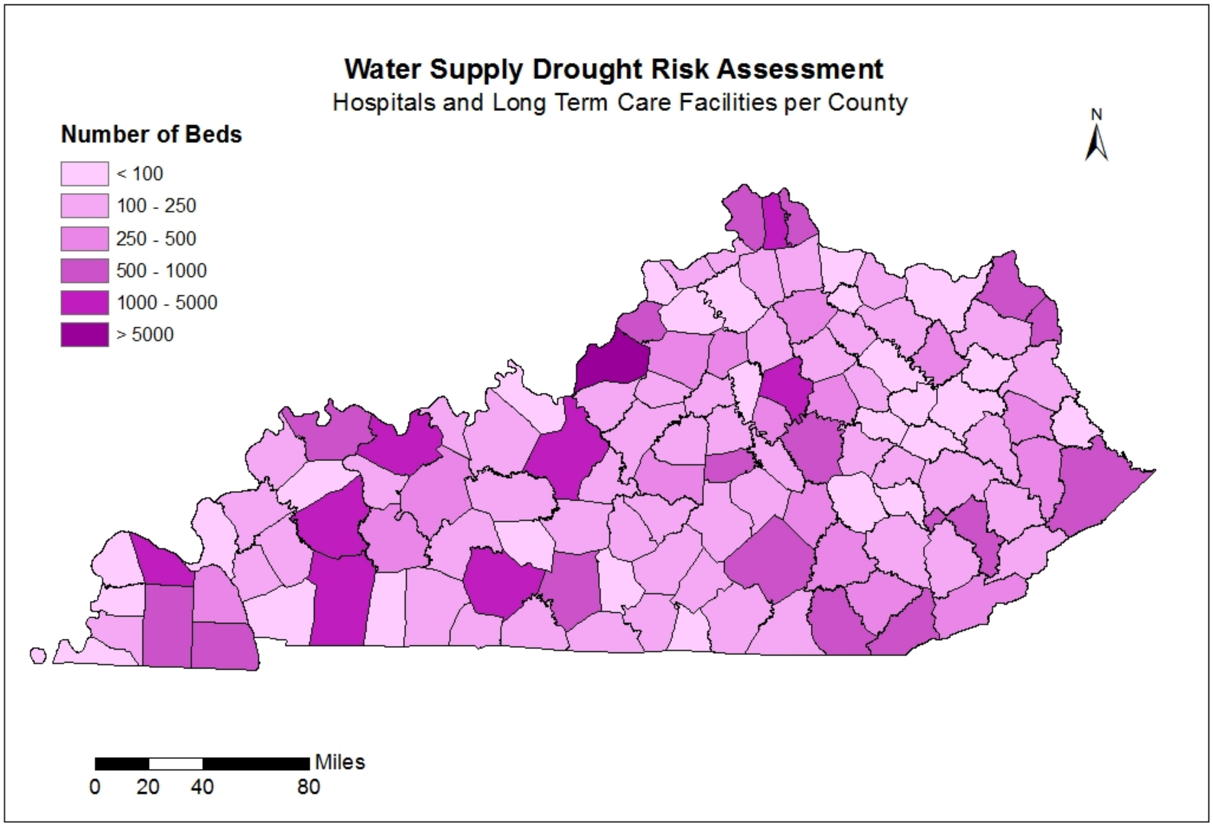


Figure 21. Human health risk: hospital ad long-term care beds served by moderate to high drought hazard water systems

