How does the drought of 2012 compare to earlier droughts in Kansas, USA?

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Abstract

Drought is a complex, least understood and one of the most expensive natural disaster. Drought impacts many sectors of environment and society. A regular question is how a current drought compares to previous droughts. Water managers, resource managers, news media and the general public want to place the event in context as they evaluate impacts, and as they attempt to plan for future events. There are many definitions of drought (meteorological, agricultural, hydrological and socioeconomic) resulting in a large number of drought metrics and indices in literature. In this study we have used Standardized Precipitation Index (SPI), a useful tool to answer these questions. SPI is a transformation of the probability of a given amount of precipitation in a set period of months. This allows for the comparison of wet/dry spells over extremely different climates and over various time scales from one month to two years (24 months).

SPI 1, 3, 6, 9, 12 and 24 was downloaded for nine climate divisions in Kansas from 1895 to 2012. Our results indicate that the Dust Bowl drought of the 1930's and the back-to-back drought of the 1950's still stand out as some of the worst droughts on record in Kansas for mid-term (SPI 6, SPI 9) and long term (SPI 12, SPI 24) droughts. However, in terms of a 3-month short-term drought (SPI 3), the summer and July of 2012 experienced the most severe drought since 1896 in Kansas.

Introduction

Drought is a complex, least understood and one of the most expensive natural disaster (Vasiliades et al., 2011). Drought impacts many sectors of environment and society. Hence there are many definitions of drought (meteorological, agricultural, hydrological and socioeconomic) resulting in a large number of drought metrics and indices in literature. Considering 2012 as a drought year for Kansas, this study intends to compare it with earlier droughts in the past 116 years using the Standardized Precipitation Index (SPI).

Methods and Data used

The Standardized Precipitation Index (SPI) developed by McKee et al. (1993) is used here to study drought and is calculated from precipitation data. The SPI is widely used throughout the world in both a research and an operational mode (Wu et al., 2007). SPI is simple, spatially consistent (invariant) in its interpretation, probabilistic so that the return periods (recurrence intervals) can be used in risk and decision analyses, and can be tailored to time periods of a user's interest (Guttman, 1998). Presence of a large number of zero precipitation values (especially in arid regions and short time-periods) could skew the SPI towards positive numbers and its lack of consideration of snow/frozen ground, soil conditions, distribution of rainfall within the time scale evaluated, temperature data are some of the weakness of using SPI. The strengths and weakness of SPI are discussed elaborately in Logan et al (2010), Guttman (1998), Hayes et al (1999) and Wu et al (2007). The moving time series precipitation data is fitted to a gamma probability distribution function and through equi-probability transformation is transferred to a normal distribution with mean zero and standard deviation one (McKee et al., 1993).

In this study, 1-, 3-, 6-, 9-, 12- and 24-month SPI (referred as SPI 1, SPI 3, SPI 6, SPI 9, SPI 12, SPI 24) were downloaded (ftp://ftp.ncdc.noaa.gov/pub/data/cirs/climdiv/) on February 2013 for nine climate divisions in Kansas (Figure 1) from 1895 to 2012. In this study, SPI 1 and SPI 3 were used to study short term drought, SPI 6 and SPI 9 for medium term drought, while SPI 12 and SPI 24 were considered for long term drought.

This analysis of drought was based on precipitation values only. Also the analysis is based on mean values across 9 climate divisions and the variability across the nine divisions are not shown.

Results and Discussion

Characterization of the drought is highly dependent upon the time scale referenced. For extremely short periods (1 month SPI), the 2012 drought falls in the more severe range, but not in the ten most severe incidents). The longer term indices (9-month, 12-month and 24-month) show increasingly less severe conditions. The 3-month SPI highlights the severity of the 2012 drought and is most focused on the summer season (Jun-Aug), with Jul also as the most severe (Table 1). An important feature of the 2012 drought was the rapid development in late spring/early summer and increase in severity in early July during a critical time of crop development (AghaKouchak, 2014) after epic floods in 2011. This is an excellent example of a “flash drought”. The 2012 droughts was the first drought since 1988 that impacted almost the entire Corn Belt (Fuchs et al., 2013).

The Dust Bowl drought of the 1930’s and the back-to-back drought of the 1950’s still stand out as some of the worst droughts on record in Kansas for mid-term (SPI 6, SPI 9) and long term (SPI 12, SPI 24) droughts. The 1930’s were the warmest decade on record with regard to hot day frequency. During this decade the heat in1934 and 1936 stand out in particular.

However, the 2012 heat was less intense, with 1954 and 1980, also had anomalously hot summers (Donat et al., 2015). They showed that the unprecedented summer heat during the Dust Bowl years was likely exacerbated by land-surface feedbacks associated with springtime precipitation deficits which coincided with anomalously warm North Atlantic and Northeast Pacific surface waters and a shift in atmospheric pressure patterns leading to reduced flow of moist air into the central US. Higher values of warm spells were observed during the Dust Bowl period (1930s) at the annual scale. Warm spells was represented using indicators such as warm spell length, average warm spell length, maximum warm spell length, warm spell duration index, and crop failure temperature (Anandhi, 2016; Anandhi et al., 2016a; Anandhi et al., 2016b).

