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Spatial and Temporal Variability of Precipitation Across Nebraska

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Introduction

Quantifying the spatial and temporal variability of precipitation is important to better understand its potential impact(s) on water resources vs. crop productivity relationships on a temporal and spatial scale. This Extension Circular presents monthly, seasonal (growing season), and annual spatial and temporal variability in precipitation for each of Nebraska's 93 counties as well as statewide.

Understanding the spatial and temporal variability of various climatic/weather parameters such as precipitation is very important for many agro-ecosystems, and provides local climatic variations over both space and time. Precipitation is the general term for rainfall, snowfall, and other forms of frozen or liquid water falling from clouds, and depends greatly on temperature and weather conditions.

Precipitation variability from season to season greatly affects soil water availability and is strongly linked to crop productivity. In agro-ecosystems, precipitation plays an important role, having both positive and negative effects. In 2012, for example, Nebraska experienced its severest drought in over 30 years. In 2012, a majority of the state was considered to be under exceptional drought, the most severe drought classification under the U.S. drought monitor. For example, Grand Island had the record driest summer with low rainfall of 2.36 inches (22 percent of normal precipitation), and increased air temperature (most 95+ degree days on record in 75 years). Such drought conditions impose stress on water resources in agricultural areas, especially irrigated regions due to decreased water supply and greater pumping costs.

Excess precipitation also has adverse effects on agro-ecosystems. For example, excess precipitation may cause more run-off, deep percolation that can result in chemical leaching to groundwater, soil erosion, floods, and other negative environmental impacts. Excess precipitation also is a major component of crop loss due to wet and/or flooded conditions (see *NebGuide G1904 Plant Growth and Yield as Affected by Wet Soil Conditions Due to Flooding or Over-irrigation*). However, adequate amounts of precipitation help to recharge the soil profile and hence the groundwater, reducing crop irrigation needs. Therefore, understanding the spatial and temporal variation of precipitation in Nebraska is very important for many agro-ecosystem functions. A good understanding of local climatic variations over both space and time also is important so that accurate agro-water resource management decisions can help to meet crop water demand under changing climatic conditions.

For the purpose of this publication the term annual precipitation is defined as the sum of precipitation recorded at the weather station from Jan. 1 to Dec. 31. The seasonal precipitation represents the total precipitation from May 1 to Sept. 30; and the monthly precipitation is defined as the sum of precipitation recorded at the weather station during a given month from January to December.

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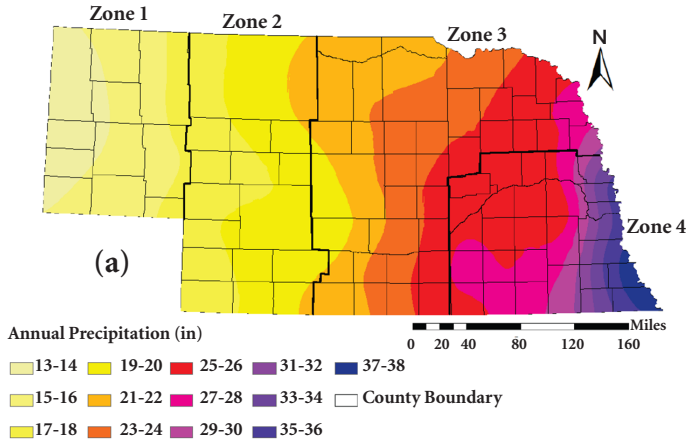