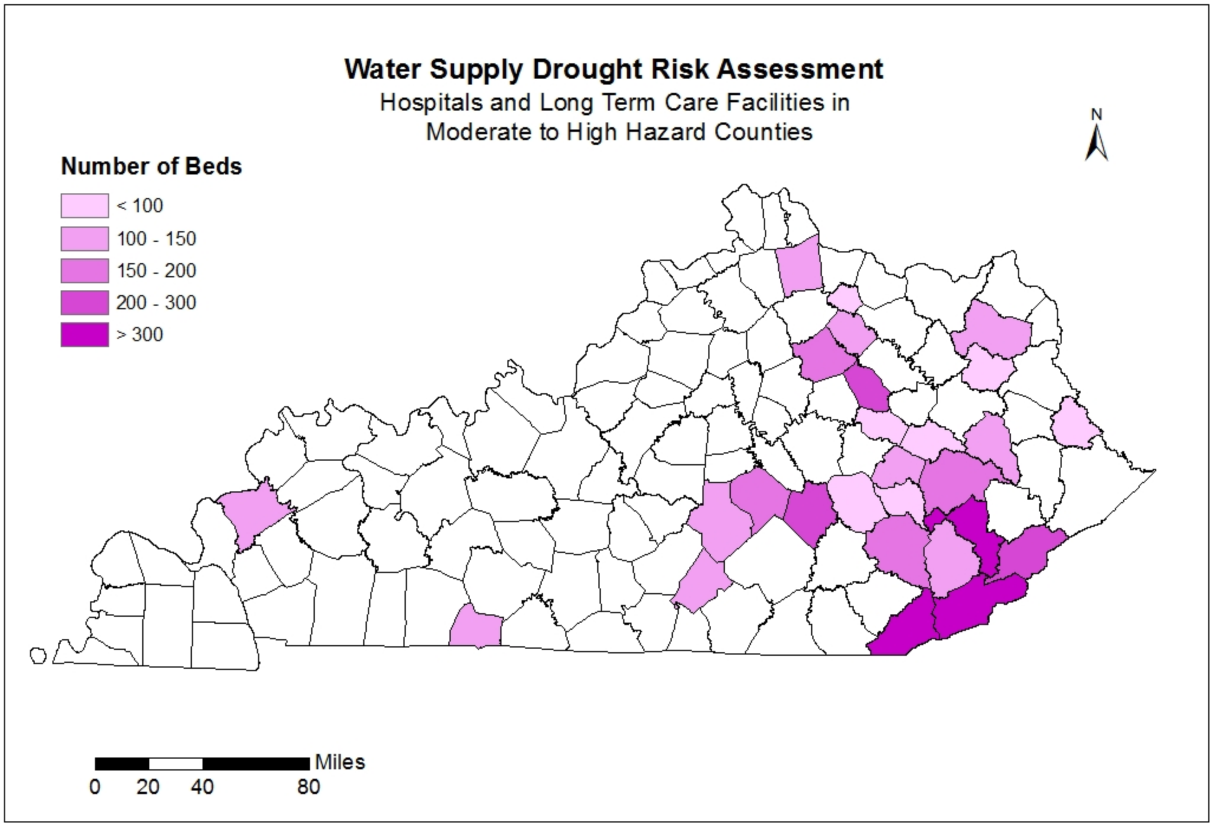


Figure 22. **State Office Buildings by Water System**

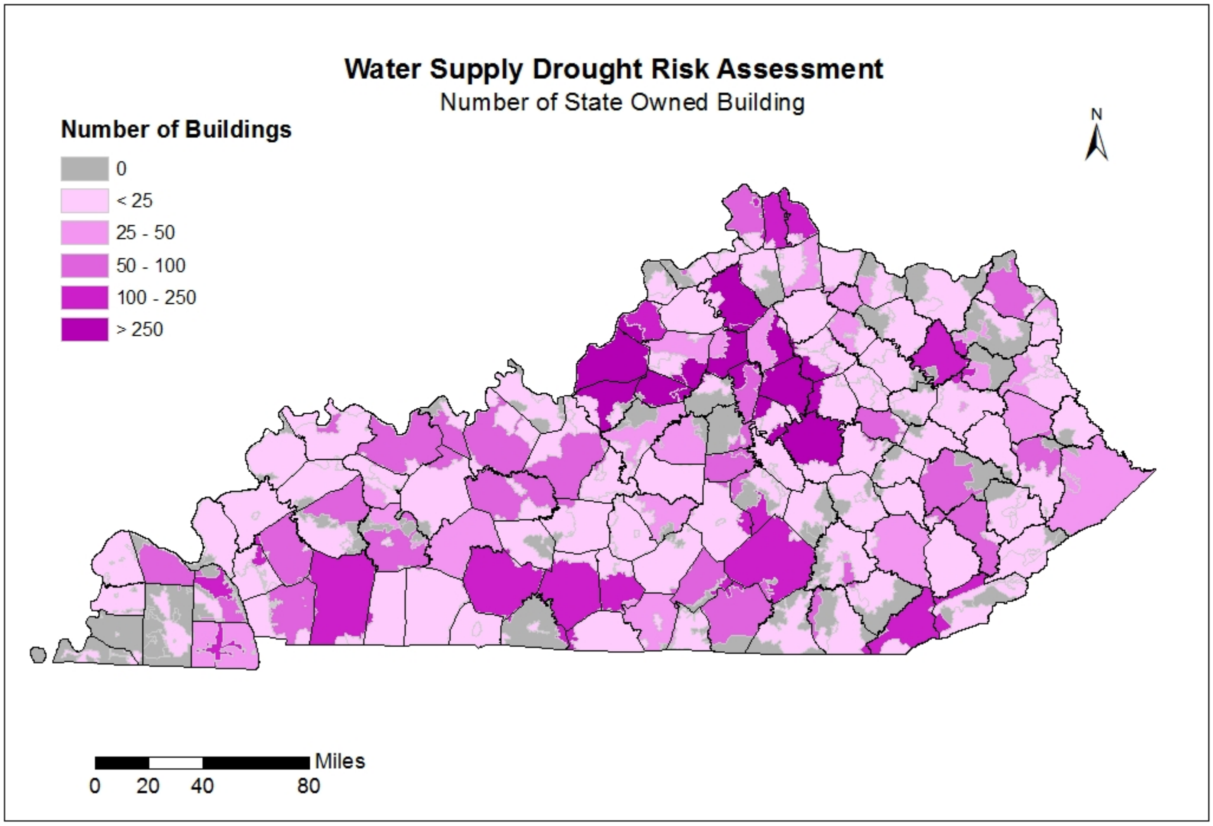


Figure 23. **State Office Buildings by County**

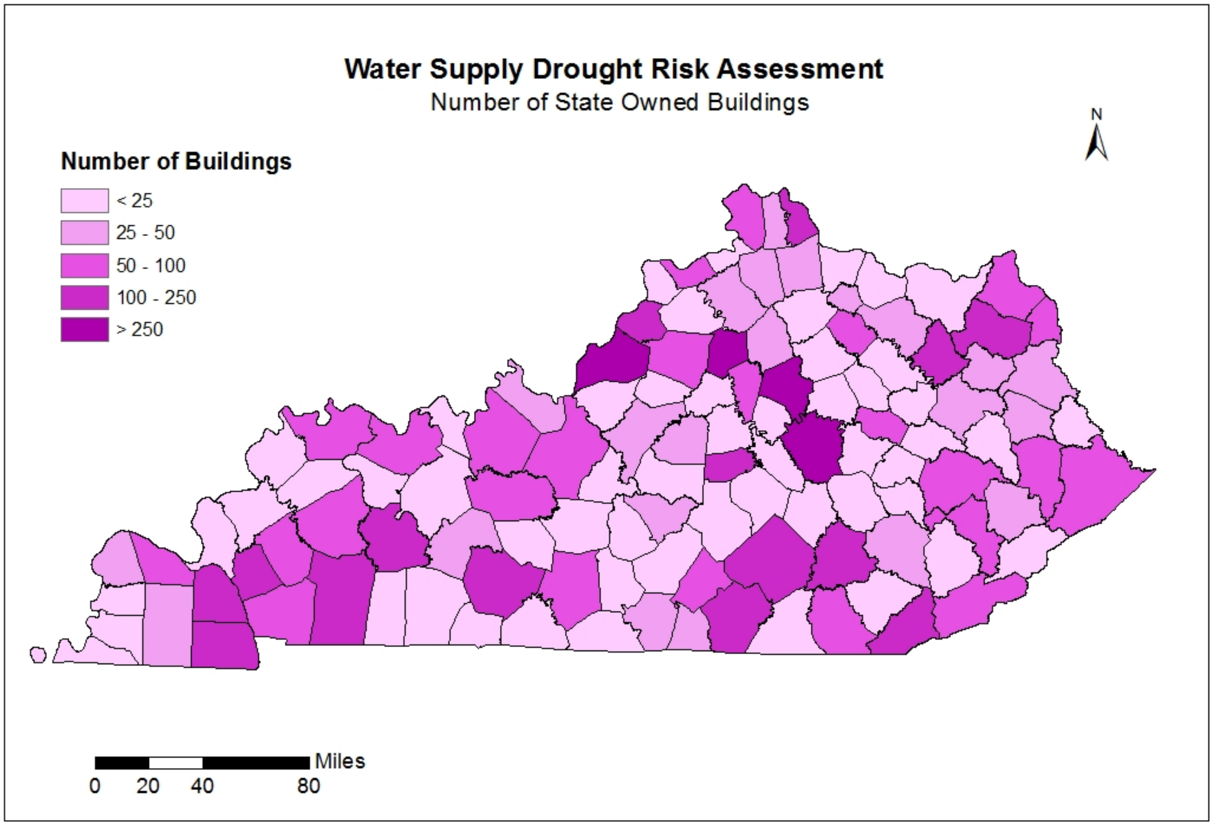


Figure 24. Number of state office buildings in moderate to high hazard counties

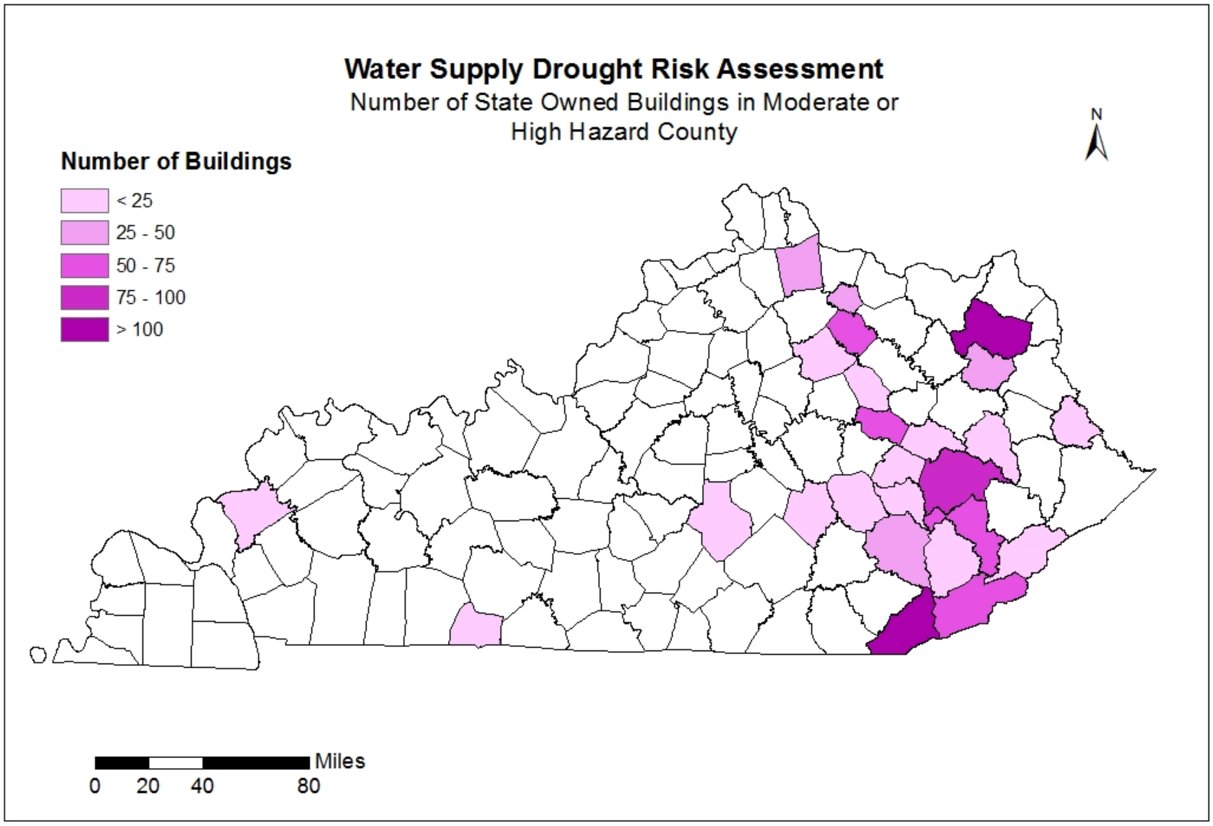
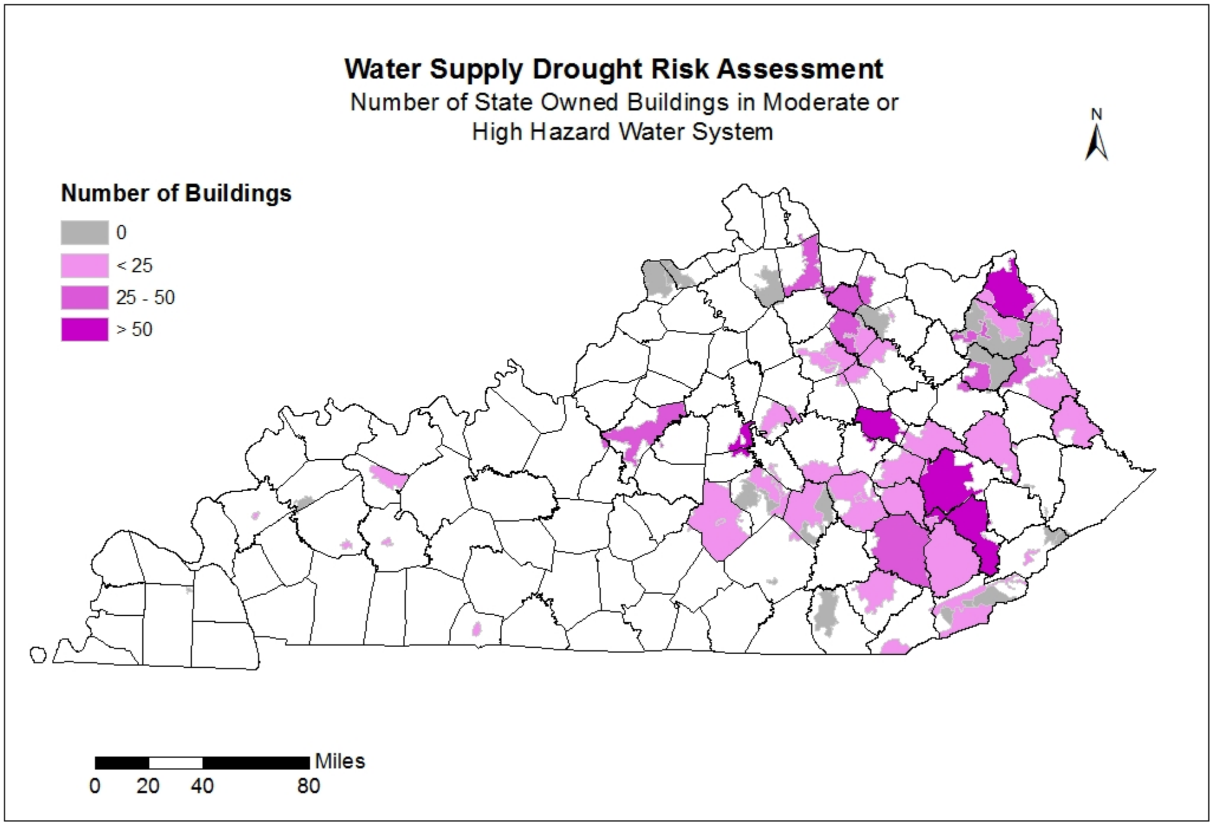


Figure 25. Number of state owned office buildings in moderate to high hazard water service areas



Agricultural Risk Assessment

Crops Risk Assessment

The drought risk assessment map for the drought soil hazard is based on the assumption that soils with superior moisture storage and release characteristics as defined by NRCS will support higher plant productivity during moderate droughts. These maps were created using a ranking system as outlined below:

Soil Hazard Score = (Infiltration + Water Movement + Water Supply)/3

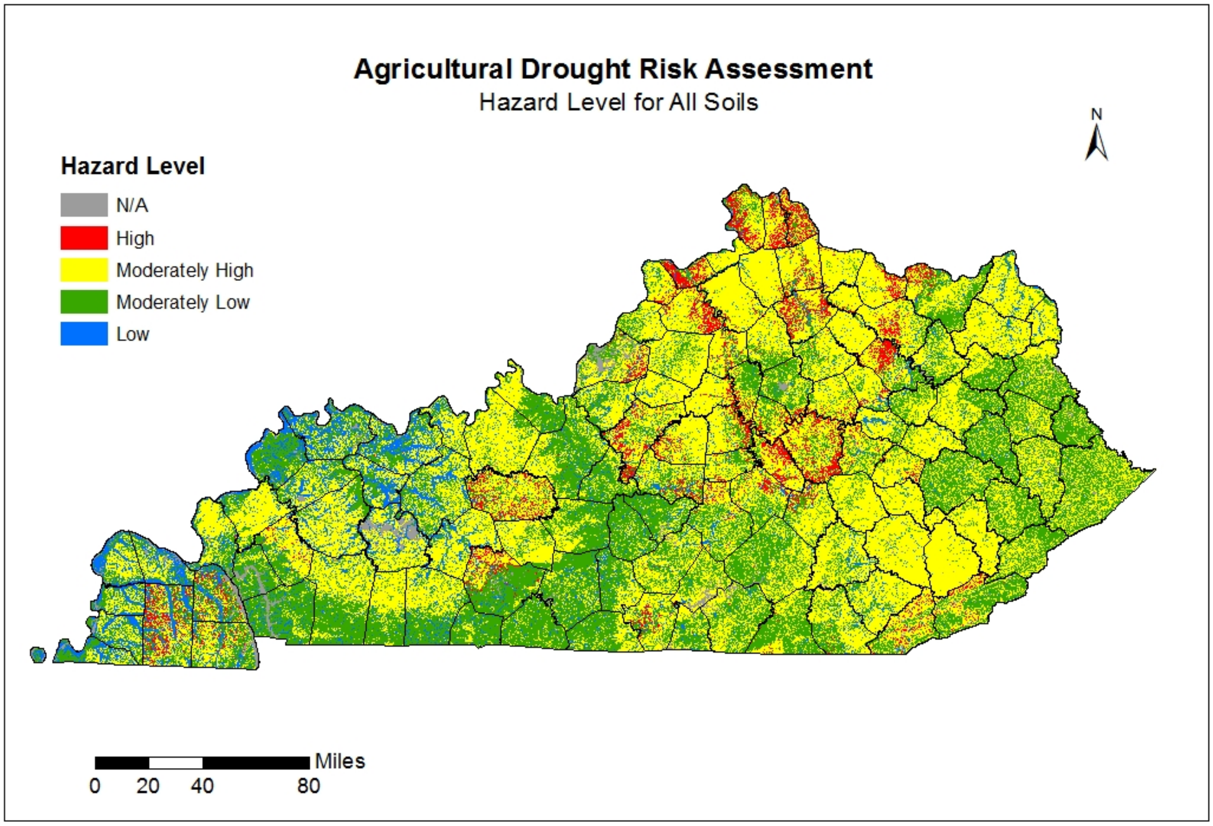
Infiltration Score = (Slope + Hydrologic Soil Group)/2

Water Movement Score = (Drainage Class + Ksat)/2

Water Supply Score = (Available Water Supply in Profile + Soil Depth to Restrictive Layer)/2

Once created the soil drought hazard layer could be analyzed for soil moisture characteristics underlying any class of land use or cropping system.

Figure 26. Soil Drought Hazard for all Kentucky Soils

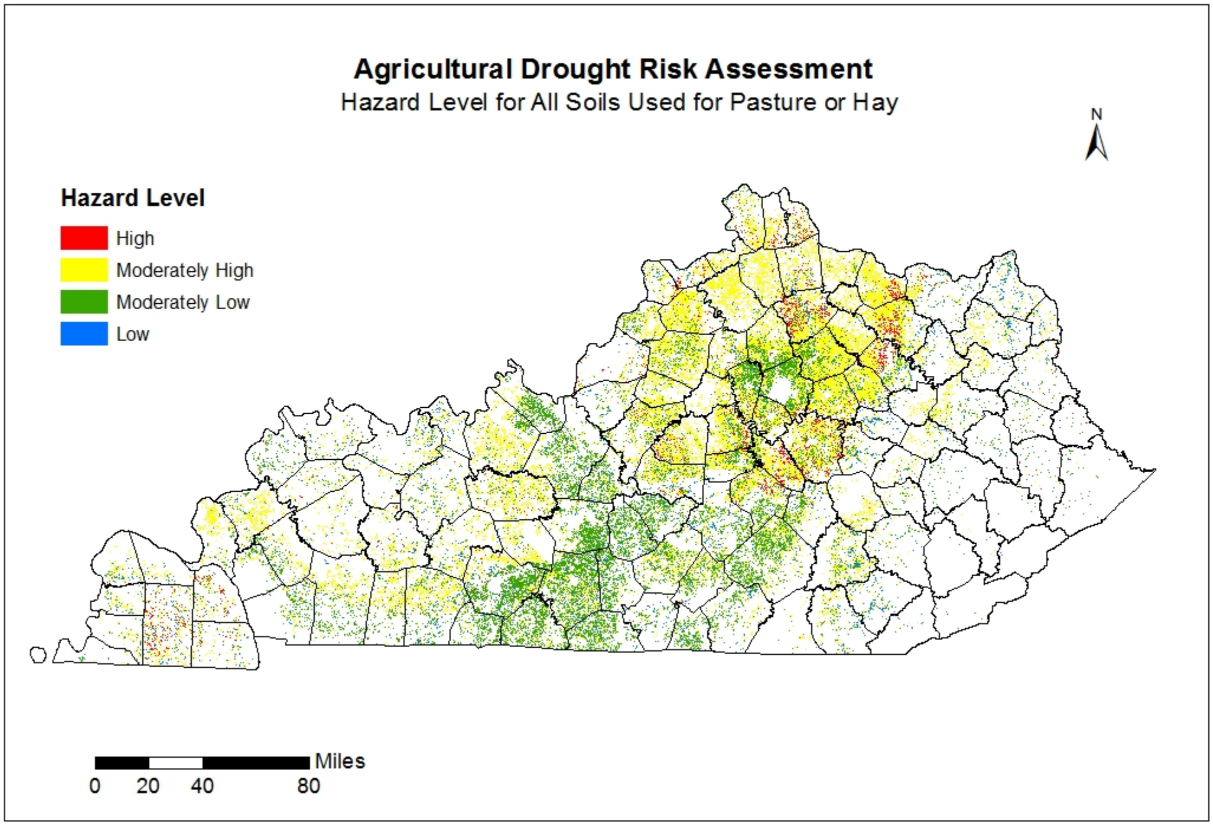


*Grey areas indicate that no soil data was available to lakes, heavily urbanized areas, or strip mining

*This map reflects a soils drought vulnerability from a moisture retention and availability perspective. It does not take into account other factors that contribute to how fertile a soil is. For example, the Purchase region is one of the most heavily farmed areas of the state due, in part, to its fertile soil. However, looking a Graves County, you can see that there are numerous areas that have a high and moderately high drought hazard. This is mainly due to the presence of a shallow fragipan, which limits the depth of the soil.