An important feature of the 2012 drought was rapid development in late spring/early summer and increase in severity in early July during a critical time of crop development (AghaKouchak, 2014). After the epic floods in 2011, March 2012 was the second warmest on record, with several locations in southeast, east central, and south central Kansas setting records for earliest date of last freeze (Fuchs et al., 2013). Earlier last freeze is observed to increase the growing season length in Kansas (Anandhi et al., 2013a). Changes in growing season are important for water resource management (Anandhi et al., 2013b).

The 2012 drought was believed to be one of the costliest in the U.S. history (Fu et al., 2013). Drought has direct and indirect impacts on agricultural sector, but its impacts on other sectors (e.g. industrial, municipal water supply, tourism) are generally underestimated or even largely neglected. The direct effects of drought are reduced cropland, rangeland, and forest productivity, increased wildfire occurrence, diminish water availability, kill livestock and wildlife, deteriorated wildlife and fish habitats (Fu et al., 2013). Not all crops are adversely affected. Wheat yields were good in 2012 because the residual moisture from the previous wet year allowed for early establishment and good over wintering conditions. In addition, dry conditions during the spring and early summer reduced disease pressure and minimized harvest delays (Fuchs et al., 2013). The summer growing season, which began with the highest area planted in corn in the United States since 1937, started off with a warm spring season, which could potentially be beneficial for fast growth but then developed into a growing season of severe to exceptional drought (Lal et al., 2012). The producers and individual responses to this drought in Kansas varied. Many crops were abandoned. Stocking rates were reduced and herd size was cut to adapt to the drought conditions (KAS, 2012).

The economic loss estimates by the end of July 2012 was $12 billion (U.S. dollars) (Hoerling et al., 2014) and the total loss estimate of the whole year exceeded USD 35 billion (Fu et al., 2013). The USDA had a 166-bushel yield expectation at the commencement of the growing season was high as the harvest averaged only 123 bushels, 26% below expectation (Hoerling et al., 2014). In addition, drought can cause even more significant indirect losses. For example, reduction in crop productivity can bring significant economic impacts in terms of reduced income and government tax revenues, increased prices of food, increased expense for food businesses, and increased budgets for disaster relief programs (Fu et al., 2013). These crops are food and fodder for the animal production systems and reduction in yield, increase the prices of the grains and meat. The grains and meats have an input-output relation, where grain is the input and meat is the output and with grain prices are increasing with drought, meat prices also follow the increase (Tegle, 2013).

Water and the Kansas economy are directly linked. Kansas water resources are ground water dominated in the western half of the state and surface water dominated in the eastern half. Climate is a significant factor in this variability. Irrigation is most prevalent in the western third of the state, where average annual rainfall is less than 20 inches per year (KWO and KDA, 2011). Earliest irrigation was flood irrigation through canals and ditches. Irrigation has buffered some agricultural sectors from recent drought more than droughts earlier in the record period (e.g. 1930's and 1950's). The rapid increase of an irrigated land area (approximately 1 million acres) during the 1970's was a result of the adoption of center pivot irrigation. By 1990, approximately 50% of the total area used center pivot sprinkler irrigation and that percentage has increased to nearly 92% today, though the total irrigated area has remained relatively stable at approximately 3 million acres (Rogers and Lamm, 2012). Depletion of the High Plains (Ogallala) aquifer has resulted in intensified irrigation management, including drip irrigation, deficit irrigation, preseason irrigation and crop selection changes. In March 2012, a new legislation [Senate Bill 272, (KS Leg., 2012)] was implemented that allowed five-year flex accounts for water appropriations. This term permit allows the water right holder to exceed their annual authorized quantity in any year but restricts total pumping over the five-year period. The state and local agencies responded to the 2012 drought in numerous ways. In December 2012, the governor released a letter encouraging public water suppliers to conserve water and evaluate their water supplies and conservation plans (including drought triggers). The Kansas Water Office had more than 300 responses to the governor's letter. They have updated and/or created more than 160 water conservation plans and drought contingency plans at the request of public water suppliers. The Kansas Grazing and Livestock Coalition held several workshops to help ranchers develop drought management plans. These plans included strategies for maintaining pasture health, determining trigger points and thresholds, and economic planning, among other issues. The Natural Resource Conservation Service worked with producers to take advantage of the dry conditions to rebuild/restore farm ponds (Fuchs et al., 2013).

This most recent drought has brought water issues to the forefront; and resulted in the development of the Vision for the Future of Water Supply in Kansas in the next 50 years (KWO, 2015).

Conclusions

Dust Bowl drought of the 1930's and the back-to-back drought of the 1950's still stand out as some of the worst droughts on record in Kansas for mid-term (SPI 6, SPI 9) and long term (SPI 12, SPI 24) droughts. However, in terms of a 3-month short-term drought (SPI 3), the summer and July of 2012 experienced the most severe drought since 1896 in Kansas. The reduction in available water in the High Plains Aquifer coupled with narrow profit margins is resulting in more intensive water management. The recent drought has motivated urban water managers to update and revise drought plans, improve aging infrastructure and increase conservation efforts.