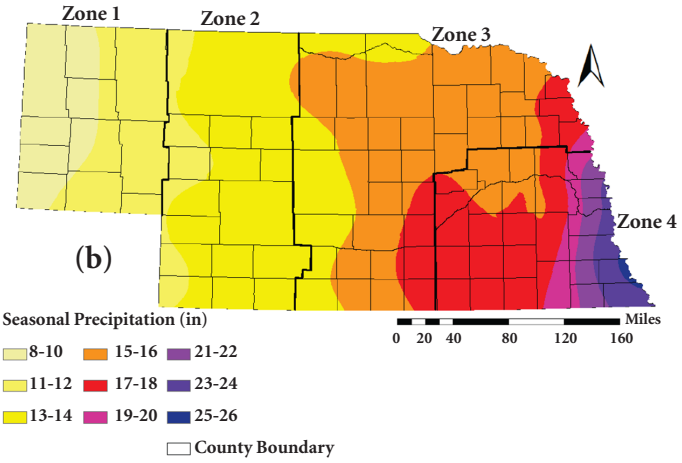

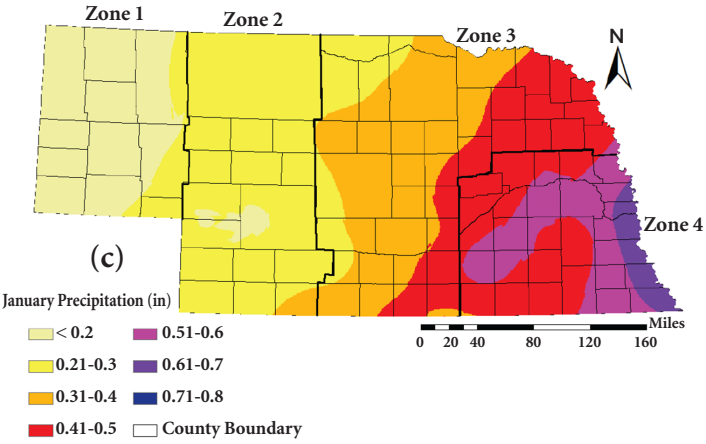

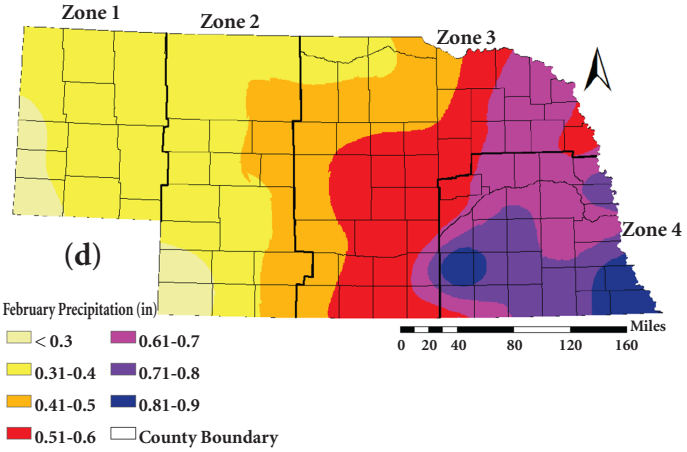

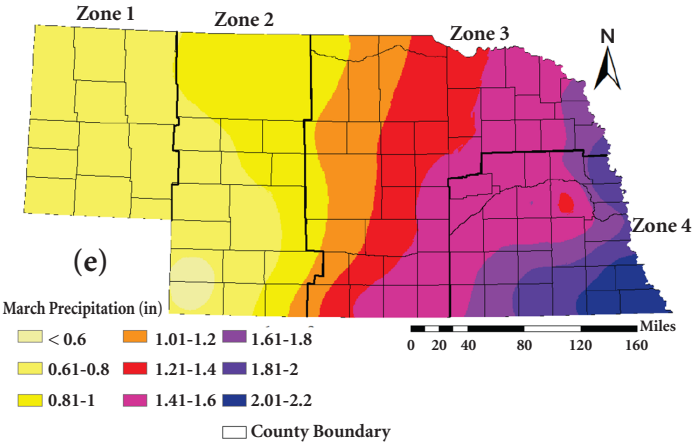

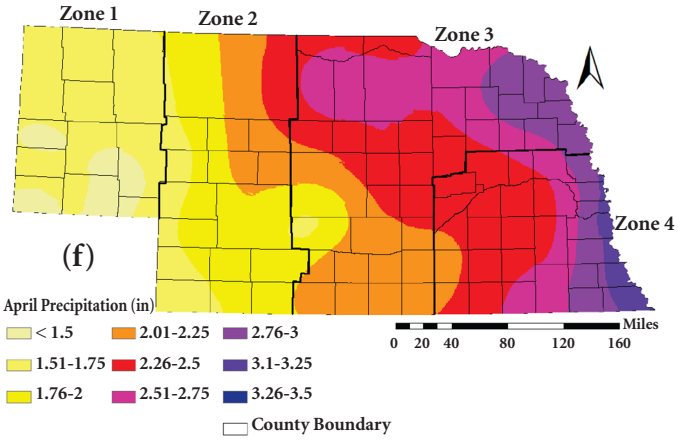

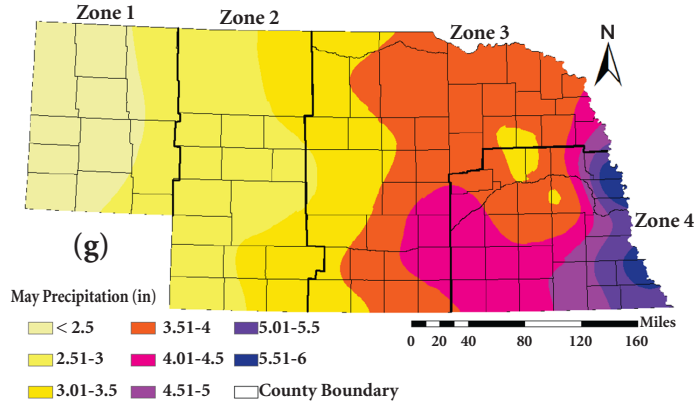

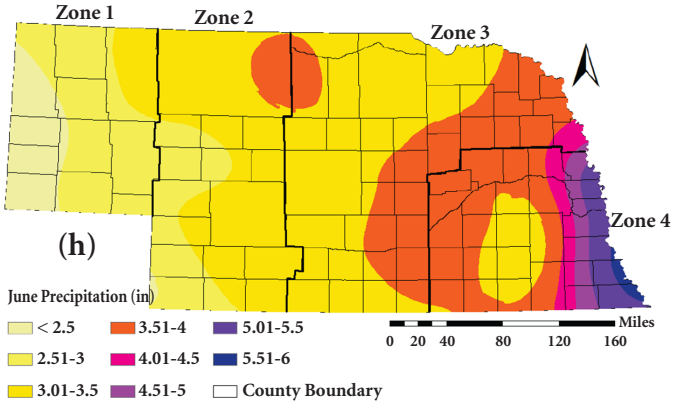

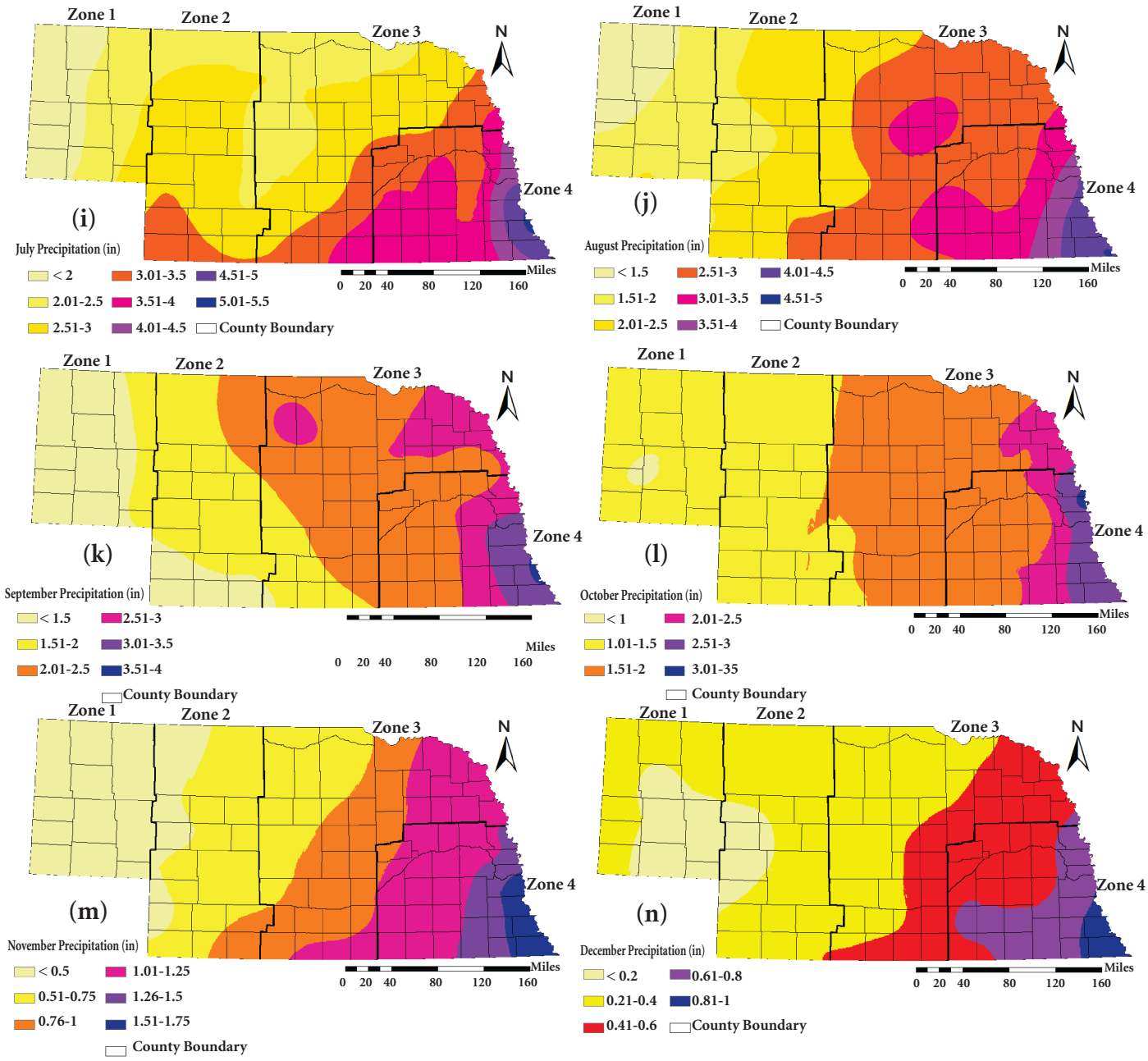

Figure 1. Spatial variation of long-term average (1986-2012) annual (a), seasonal (b), January (c), February (d), March (e), April (f), May (g), June (h), July (i), August (j), September (k), October (l), November (m), and December (n) precipitation (P, inch) across Nebraska.

In this publication, the state of Nebraska is divided into four management zones (*Figure 1*) according to differences in environmental characteristics, along with the combined effects of climatic conditions, soil, and topographic characteristics. *Table 1* represents the counties included in each zone. For each zone, long-term average (1986-2012), monthly, growing season (May 1 to Sept. 30) and annual (Jan. 1 to Dec. 31) precipitation spatial and temporal variability were analyzed and discussed. A total of 50 High Plains Regional Climate Center (HPRCC)-Automated Weather Data Network (AWDN) weather stations were used in the analyses. To increase the climatic data density and to decrease the interpolation error across the Nebraska boundaries, some stations outside Nebraska, also part of the HPRCC-AWDN, were used. This includes 38 counties in Nebraska, two from Colorado, three from Kansas, three from South Dakota, two from Missouri, and two from Iowa. The precipitation data from each weather station were then interpolated using ArcGIS geospatial analyst. Town and county names are in Nebraska unless otherwise noted.