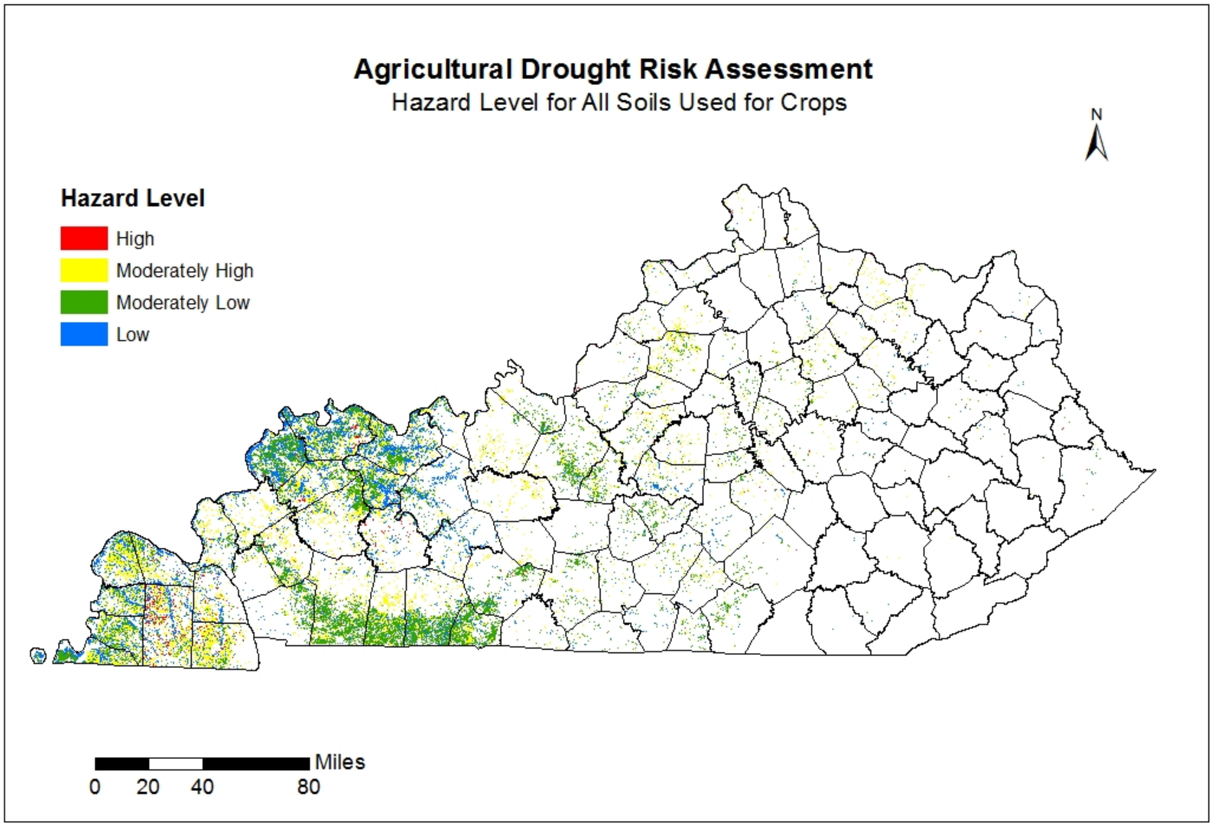
*The data used to create this map is based on NRCS soil surveys which are produced at a county level. As a result, there are some places where hazard levels do not flow smoothly over county boundaries due to difference in how a soil, or soils, where characterized in that particular soil survey. The most obvious of these areas is on the Carroll/Trimble county line.

Figure 27. Soil Drought Hazard for soils used for producing pasture and hay



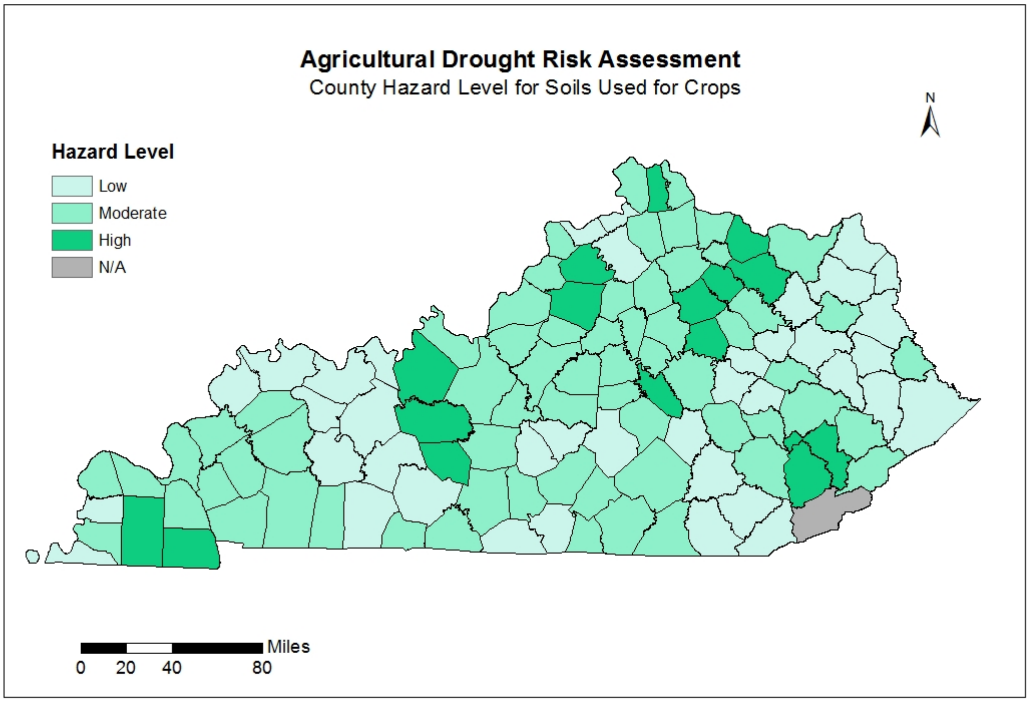
The Pasture/Hay Drought Hazard soils map was created in ArcMap by laying the Soil Drought Hazard map on top of the 2011 National Land Cover Data (NLCD) map and then clipping the NLCD layer to leave only the areas designated as "pasture" and "hay", leaving only the soils that overlay these areas.

Figure 28. Soil Drought Hazard for soils used to produce row crops, primarily corn and soybeans



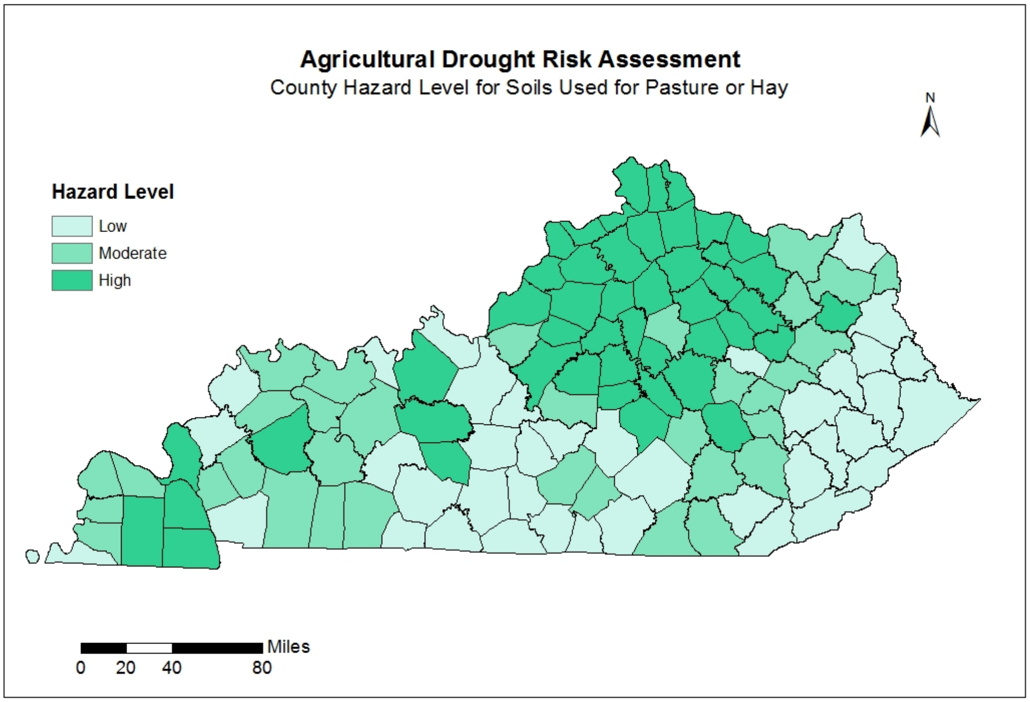
The Crop Soil Drought Hazard map was created in ArcMap by laying the Soil Drought Hazard map on top of the 2011 National Land Cover Data (NLCD) map and then clipping the NLCD layer to leave only the areas designated as "crop", leaving only the soils that overlay the crop areas.

Figure 29. Soil Drought Hazard rankings produced from a weighted average of soil drought hazard scores used for crops by county



Results suggest moderate to high hazard moisture characteristics present in much of western Kentucky. These are productive soils from nearly all standpoints but score less in terms of critical moisture characteristics (due to shallow soils, depth to fragipan, fertile if drained). Favorable soils for crops are located in the Central and Midwestern agricultural districts, and in some forested soils or river bottoms located in southern and eastern Kentucky.

Figure 30. Soil Drought Hazard rankings produced from a weighted average of soil drought hazard scores used for pasture/hay by county



Soil assessments of pasture and hay producing soils suggest moderate to high hazard moisture characteristics present in much of the Bluegrass and Northern agricultural districts. Pasture is a dominant land use in this area and soils with low favorability for row crop production support hay and grazing in the "cattle belt".

Figure 31. Number of row crop or pasture acres (left-hand column) utilizing Moderately High and High Hazard soils; Percent of row crop or pasture acres (right-hand column) in each county that are utilizing Moderately High to High Hazard soils

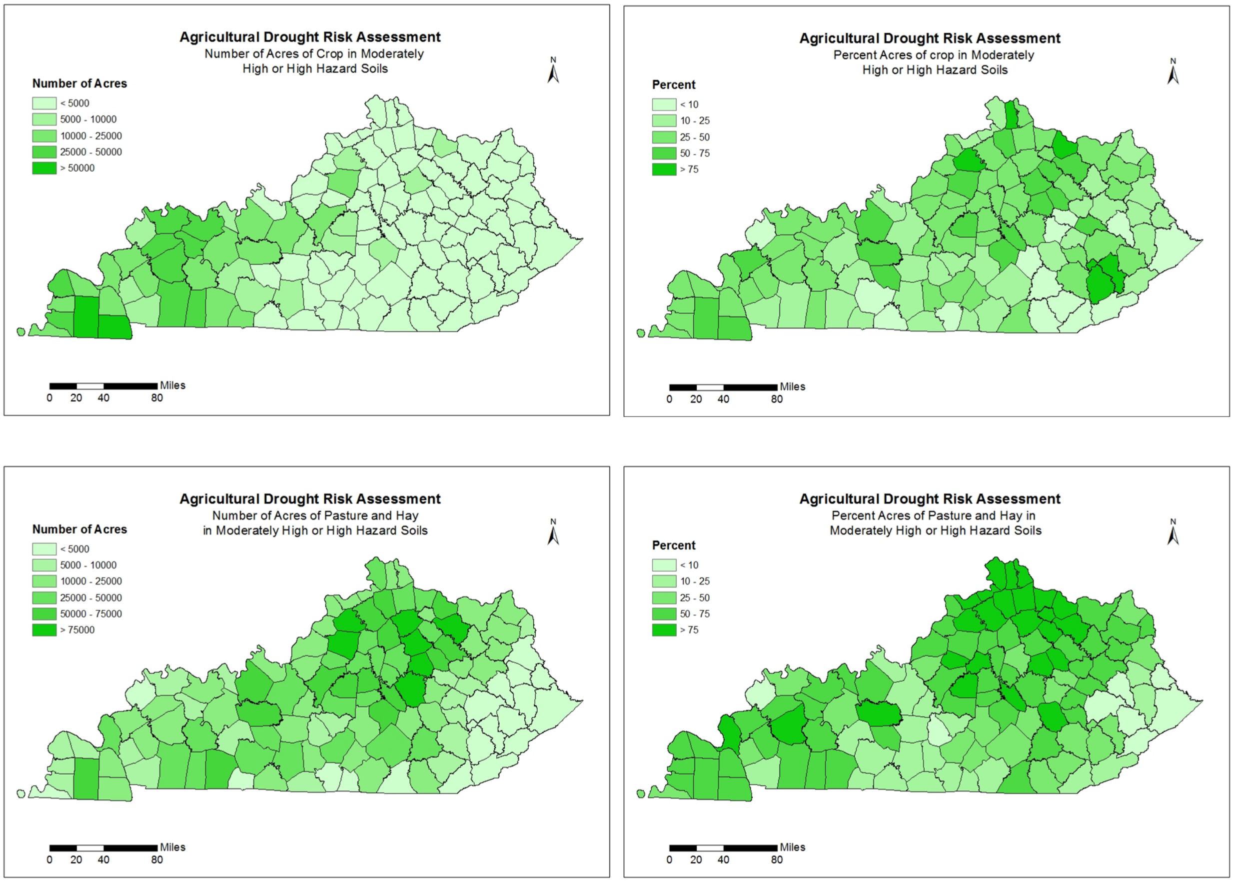
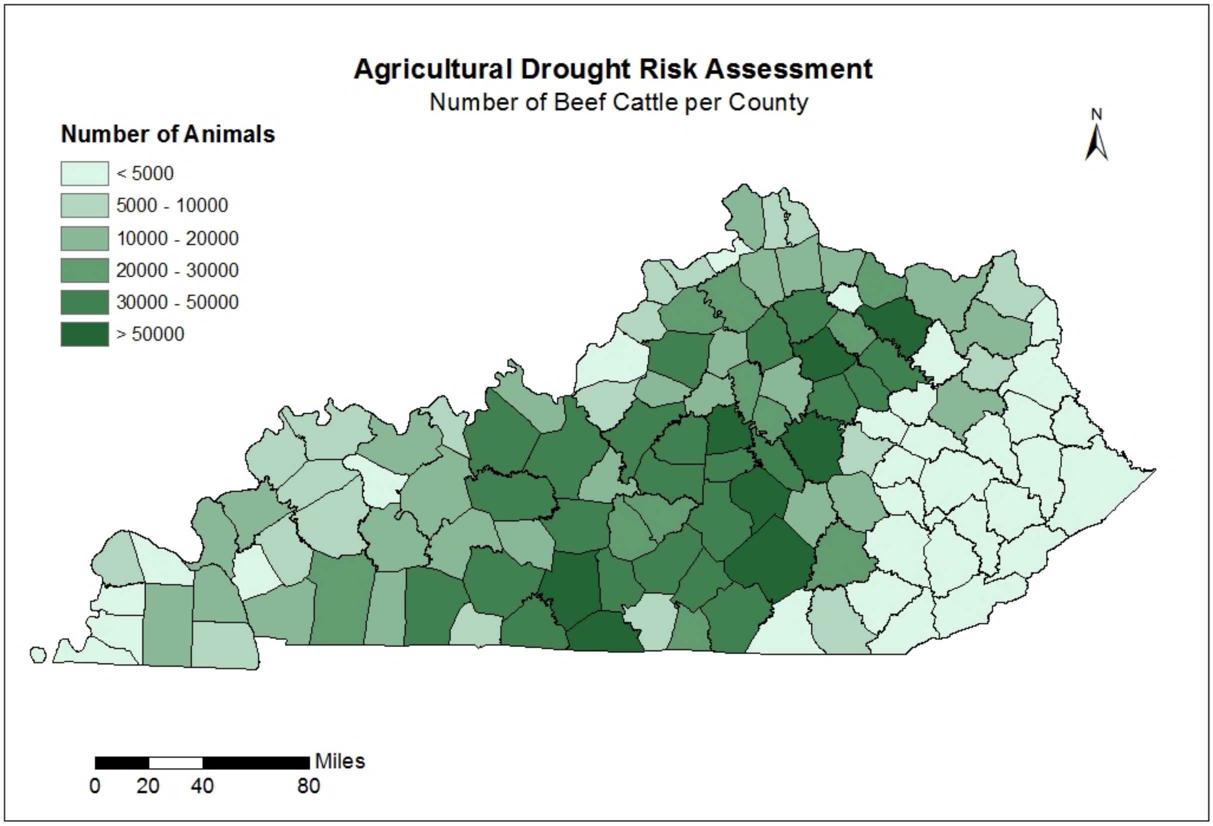
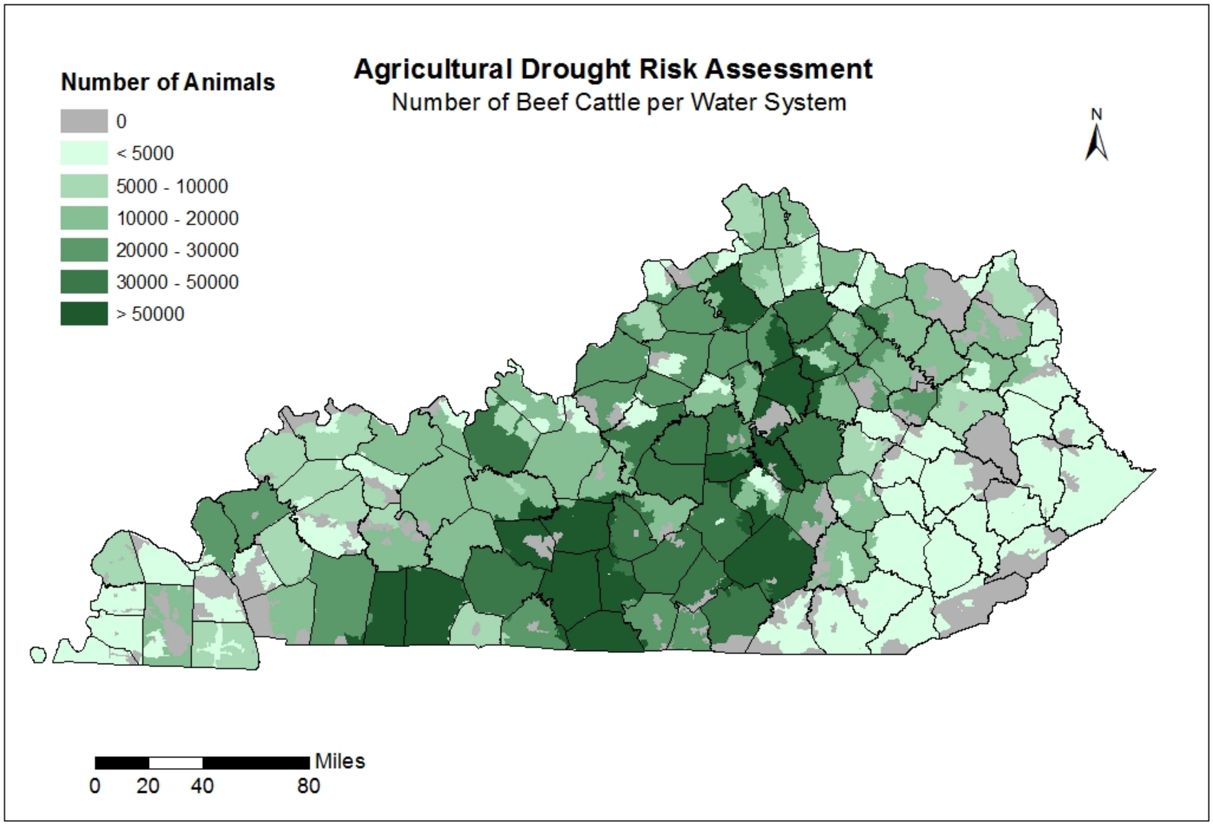