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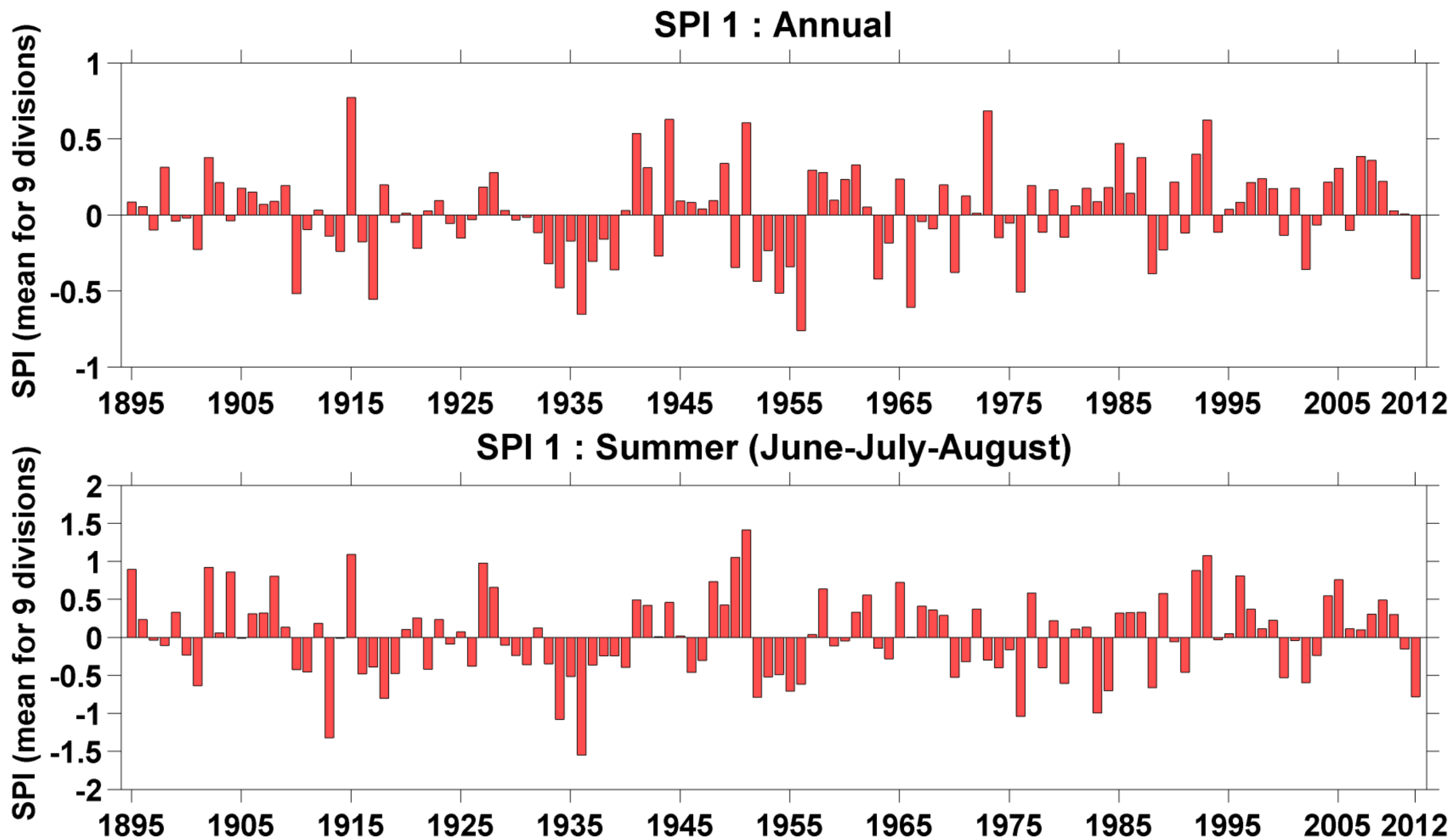

Figure 1. Mean SPI 1 for Kansas averaged from 9 climate divisions over a year and summer for the period 1896-2012.