Spatial Variation of Annual, Seasonal, and Monthly Precipitation

Long-term (1986-2012) average annual, seasonal (growing season), and monthly (January to December) precipitation mean values show similar spatial distribution (*Figure 1*). Precipitation gradually increased from the northwest corner (Zone 1) to the eastern part (Zone 4) of the state. The statewide long-term average annual precipitation ranged from 12.61 inches to 34.99 inches with a mean of 22.38 inches. In the western half of the state, precipitation is usually a limiting factor for crop production. The average precipitation of 14.4 inches with a maximum of 15.8 inches in Deuel County and minimum of 12.6 inches in Scotts Bluff County was observed in Zone 1. However, higher annual average precipitation amounts of 27.5 inches (maximum: 35 inches in Nemaha County and minimum: 23.6 inches in Platte County) and 22.9 inches (maximum: 27 inches in Burt County and minimum: 18.9 inches in Dawson County) were observed in Zone 4 and Zone 3, respectively. Zone 3 is heavily irrigated, with approximately 75,000 of the state's 110,000 active irrigation wells located there, as are approximately about 40,000 center pivot irrigation systems (USDA-NASS 2007). A gradual decreasing trend in precipitation was also observed from south to north with a maximum of 35 inches in Nemaha County (Zone 4). This gradually decreased to 27 inches in Burt County, Zone 3 along the eastern edge of the state (*Figure 1*).

The statewide long-term average seasonal precipitation showed a similar spatial trend in annual precipitation (*Figure 1b*). Average statewide seasonal precipitation ranged from 6.36 inches to 23.02 inches with a statewide average of 13.39 inches (60 percent of total annual precipitation). The average seasonal precipitation showed a similar distribution as annual precipitation with average precipitation of 7.76 inches, 10.25 inches, 13.01 inches, and 17.94 inches for Zone 1, Zone 2, Zone 3, and Zone 4, respectively, which is 54 percent, 57 percent, 57 percent, and 65 percent of the total annual precipitation; *Figures 1c* to *1n* represent the spatial distribution of monthly precipitation across Nebraska.

The long-term average (1986-2012) annual, seasonal, and monthly precipitation total values for statewide and

Table 1. Climatic regions (zones) and counties included in each zone.

ZONE	Region	Counties
Zone 1	Panhandle	Banner, Box Butte, Cheyenne, Deuel, Garden, Kimball, Morrill, Scotts Bluff, Sheridan, Sioux, Dawes
Zone 2	West Central	Arthur, Cherry, Grant, Hooker, Logan, McPherson, Thomas, Chase, Dundy, Frontier, Hayes, Hitchcock, Keith, Lincoln, Perkins, Red Willow
Zone 3	East Central	Antelope, Boone, Burt, Boyd, Cedar, Cuming, Dakota, Dixon, Knox, Madison, Pierce, Stanton, Thurston, Wayne, Buffalo, Custer, Dawson, Greeley, Hall, Howard, Sherman, Valley, Adams, Franklin, Furnas, Gosper, Harlan, Kearney, Phelps, Webster, Keya Paha, Brown, Rock, Holt, Blaine, Loup, Wheeler, Garfield
Zone 4	Southeast	Butler, Colfax, Dodge, Douglas, Hamilton, Lancaster, Merrick, Nance, Platte, Polk, Sarpy, Saunders, Seward, Washington, York, Cass, Clay, Fillmore, Gage, Jefferson, Johnson, Nemaha, Nuckolls, Pawnee, Richardson, Saline, Thayer, Otoe

Table 2. Long-term average monthly (statewide), seasonal [May 1 to Sept. 30 (statewide and zonewise)], and annual [Jan. 1 to Dec. 31 (statewide and zonewise)] interpolated precipitation (inches) of all 93 counties (number of counties = 93) for the observation period of 1986-2012 across Nebraska. (SD = Standard Deviation).