Figure 32. Total number of Beef Cattle per county



Source: USDA National Agricultural Statistics Service

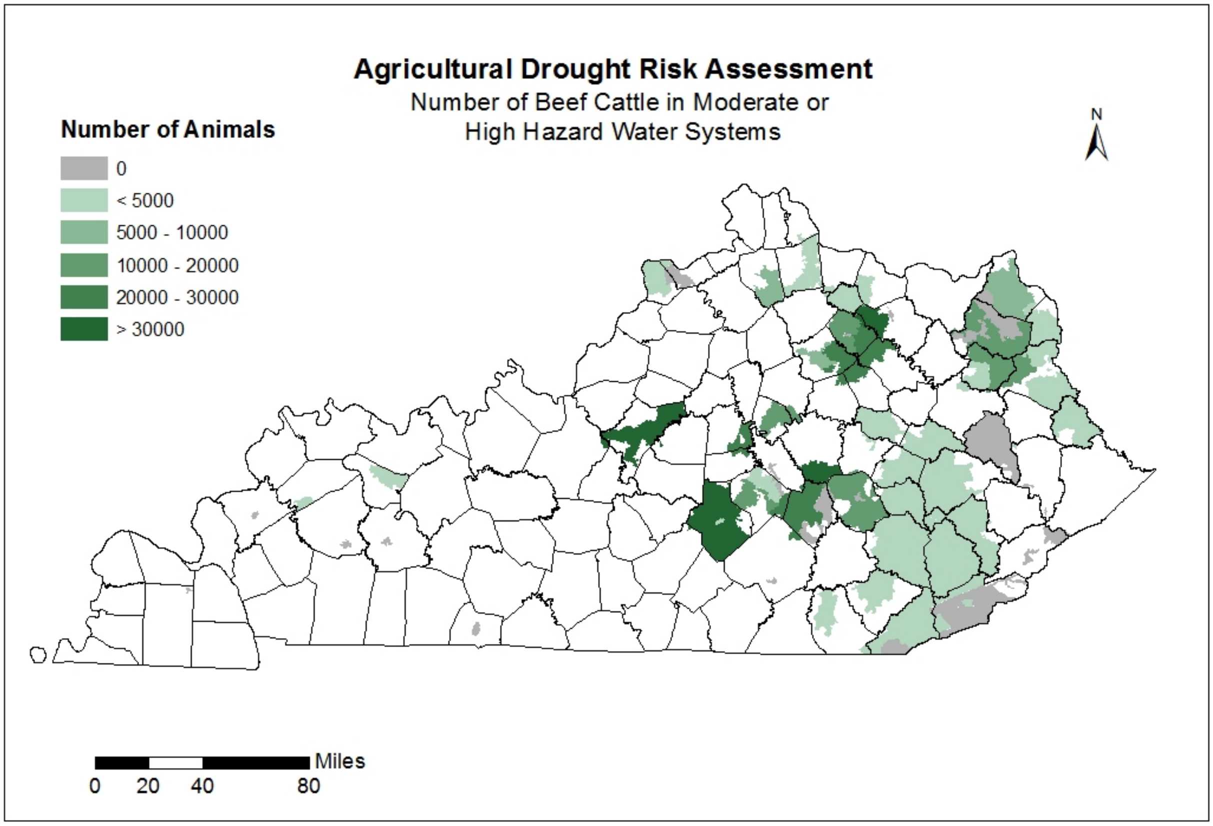
Figure 33. Potential beef cattle demand (weighted numbers of animals based on Ag census cattle numbers) on public water supplies



*Unlike previous maps, areas with no PWS are included livestock water system maps and county maps. It is assumed that these areas are self served, but it is possible that farms could haul water if on farm sources dry up.

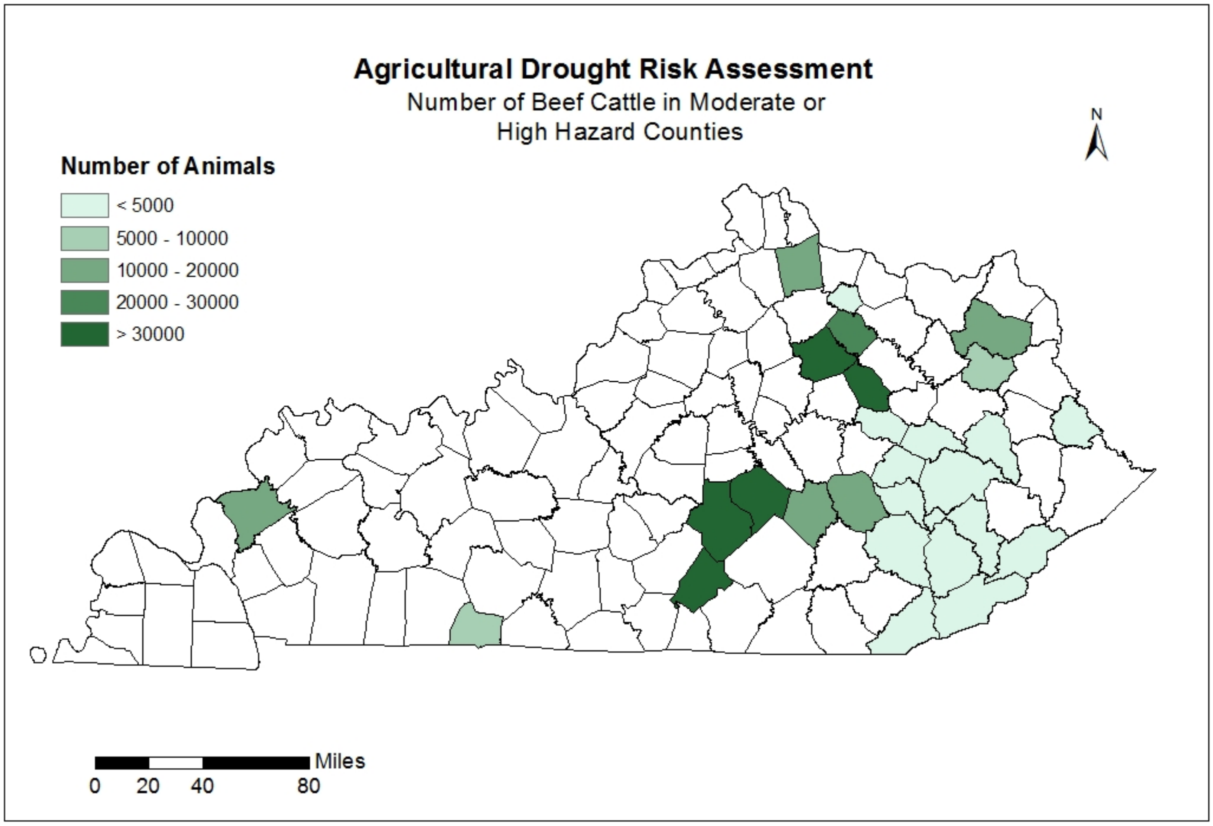
*DEP databases for locations of beef cattle and ranching operations were used to estimate likely locations for beef cattle in each water system service area. Each water system service area was then weighted based on the number of beef cattle and ranching operations identified within the water service boundaries. A final score was arrived at using estimates for beef cattle from the Ag Census of 2012 for each county.

Figure 34. Number of Beef Cattle within Moderate to High Hazard water service areas



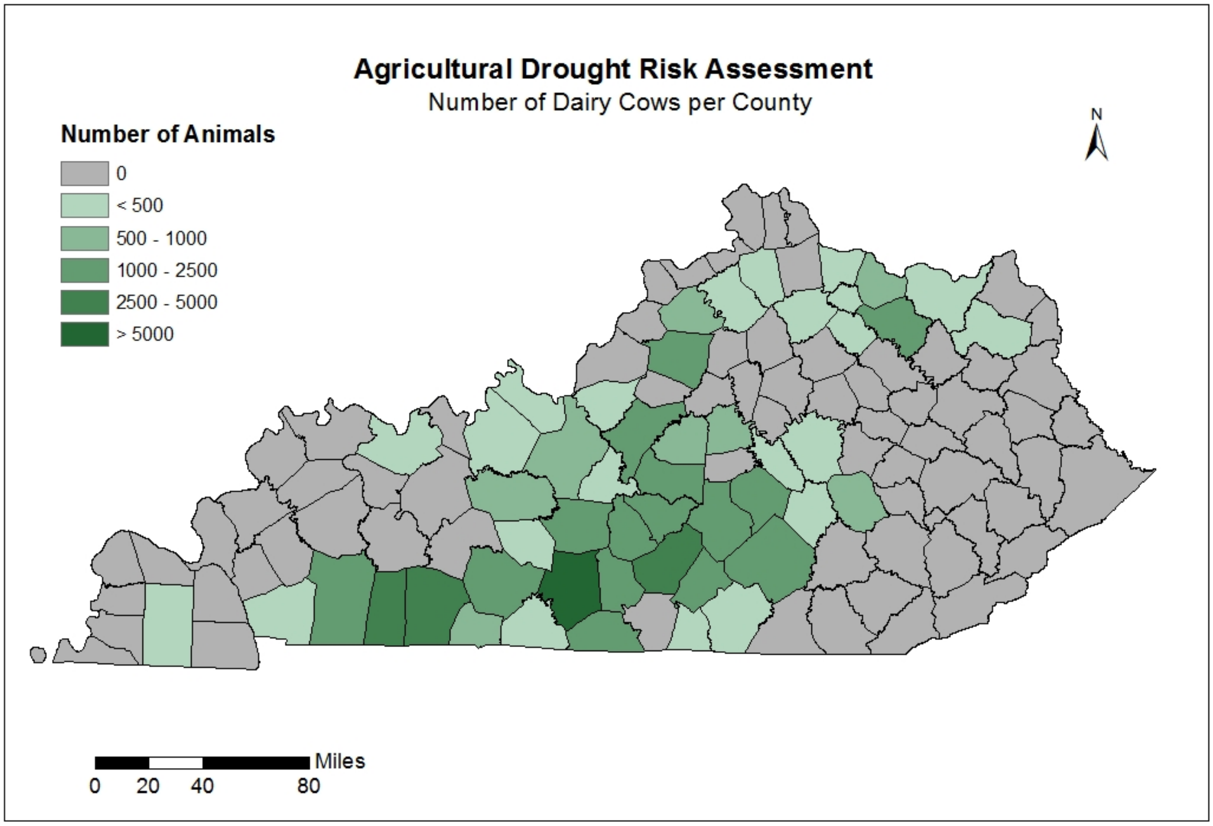
*Unlike previous maps, areas with no PWS are included livestock water system maps and county maps. It is assumed that these areas are self served, but it is possible that farms could haul water if on farm sources dry up.