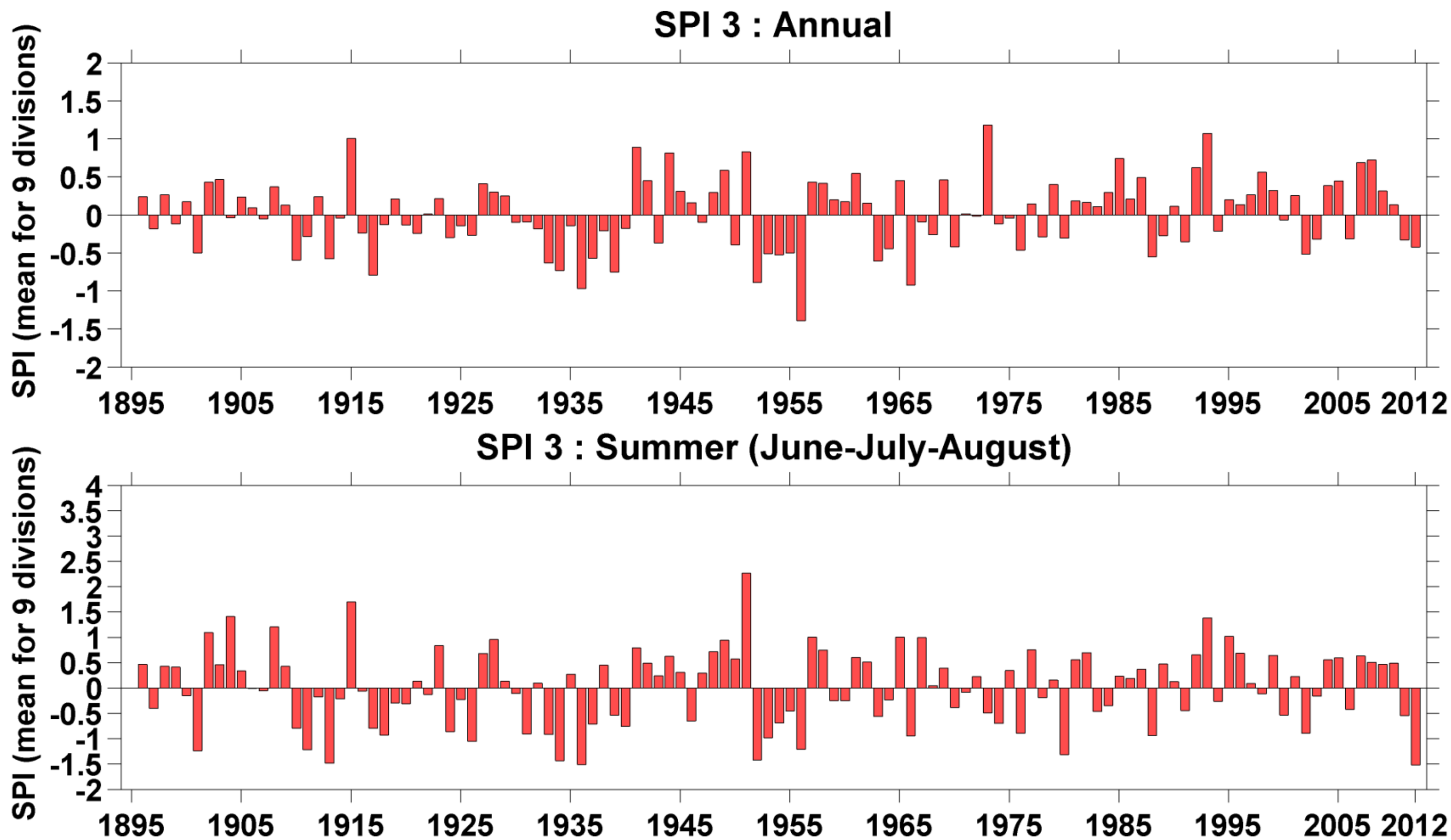

Figure 2. Mean SPI 3 for Kansas averaged from 9 climate divisions over a year and summer for the period 1896-2012. The individual SPI 3 values from June, July and August months of a year were averaged to obtain Summer SPI 3. Similarly, all month's SPI 3 for a given year was averaged to obtain one Annual SPI 3 value for the year.