		Precipitation (P)			
	Month	Mean (inches)	Maximum (inches)	Minimum (inches)	Standard Deviation (inches)
Monthly	Jan	0.37	0.62	0.13	0.13
	Feb	0.54	0.89	0.25	0.16
	Mar	1.29	2.14	0.58	0.42
	Apr	2.28	3.05	1.49	0.43
	May	3.57	5.31	2.13	0.75
	Jun	3.58	5.33	2.26	0.66
	Jul	2.97	4.74	1.60	0.62
	Aug	2.67	4.46	1.16	0.64
	Sep	2.07	3.39	1.09	0.55
	Oct	1.73	2.92	1.00	0.45
	Nov	0.89	1.62	0.35	0.32
	Dec	0.42	0.88	0.17	0.18
Seasonal	Statewide	13.39	23.02	6.36	3.03
	Zone 1	7.76	9.08	6.36	0.90
	Zone 2	10.25	10.95	9.54	0.49
	Zone 3	13.01	15.04	11.15	1.01
	Zone 4	17.94	23.02	15.63	2.39
Annual	Statewide	22.38	34.99	12.61	4.99
	Zone 1	14.38	15.81	12.61	1.07
	Zone 2	18.01	19.46	16.35	0.97
	Zone 3	22.87	27.00	18.92	2.00
	Zone 4	27.45	34.99	23.57	3.62

zone-wise, with standard deviation (SD) are presented in *Table 2*. Standard deviation is the measure of amount of variation from the average values (precipitation) in each period. Higher standard deviation indicates more variation or deviation of the precipitation data point from the average value in a given period; while the low standard deviation indicates that the data points are close to the average value. Monthly maximum and minimum precipitation amounts ranged from 0.62 inch to 5.33 inches and from 0.13 inch to 2.26 inches, respectively, with minimum values observed in January and maximum values in June (*Table 2*). The SD of daily precipitation increased gradually from January toward summer months and decreased again gradually toward November-December, with maximum (0.75 inch) and minimum (0.13 inch) of precipitation observed in the month of May and January, respectively. Higher statewide variation was observed for higher seasonal and annual precipitation mean. Lower precipitation toward the western part of the state might be due to the fact that the western parts of the state (Zone 1 and Zone 2) are low-pressure areas. When a low pressure moves in from the northwest direction from Rocky Mountains region, it is usually followed by a cold front, but seldom brings precipitation to the western part of the state (Hall, 1938).

Effectively evaluating the difference in annual and seasonal precipitation statewide is useful so that priority counties can be identified for close monitoring and assessment. *Figure 2* represents the long-term average annual and seasonal precipitation values for each county across Nebraska and the SD for the 27-year period evaluating the variation in precipitation. According to the annual and seasonal average precipitation data, there was approximately an 1.2 inch decrease in annual precipitation for every 25 miles going from east to west in the state. Also, there was about a 0.85 inch decrease in seasonal (growing season) precipitation for every 25 miles going from east to west. University of Nebraska–Lincoln Extension Circular EC717 titled *Long-term (1893-2012) Changes in Monthly, Growing Season and Annual Precipitation Trends and Magnitudes in Central Nebraska* presents detailed analyses of precipitation magnitudes for central Nebraska.

Figure 2 shows a greater difference in annual and seasonal precipitation toward the eastern part of the