Figure 35. Number of Beef Cattle by county in Moderate to High Hazard water service areas



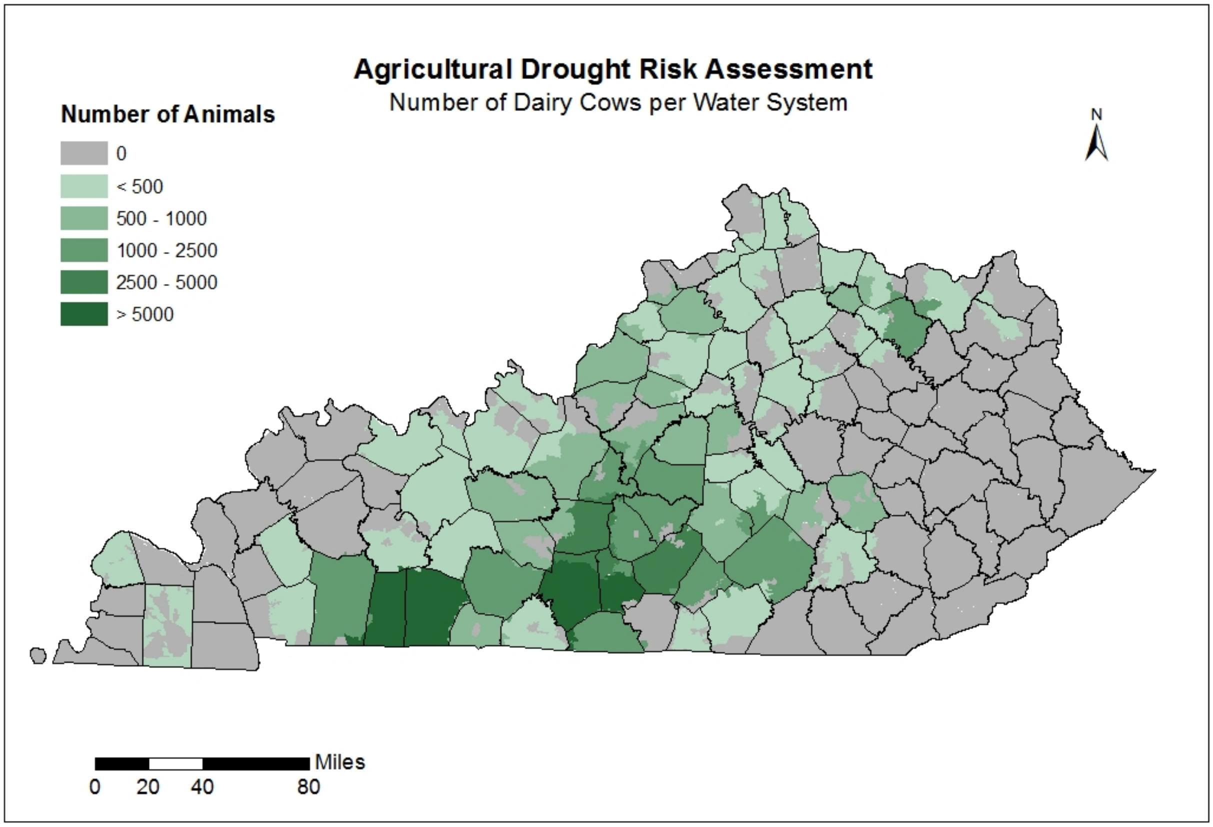
Cattle, both beef and dairy, are the most at risk to drought. When compared to row crops, the pasture and hay used to feed cattle are located on soils that tend to be more drought vulnerable. When compared to other livestock, cattle are more likely to be found in water systems that have a moderate to high drought hazard.

Figure 36. Total number of Dairy Cattle per county



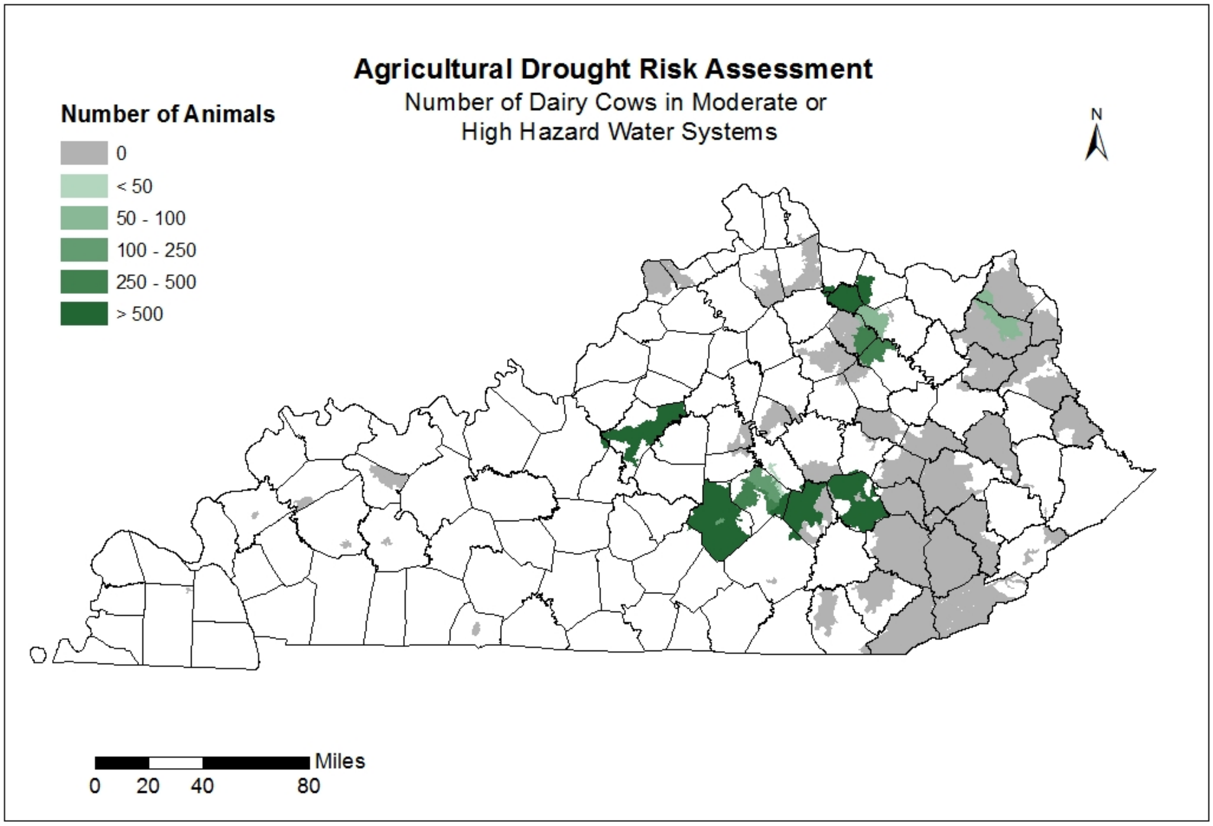
Source: USDA Agricultural Census, Survey Data 2016

Figure 37. Potential dairy cattle demand (weighted numbers of animals based on NASS Ag survey cattle numbers, 2016) on public water supplies



*Unlike previous maps, areas with no PWS are included livestock water system maps and county maps. It is assumed that these areas are self served, but it is possible that farms could haul water if on farm sources dry up.

Figure 38. Number of Beef Cattle by county in Moderate to High Hazard water service areas



*Unlike previous maps, areas with no PWS are included livestock water system maps and county maps. It is assumed that these areas are self served, but it is possible that farms could haul water if on farm sources dry up.

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Figure 39. Number of Dairy Cattle by county in Moderate to High Hazard water service areas

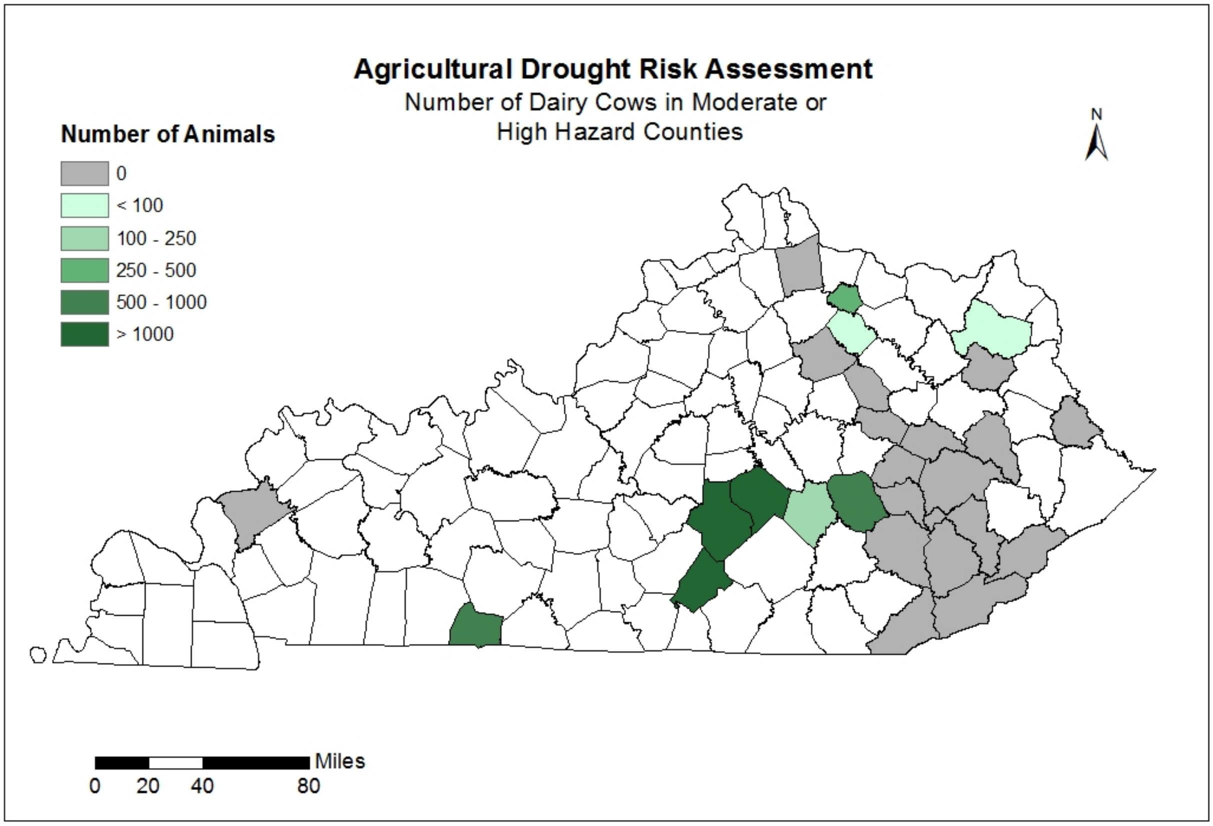
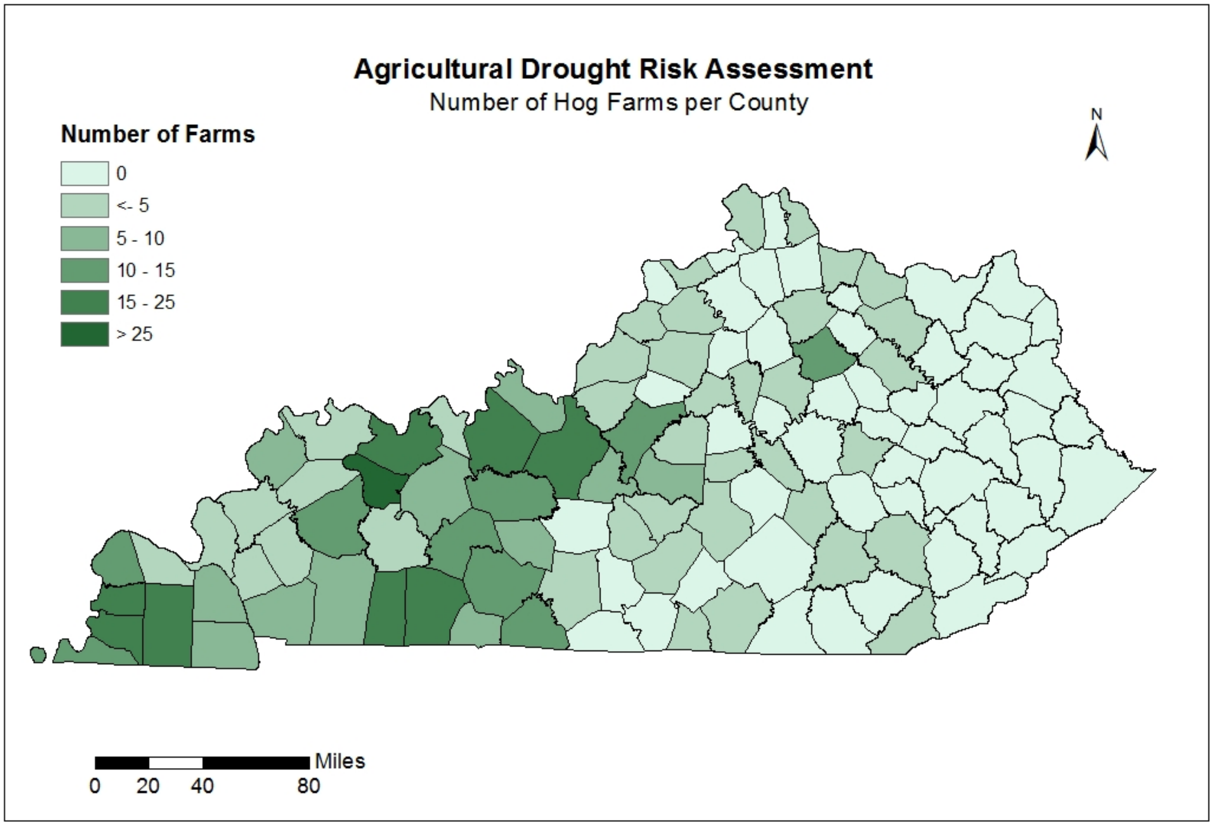
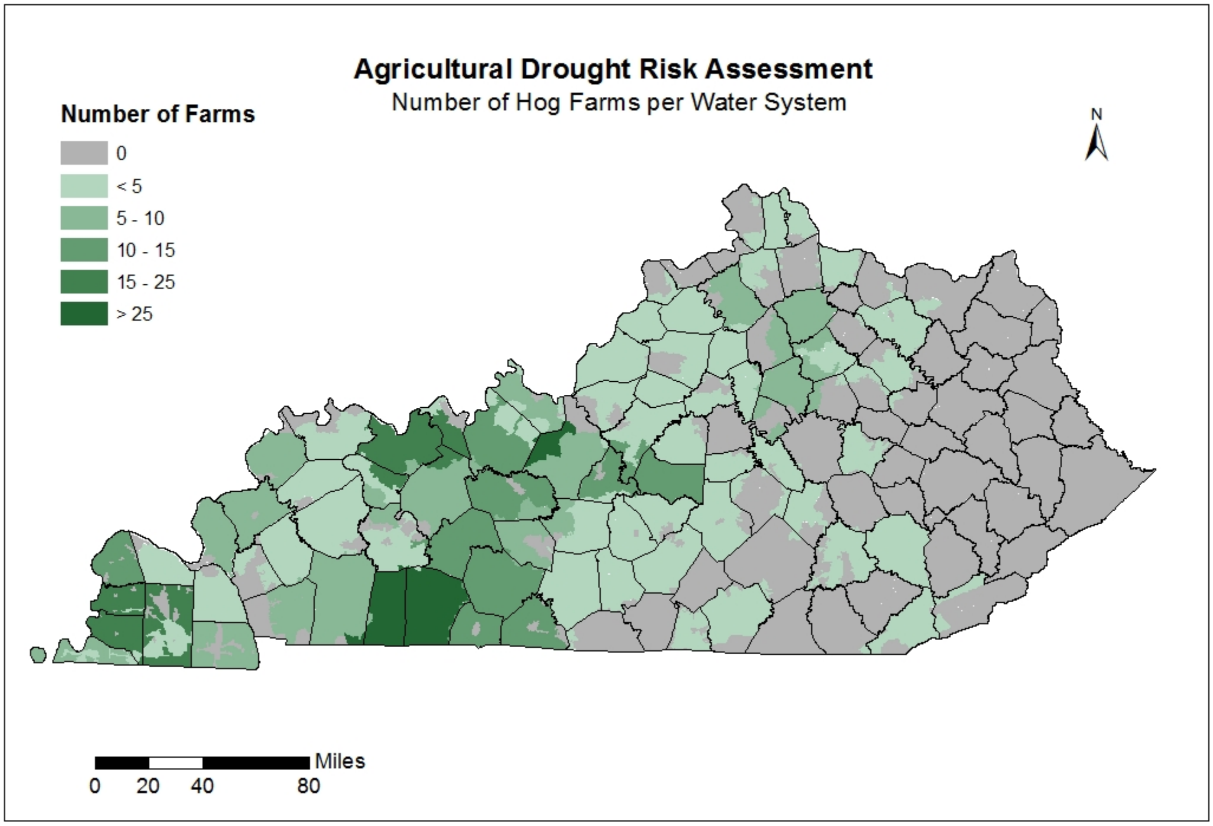