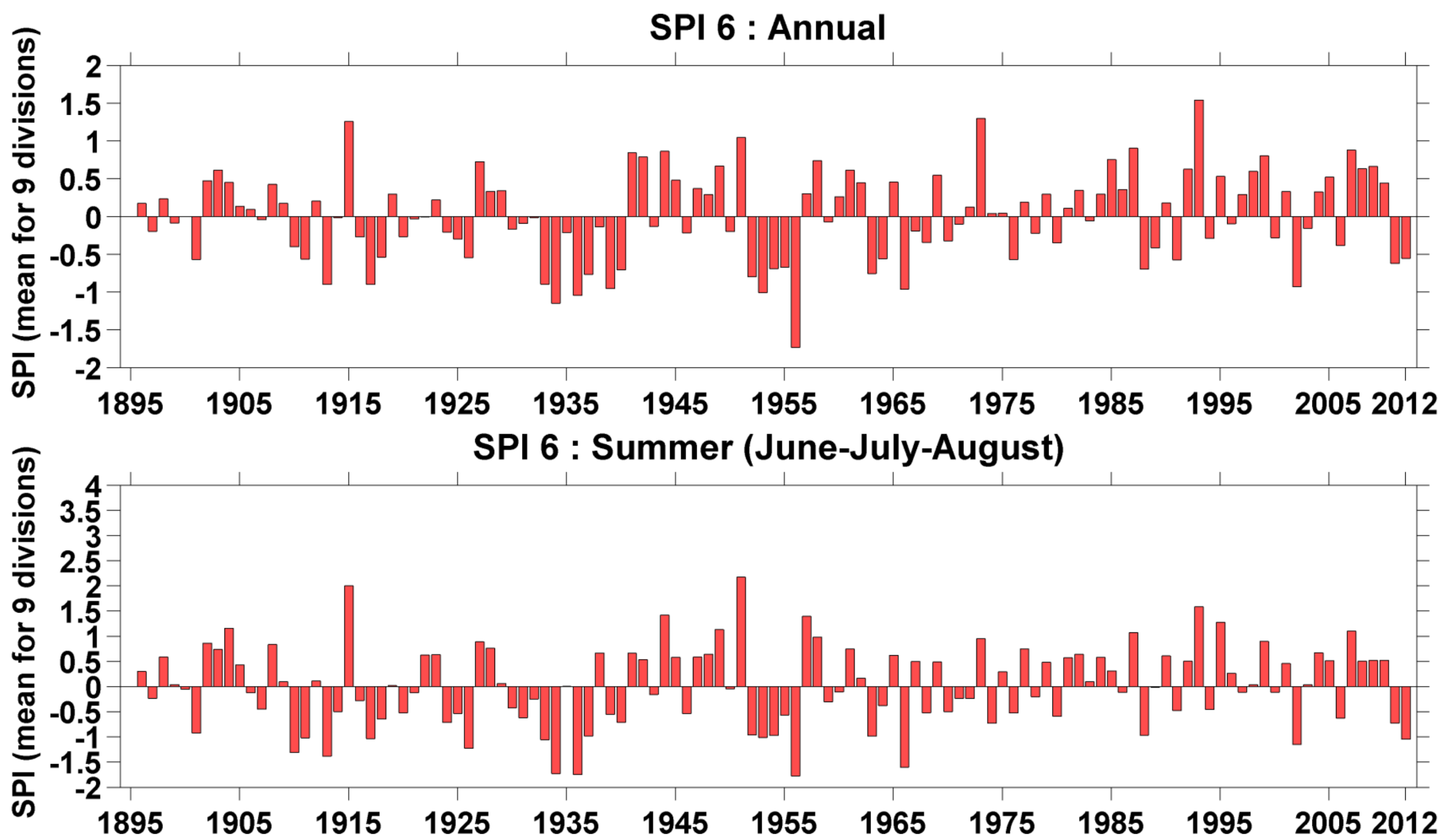

Figure 3. Mean SPI 6 for Kansas averaged from 9 climate divisions over a year and summer for the period 1896-2012. In addition, SPI 6 values from June, July and August months of a year were averaged to obtain Summer SPI 6. Similarly, all month's SPI 6 for a given year was averaged to obtain one Annual SPI 6 value for the year.

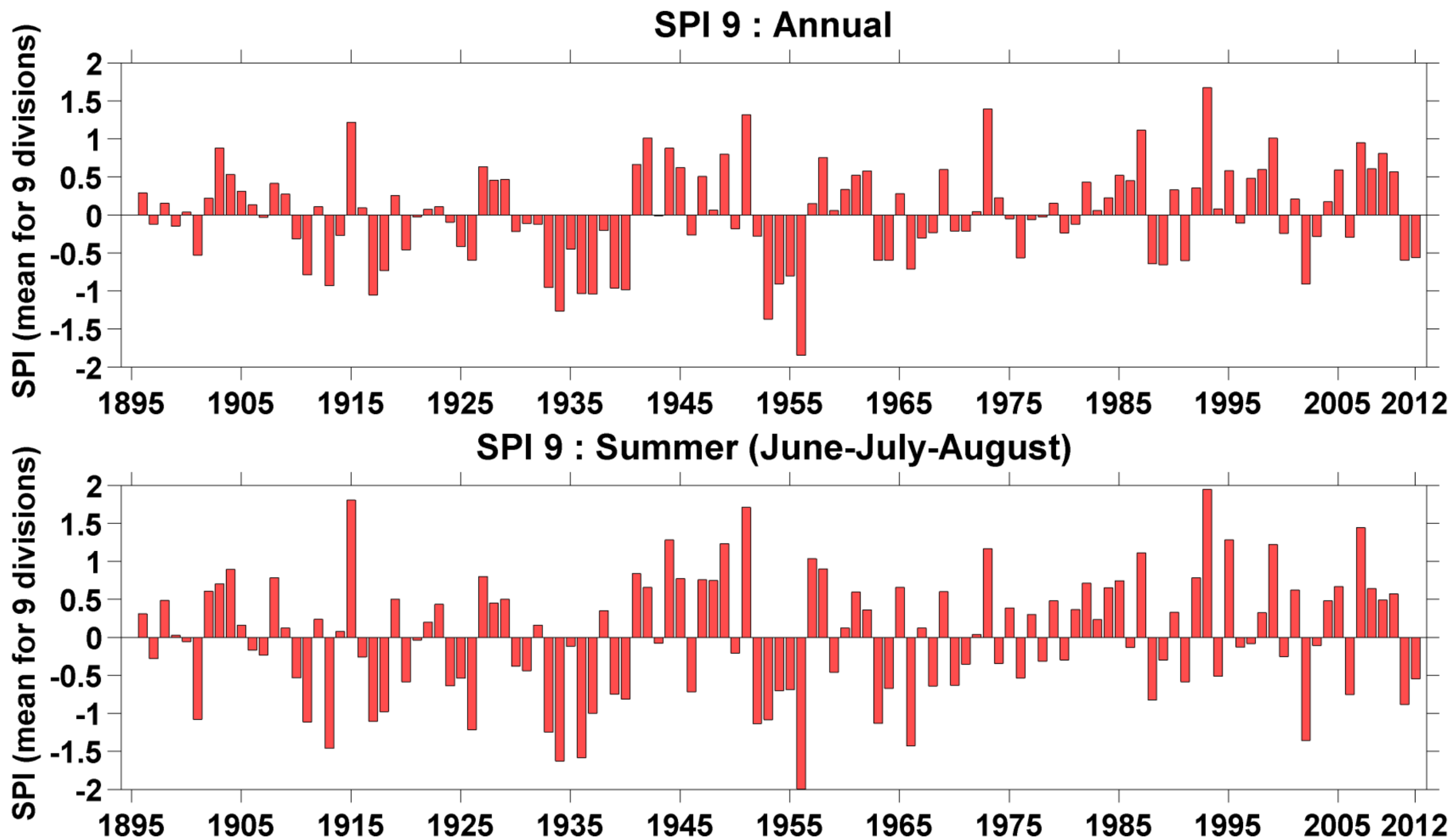

Figure 4. Mean SPI 9 for Kansas averaged from 9 climate divisions over a year and summer for the period 1896-2012. In addition, SPI 9 values from June, July and August months of a year were averaged to obtain Summer SPI 9. Similarly, all month's SPI 9 for a given year was averaged to obtain one Annual SPI 9 value for the year.