Figure 40. Total number of Hog Farms per county



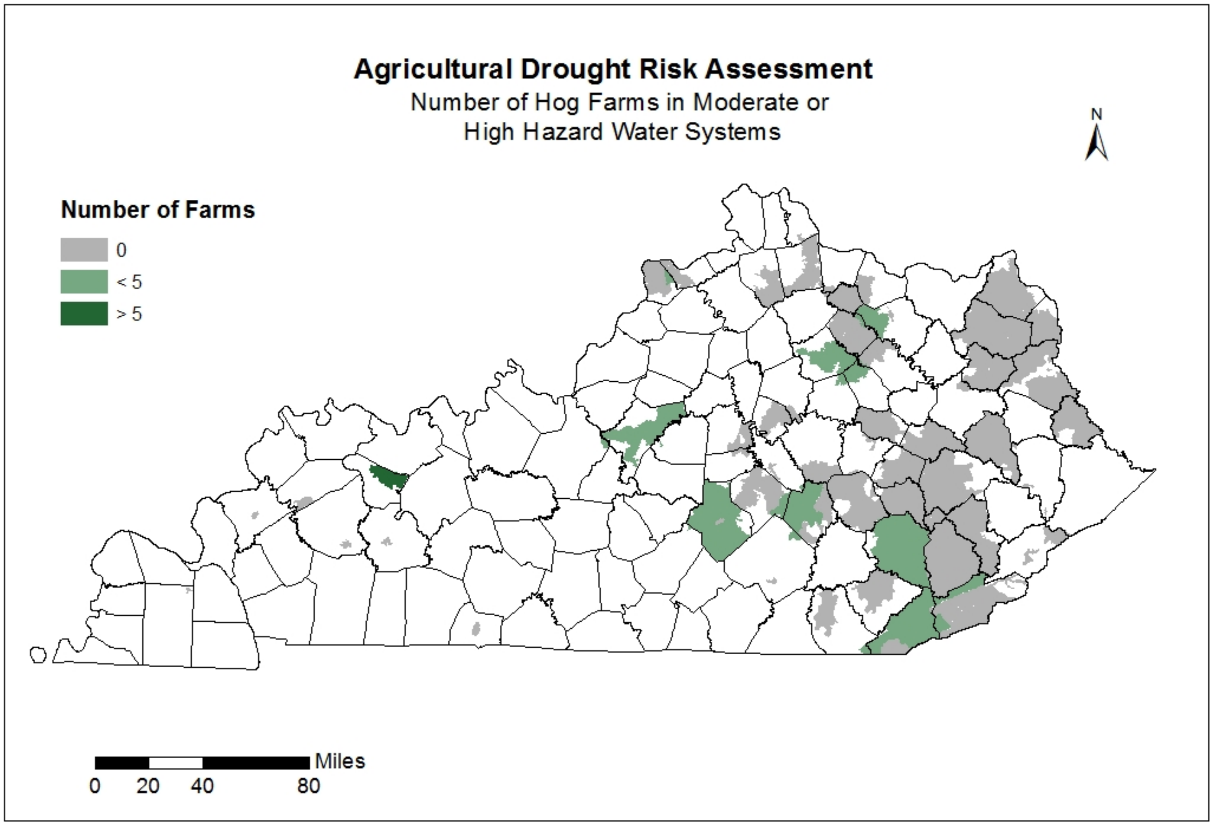
Source: Kentucky DEP database; KNDOP (No discharge operating permit) data

Figure 41. Potential hog demand (numbers of hog farms) on public water supplies



*Unlike previous maps, areas with no PWS are included livestock water system maps and county maps. It is assumed that these areas are self served, but it is possible that farms could haul water if on farm sources dry up.

Figure 42. Number of Hog Farms by county in Moderate to High Hazard water service areas



*Unlike previous maps, areas with no PWS are included livestock water system maps and county maps. It is assumed that these areas are self served, but it is possible that farms could haul water if on farm sources dry up.

Figure 43. Number of Hog Farms by county in Moderate to High Hazard water service areas

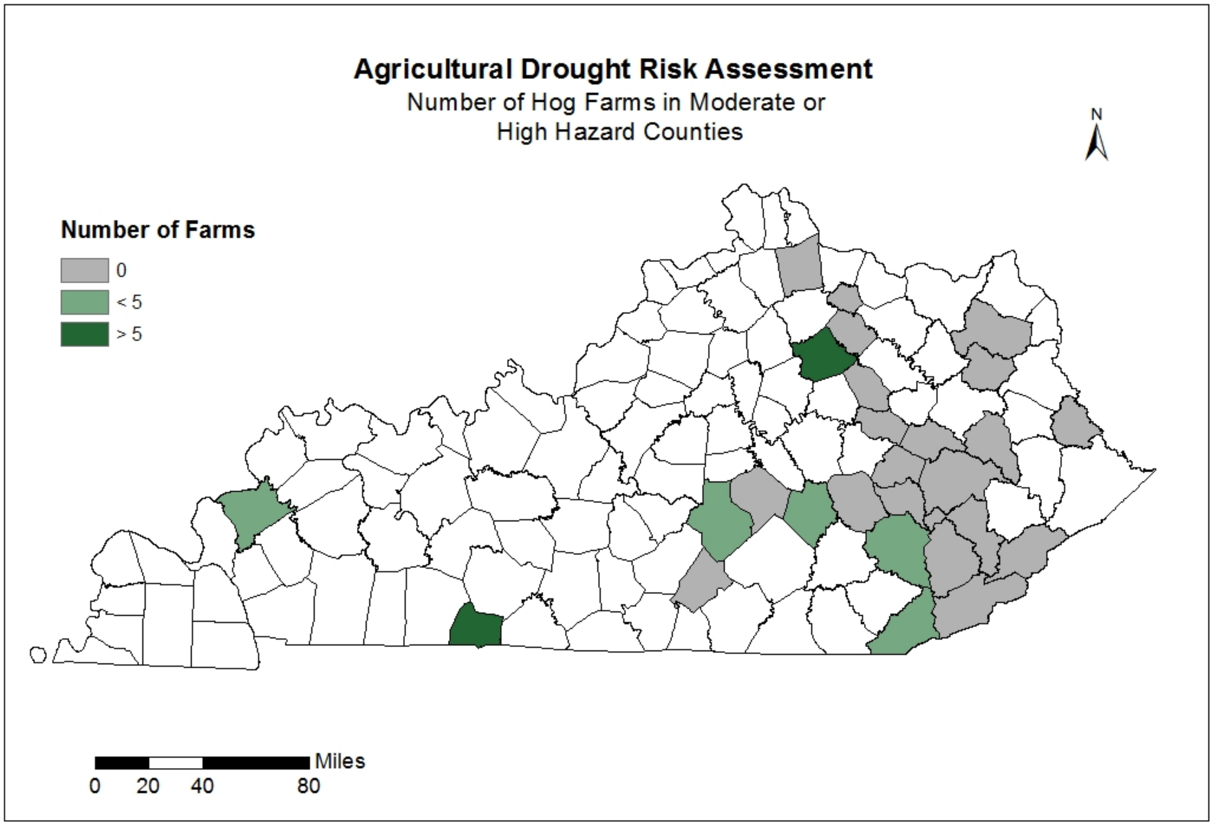
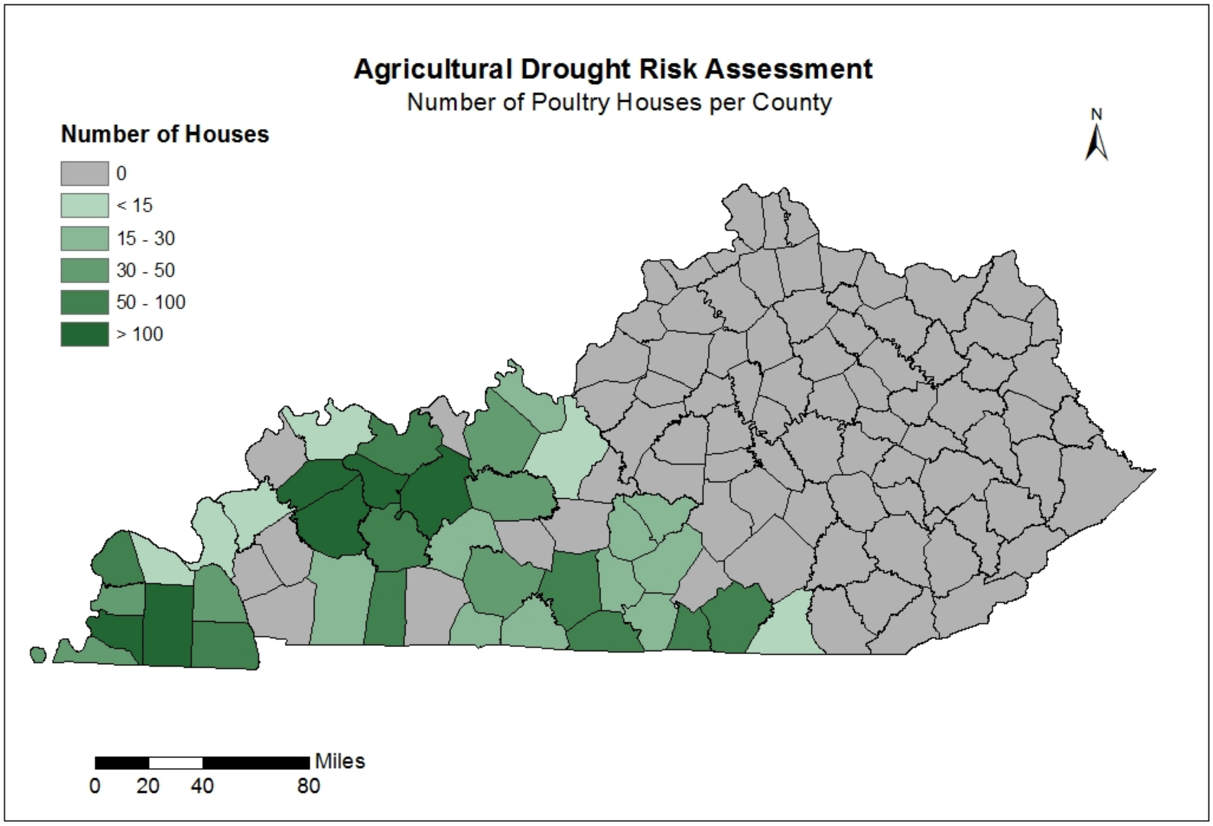
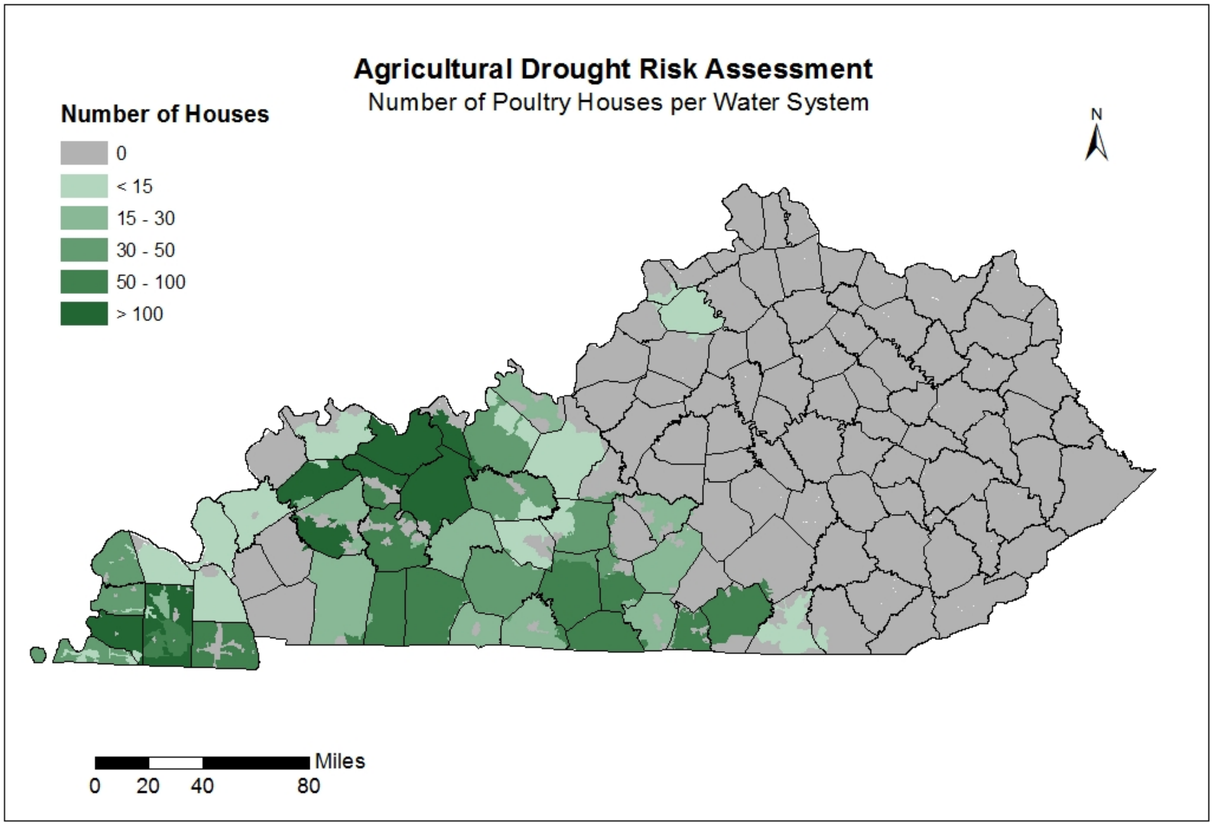


Figure 44. Total number of Poultry Houses per county



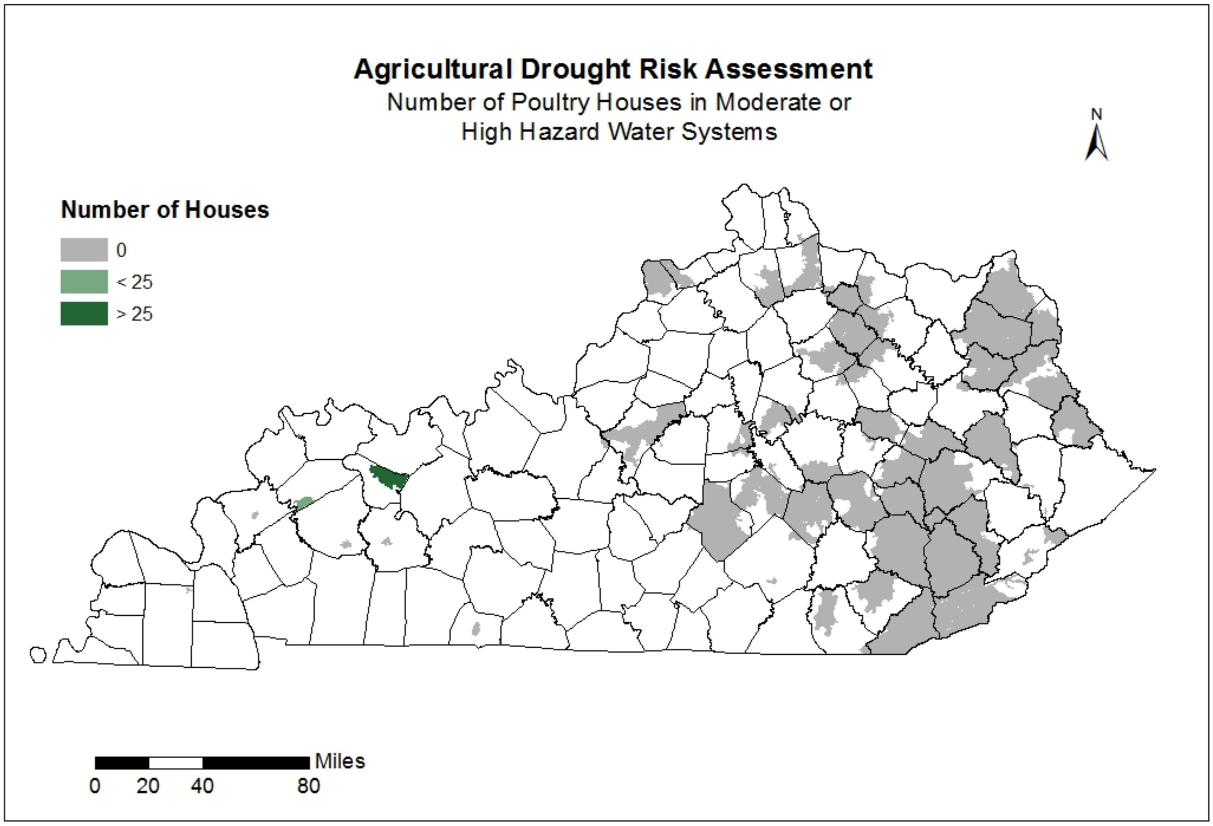
Source: Kentucky Division of Water analysis of aerial imagery

Figure 45. Potential Poultry demand (numbers of poultry houses) on public water supplies



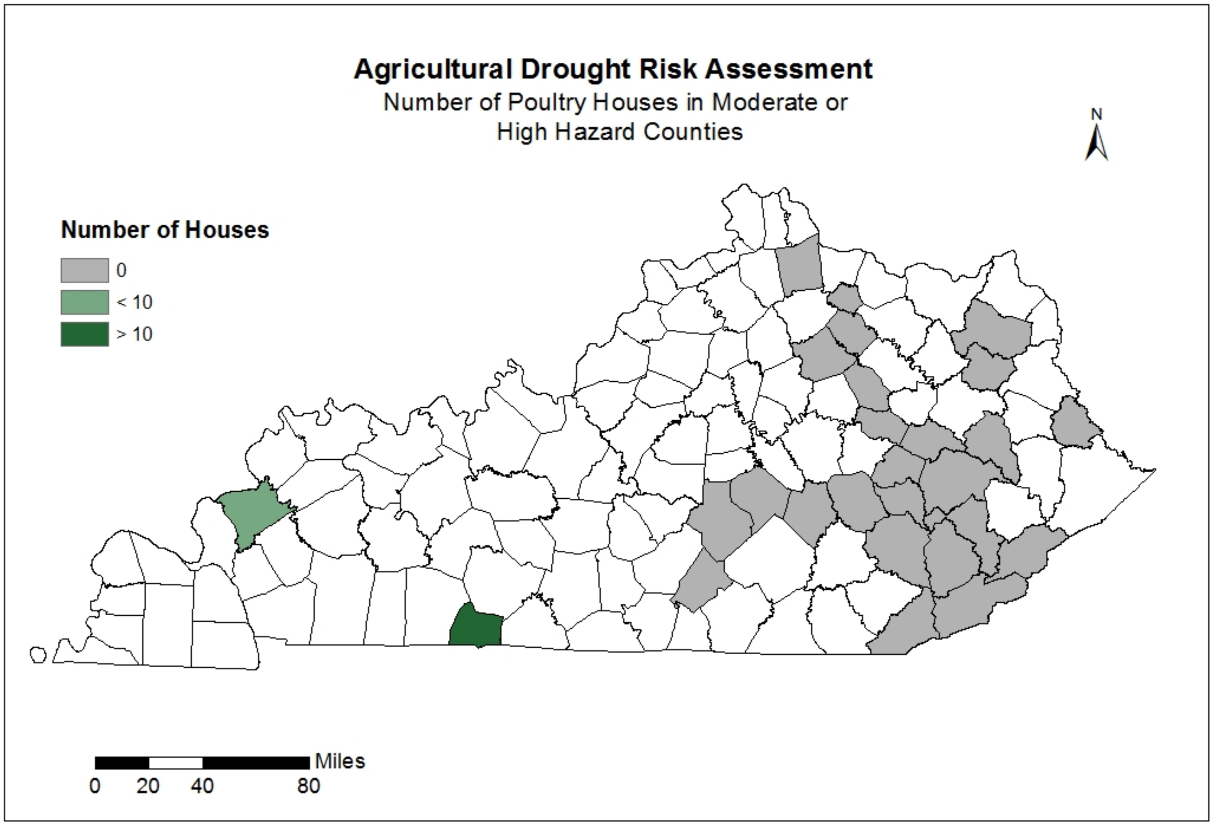
*Unlike previous maps, areas with no PWS are included livestock water system maps and county maps. It is assumed that these areas are self served, but it is possible that farms could haul water if on farm sources dry up.

Figure 46. Number of Poultry Houses by county in Moderate to High Hazard water service areas



*Unlike previous maps, areas with no PWS are included livestock water system maps and county maps. It is assumed that these areas are self served, but it is possible that farms could haul water if on farm sources dry up.

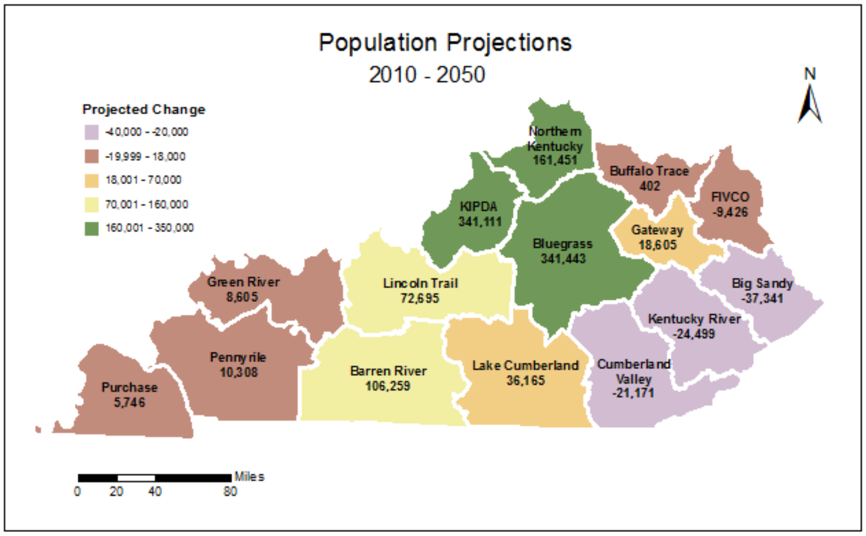
Figure 47. Number of Poultry Houses by county in Moderate to High Hazard water service areas



CHANGE

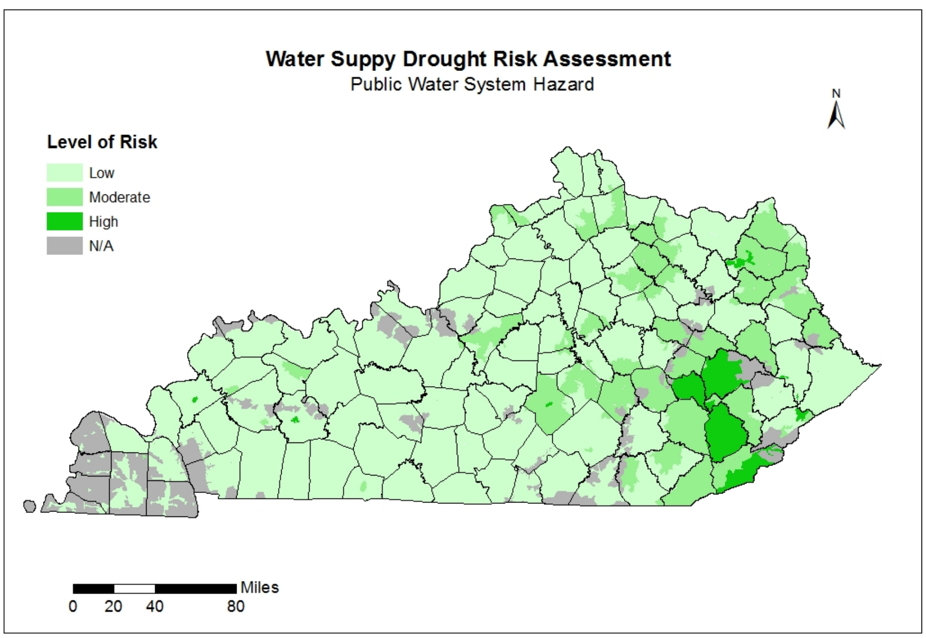
NOTE: For CHANGE, note the minority of animal operations in mod to high risk systems. Expect that water could attract especially housed operations that rely on PWS> or in some places groundwater (show the aquifer map.

Figure 48. Population Change Estimates 2010-2050 by Area Development District



Source: Kentucky State Data Center and Kentucky Cabinet for Education and Workforce Development

Figure 49. Water Supply Systems Final Drought Risk Score.



Populations are estimated to change in Kentucky through 2050 as a result of emigration and attrition (death rates>birth rates) in the coal counties of eastern Kentucky, and a surge in immigration to the Louisville, Northern Kentucky and Bluegrass (Figure 44). From a risk perspective this change in the water supply landscape will likely reduce future water supply drought risks, assuming a simple straight-line estimate of water demand and population change (Table 10). The ADDs that are predicted to lose the most in population are also the ADDs with a majority of the moderate and high hazard public water systems. Conversely, areas that are predicted to grow in populations are predominantly in areas with Low or No Risk public water supplies and systems. Looking ahead, investment in eastern Kentucky infrastructure that coincides with diminishing populations may produce reductions in drought risk in the region.