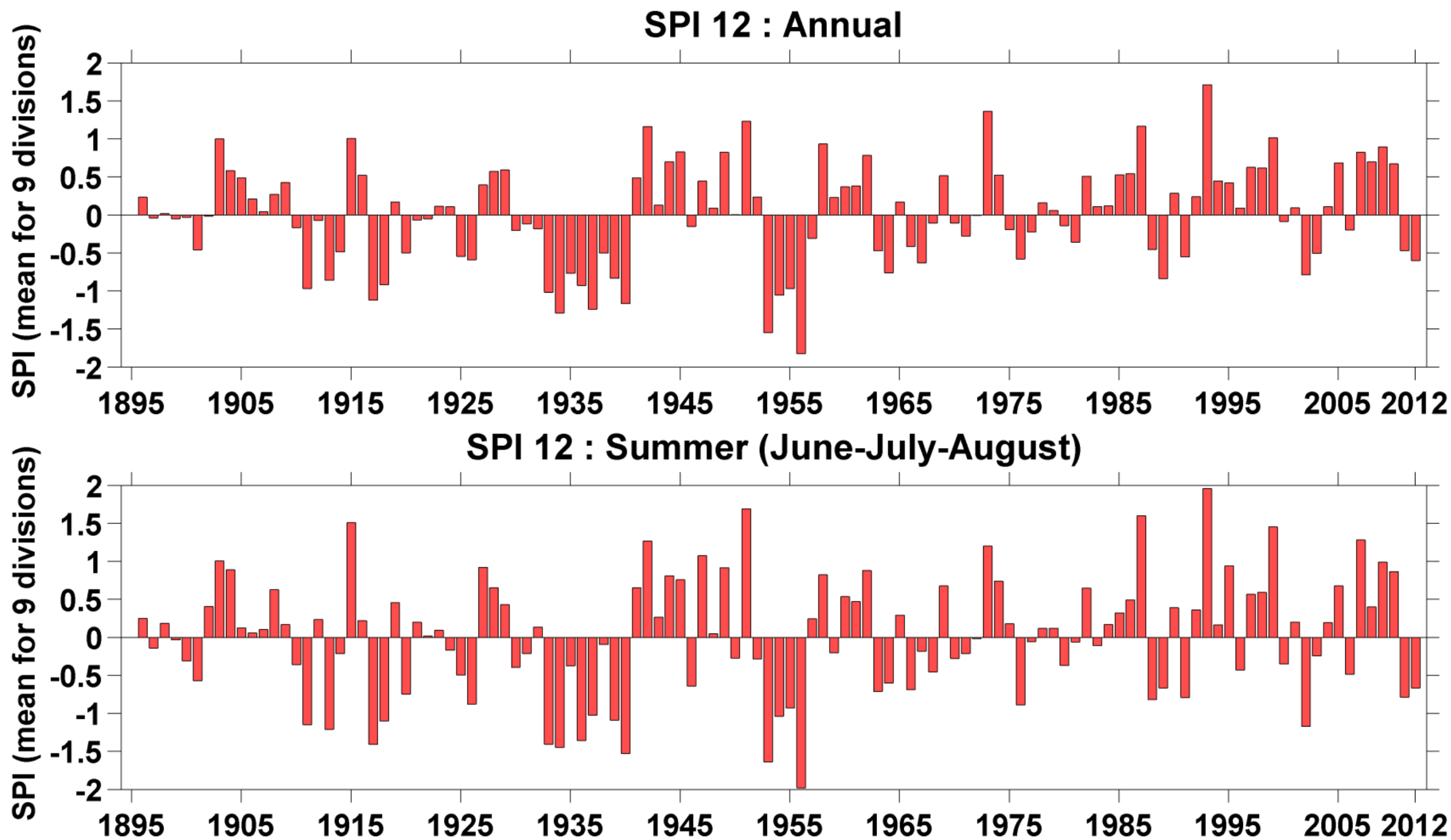

Figure 5. Mean SPI 12 for Kansas averaged from 9 climate divisions over a year and summer for the period 1896-2012. In addition, SPI 12 values from June, July and August months of a year were averaged to obtain Summer SPI 12. Similarly, all month's SPI 12 for a given year was averaged to obtain one Annual SPI 12 value for the year.