Table 9. Estimated Change in Kentucky Water Withdrawal for Public Water Supply through 2050

REGION	Total Water Withdrawal, 2015	Population, 2015	Per Capita Use	Population, 2050	Projected Total Water Withdrawn, 2050
	MGD		GPPD		MGD
KENTUCKY	**558**	**4,509,429**	**122**	**5,349,720**	**663**
Area Development Districts					
BarrenRiver	36	300,141	120	390,454	47
Big Sandy	18	151,480	119	116,752	14
Bluegrass	104	816,391	127	1,111,847	142
Buffalo Trace	6	57,508	104	56,880	6
Cumberland Valley	30	237,699	126	215,447	27
FIVCO	20	138,868	144	128,458	19
Gateway	11	84,781	130	100,257	13
Green River	30	217,407	138	222,077	31
Kentuckiana	143	1,008,643	142	1,300,202	184
Kentucky River	12	113,343	106	90,263	10
Lake Cumberland	24	214,745	112	243,421	27
Lincoln Trail	30	282,481	106	341,812	36
Northern KY	42	463,305	91	600,098	54
Pennyrile	32	223,324	143	229,613	33
Purchase	20	199,313	100	202,139	20

MGD = million gallons per day; GPPD = gallons per person per day

A majority of population increase projected in areas with low-risk water supplies as defined by this assessment.

Mitigation

See Link to Kentucky State Drought Mitigation and Response plan, chapter 7.

http://water.ky.gov/wa/Documents/State%20Plan_Final.pdf

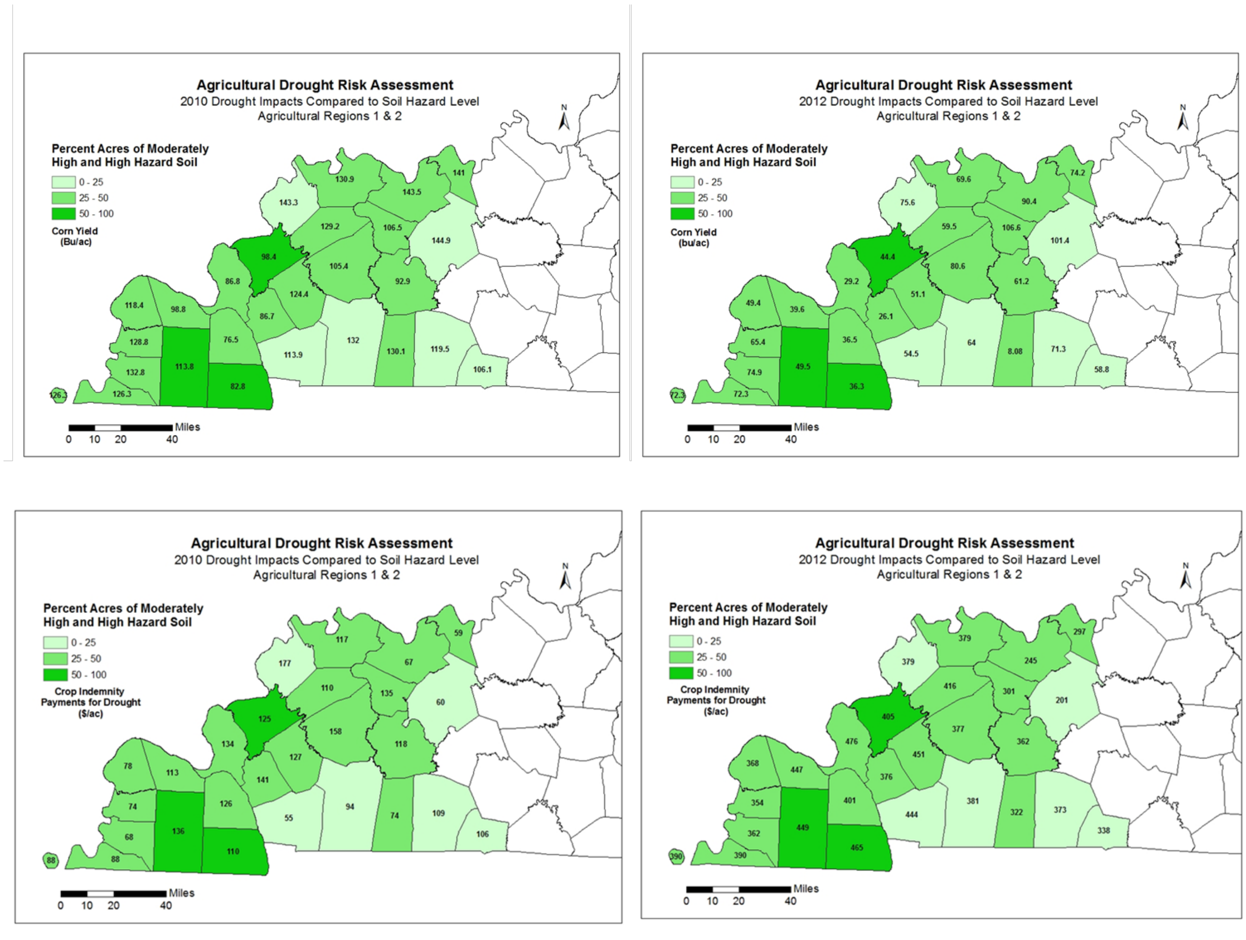
Mitigation efforts to address drought have been ongoing since the mid 1980s when Kentucky developed its first water shortage response plan. In 2008 under direction of the state legislature the Division of Water formed the Kentucky Drought Mitigation Council and developed its first statewide drought response and mitigation plan. This plan created criteria for drought characterization as well as a communication network among multiple local, state and federal agencies. Perhaps most importantly, the plan outlined several categories of need to address long term mitigation efforts: many of these align with those of FEMA.

- There is a need to continue to develop better mechanisms to assess drought risk as well as determine drought impacts.
- Drought monitoring is a combination of human intelligence and technology (climate, streams, wells).. There is a need for additional investment in Kentucky, most critically in the development of a groundwater level monitoring network.
- Infrastructure Assessments: this risk assessment underscores the need for additional assessments and investment in hardening our water infrastructure against drought. Given the projections by the Corps of Engineers of a more variable, extreme climate, with diminishing flows in typical hydrologic drought months (OCTOBER), it is critical that we assess our capabilities to withstand a return to the a more drought prone era. Projections made by the Corps of up to 35 percent reduction in October low flows is the opposite of trends observed in Kentucky flows and variability (DOW data, not published)
- Planning for drought is critical. The Division of Water has begun a new program to focus on water efficiency and elevated levels of local drought planning. It is hoped that funding will become available to assist vulnerable communities in this effort.
- The Kentucky Division of Water is preparing additional data to highlight the need for mitigation efforts in a "water –rich state". It is hoped that efforts to assist farmers in finding new sources or new water supply alternatives can be coupled with infrastructure assessments and improvements in agricultural and rural communities.

Palmer, W.C., 1965: *Meteorological Drought*. Research Paper No. 45, US Weather Bureau, Washington, DC.

APPENDIX 1.

Figure 50. Soil Hazard Scores and Crop Yield (top); Soil Hazard Scores and Crop Indemnity per Acre (bottom)

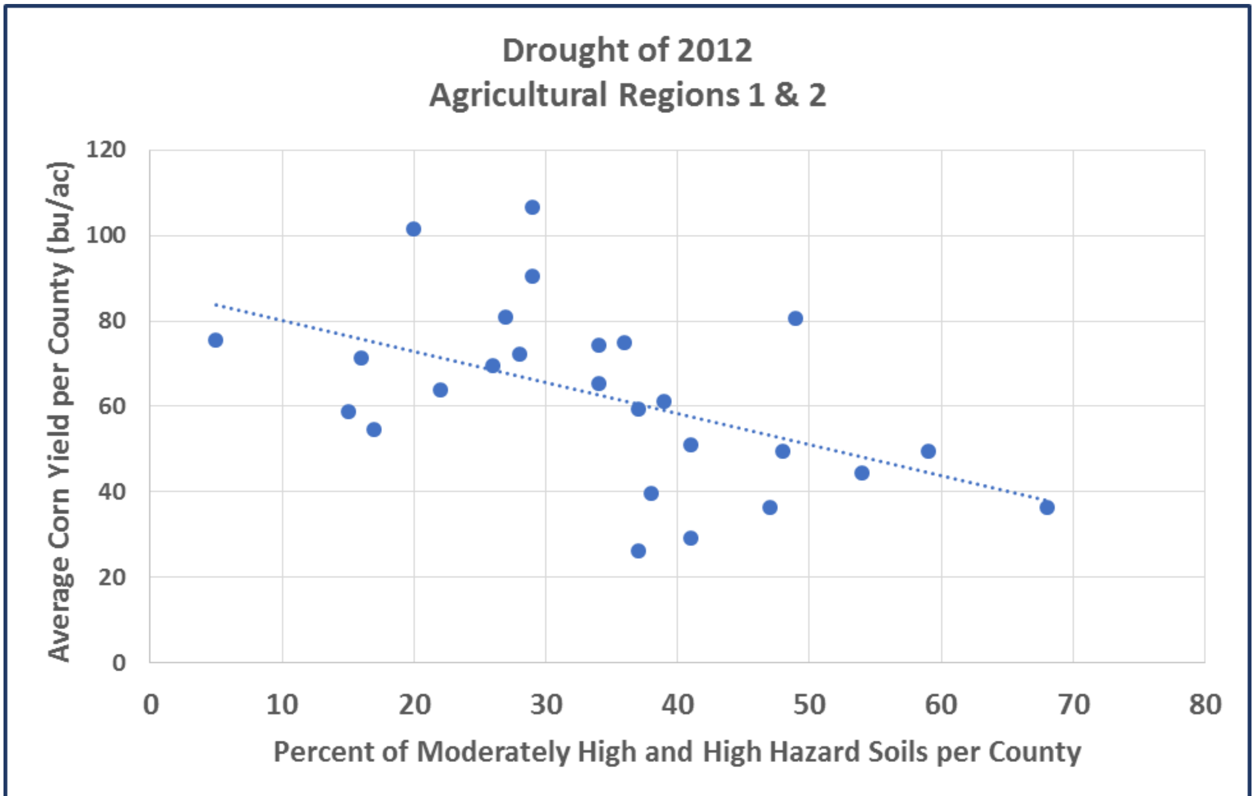


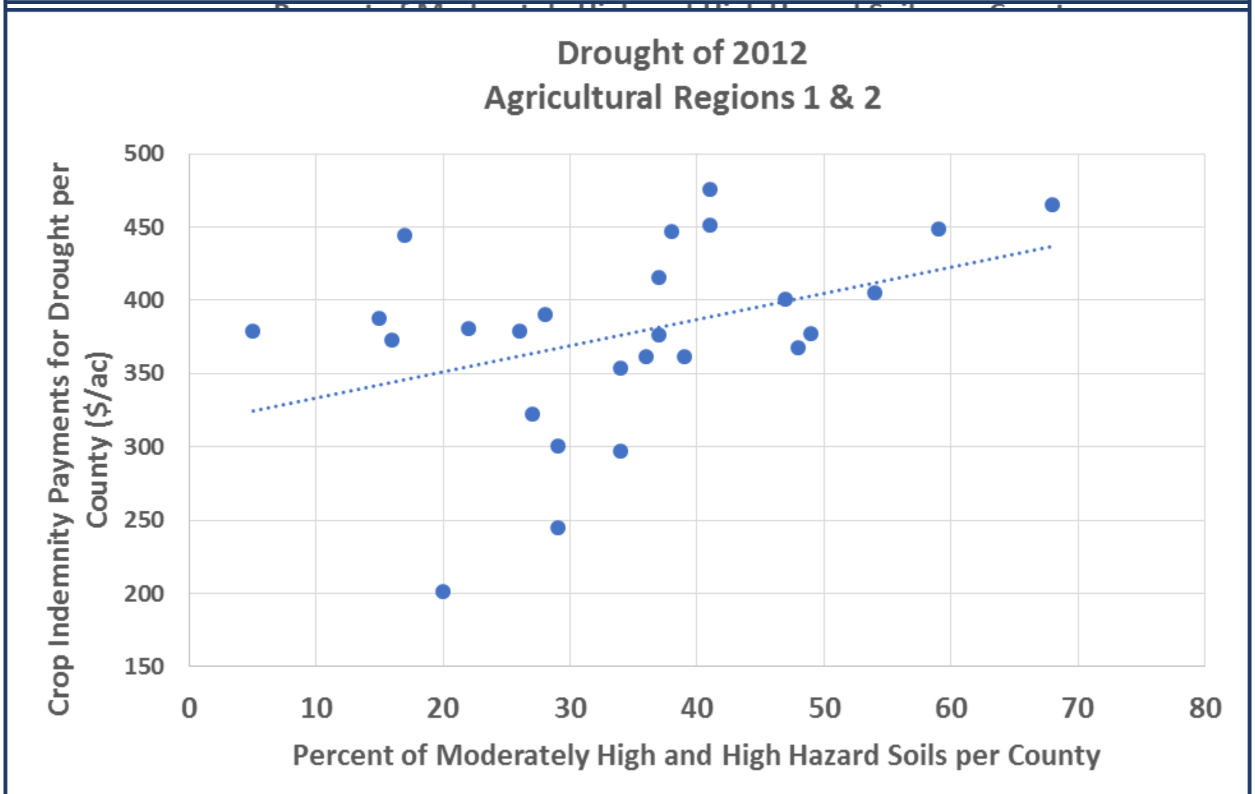
2010 Corn

The amount of high hazard soils in a county clearly had an impact on county average yields during the drought of 2010 with places like Graves and Crittenden counties having much lower yields than their neighbors. Crop Indemnity Payments isn't quite as clear in all areas but a relationship still exists especially in the Puchase Region and along the Tennessee boarder.

2012 Corn

The drought of 2012 had a huge impact on corn yields in every county, however, much like in 2010, the counties with the highest percentage of high hazard soils had lower yield when compared to their neighbors.





Percent of Moderately High and High Hazard Soils per County