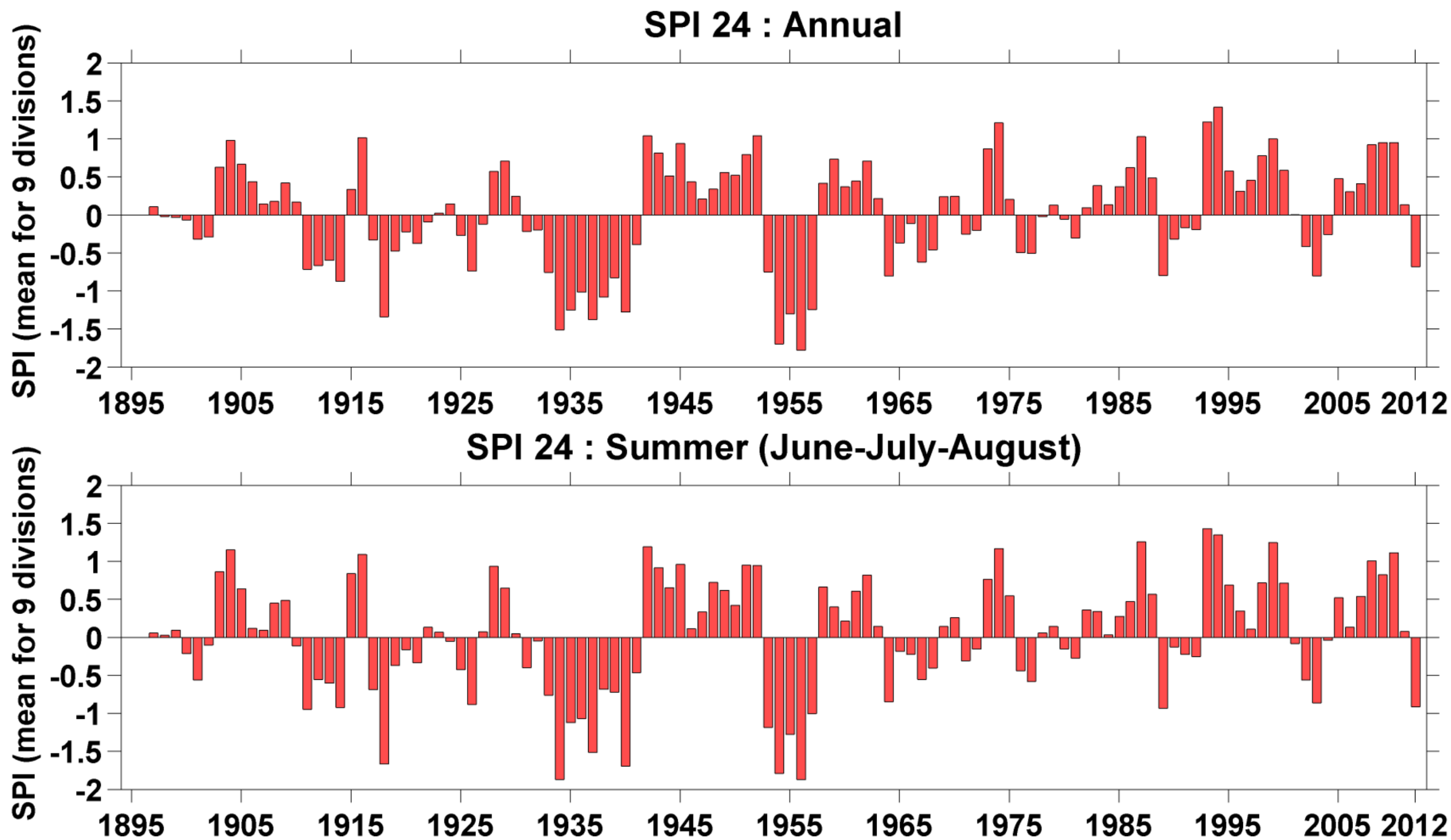

Figure 6. Mean SPI 24 for Kansas averaged from 9 climate divisions over a year and summer for the period 1896-2012. In addition, SPI 24 values from June, July and August months of a year were averaged to obtain Summer SPI 24. Similarly, all month's SPI 24 for a given year was averaged to obtain one Annual SPI 24 value for the year.

Table 1: Rank, year and mean SPI values for Kansas averaged from 9 climate divisions over a year, summer and July month for the period 1896-2012.

Short-term drought (SPI 1, SPI 3), Medium-term drought (SPI 6) : July								
Rank	**Year**	**SPI 1**	**Rank**	**Year**	**SPI 3**	**Rank**	**Year**	**SPI 6**
1	1935	-1.873	1	2012	-2.009	1	1936	-1.871
2	1983	-1.816	2	1952	-1.73	2	1934	-1.721
3	1916	-1.746	3	1901	-1.704	3	1956	-1.647
4	2003	-1.712	4	1980	-1.628	4	1910	-1.588
5	1936	-1.683	5	1934	-1.392	5	1966	-1.512
6	1934	-1.607	6	1913	-1.277	6	1917	-1.359
7	1974	-1.567	7	1917	-1.169	7	2002	-1.348
8	1975	-1.503	8	1933	-1.164	8	1933	-1.274
9	1980	-1.322	9	1974	-1.136	9	1926	-1.259
10	1984	-1.276	10	1931	-1.112	10	1913	-1.229
12	**2012**	**-1.191**	**1**	**2012**	**-2.009**	**12**	**2012**	**-1.057**
Short-term drought (SPI 1, SPI 3), Medium-term drought (SPI 6): Summer*								
Rank	**Year**	**SPI 1**	**Rank**	**Year**	**SPI 3**	**Rank**	**Year**	**SPI 6**
1	1936	-1.549	1	2012	-1.522	1	1956	-1.776
2	1913	-1.318	2	1936	-1.504	2	1936	-1.748
3	1934	-1.078	3	1913	-1.48	3	1934	-1.725
4	1976	-1.038	4	1934	-1.431	4	1966	-1.601
5	1983	-0.996	5	1952	-1.416	5	1913	-1.379
6	1918	-0.802	6	1980	-1.312	6	1910	-1.308
7	1952	-0.79	7	1901	-1.238	7	1926	-1.227
8	2012	-0.782	8	1911	-1.218	8	2002	-1.149
9	1955	-0.708	9	1956	-1.207	9	1933	-1.054
10	1984	-0.701	10	1926	-1.052	10	2012	-1.049
8	**2012**	**-0.782**	**1**	**2012**	**-1.522**	**10**	**2012**	**-1.049**
Short-term drought (SPI 1, SPI 3), Medium-term drought (SPI 6) : Annual*								
Rank	**Year**	**SPI 1**	**Rank**	**Year**	**SPI 3**	**Rank**	**Year**	**SPI 6**
1	1956	-0.761	1	1956	-1.394	1	1956	-1.736
2	1936	-0.655	2	1936	-0.969	2	1934	-1.153
3	1966	-0.607	3	1966	-0.923	3	1936	-1.051
4	1917	-0.555	4	1952	-0.888	4	1953	-1.013
5	1910	-0.518	5	1917	-0.792	5	1966	-0.965
6	1954	-0.514	6	1939	-0.75	6	1939	-0.958
7	1976	-0.507	7	1934	-0.731	7	2002	-0.931
8	1934	-0.482	8	1933	-0.635	8	1917	-0.904
9	1952	-0.437	9	1963	-0.607	9	1913	-0.903
10	1963	-0.422	10	1910	-0.595	10	1933	-0.9
11	**2012**	**-0.418**	**26**	**2012**	**-0.329**	**29**	**2012**	**-0.379**

Table 1 continued...: Rank, year and mean SPI values for Kansas averaged from 9 climate divisions over a year, summer and July month for the period 1896-2012.

Medium-term drought (SPI 9), Long-term drought (SPI 12 and SPI 24): July								
Rank	**Year**	**SPI 9**	**Rank**	**Year**	**SPI 12**	**Rank**	**Year**	**SPI 24**
1	1956	-1.902	1	1956	-1.909	1	1934	-1.854
2	1934	-1.619	2	1933	-1.613	2	1954	-1.814
3	1936	-1.561	3	1940	-1.586	3	1940	-1.811
4	1966	-1.516	4	1917	-1.556	4	1956	-1.657
5	1933	-1.489	5	1953	-1.536	5	1918	-1.554
6	2002	-1.468	6	2002	-1.403	6	1937	-1.351
7	1913	-1.467	7	1934	-1.317	7	1955	-1.288
8	1917	-1.364	8	1939	-1.283	8	1953	-1.223
9	1901	-1.258	9	1936	-1.259	9	1911	-1.086
10	1952	-1.230	10	1954	-1.224	10	1935	-1.068
32	**2012**	**-0.598**	**24**	**2012**	**-0.721**	**13**	**2012**	**-1.020**
Medium-term drought (SPI 9), Long-term drought (SPI 12 and SPI 24): Summer*								
Rank	**Year**	**SPI 9**	**Rank**	**Year**	**SPI 12**	**Rank**	**Year**	**SPI 24**
1	1956	-1.992	1	1956	-1.978	1	1956	-1.871
2	1934	-1.625	2	1953	-1.637	2	1934	-1.870
3	1936	-1.582	3	1940	-1.526	3	1954	-1.789
4	1913	-1.457	4	1934	-1.444	4	1940	-1.694
5	1966	-1.424	5	1917	-1.407	5	1918	-1.665
6	2002	-1.353	6	1933	-1.406	6	1937	-1.514
7	1933	-1.247	7	1936	-1.356	7	1955	-1.274
8	1926	-1.213	8	1913	-1.209	8	1953	-1.184
9	1952	-1.134	9	2002	-1.172	9	1935	-1.121
10	1963	-1.130	10	1911	-1.149	10	1936	-1.068
31	**2012**	**-0.550**	**24**	**2012**	**-0.67**	**15**	**2012**	**-0.914**
Medium-term drought (SPI 9), Long-term drought (SPI 12 and SPI 24) : Annual*								
Rank	**Year**	**SPI 9**	**Rank**	**Year**	**SPI 12**	**Rank**	**Year**	**SPI 24**
1	1956	-1.853	1	1956	-1.828	1	1956	-1.783
2	1953	-1.374	2	1953	-1.552	2	1954	-1.699
3	1934	-1.271	3	1934	-1.295	3	1934	-1.512
4	1917	-1.056	4	1937	-1.244	4	1937	-1.378
5	1937	-1.046	5	1940	-1.169	5	1918	-1.342
6	1936	-1.038	6	1917	-1.124	6	1955	-1.302
7	1940	-0.987	7	1954	-1.058	7	1940	-1.280
8	1939	-0.967	8	1933	-1.02	8	1935	-1.254
9	1933	-0.958	9	1911	-0.971	9	1957	-1.247
10	1913	-0.934	10	1955	-0.969	10	1938	-1.083
29	**2012**	**-0.362**	**30**	**2012**	**-0.468**	**24**	**2012**	**-0.592**

*Note: The individual SPI 9 values from June, July and August months of a year were averaged to obtain Summer SPI 9. Similarly, all month's SPI 24 for a given year was averaged to obtain one Annual SPI 24 value for the year.