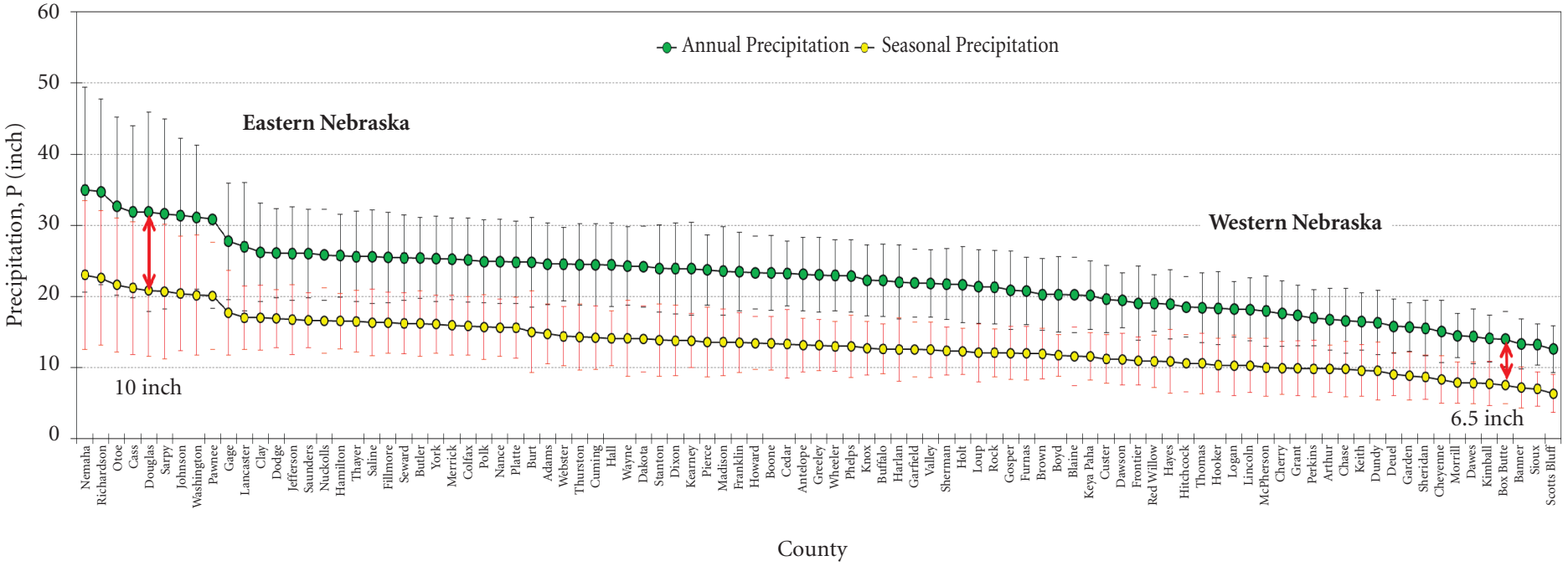

Figure 2. Graphical representation of long-term (1986-2012) average annual (Jan. 1 to Dec. 31) and seasonal (May 1 to Sept. 30) mean precipitation values along with standard deviation bars (vertical bars on each data point) for all 93 counties across Nebraska.

state as compared to the difference between the annual and seasonal precipitation toward the western portion. Higher SD was generally observed for eastern Nebraska as compared to western Nebraska, depicting more variation in annual and seasonal precipitation in Zone 3 and Zone 4. This indicates a higher degree of spatial variability in precipitation in eastern Nebraska. Zone 4 had higher SD values for both seasonal and annual precipitation than other Zones; and Zone 2 had the lowest SD values, indicating least precipitation variability across Zone 2.

Monthly Variation of Precipitation

Figure 3 provides the monthly distribution of precipitation along with standard deviations for each zone. Each monthly value was calculated by averaging monthly data for 27 years. For example, May precipitation in *Figure 3* is the average precipitation received in 27 months of May from 1986-2012. Typical bell-shaped (normal distribution) distribution of precipitation was observed for each zone, with maximum values occurring in summer and lowest values in winter months. From 1986 to 2012 the mean monthly precipitation values for Zone 1 varied between 0.17 inch (January) to 2.64 inches (June) with the maximum monthly value of 3.17 inches (June) and minimum 0.13 inch (January) in Deuel and Sioux Counties, respectively. Standard deviation distribution over the years also showed the bell-shape pattern with the maximum observed in the middle of the year, when the precipitation amounts are high and minimum in the winter months. For Zone 1, maximum and minimum SD of 0.37 inch and 0.015 inch was observed during July and December, respectively.

A similar annual distribution was observed for Zone 2, but with higher magnitude. Over a period of 27 years the mean precipitation varied from 0.24 inch (January and December) to 3.07 inches (June). The maximum precipitation of 3.59 inches (June) and minimum of 0.17 inch (December) were observed in Cherry and Arthur counties, respectively. On average, Zone 2 annual precipitation was about 19 percent higher than the precipitation for Zone 1. For central and eastern Nebraska (Zones 3 and 4), the mean monthly precipitation varied between 0.38 inch (January) to 3.67 inches (May) and 0.52

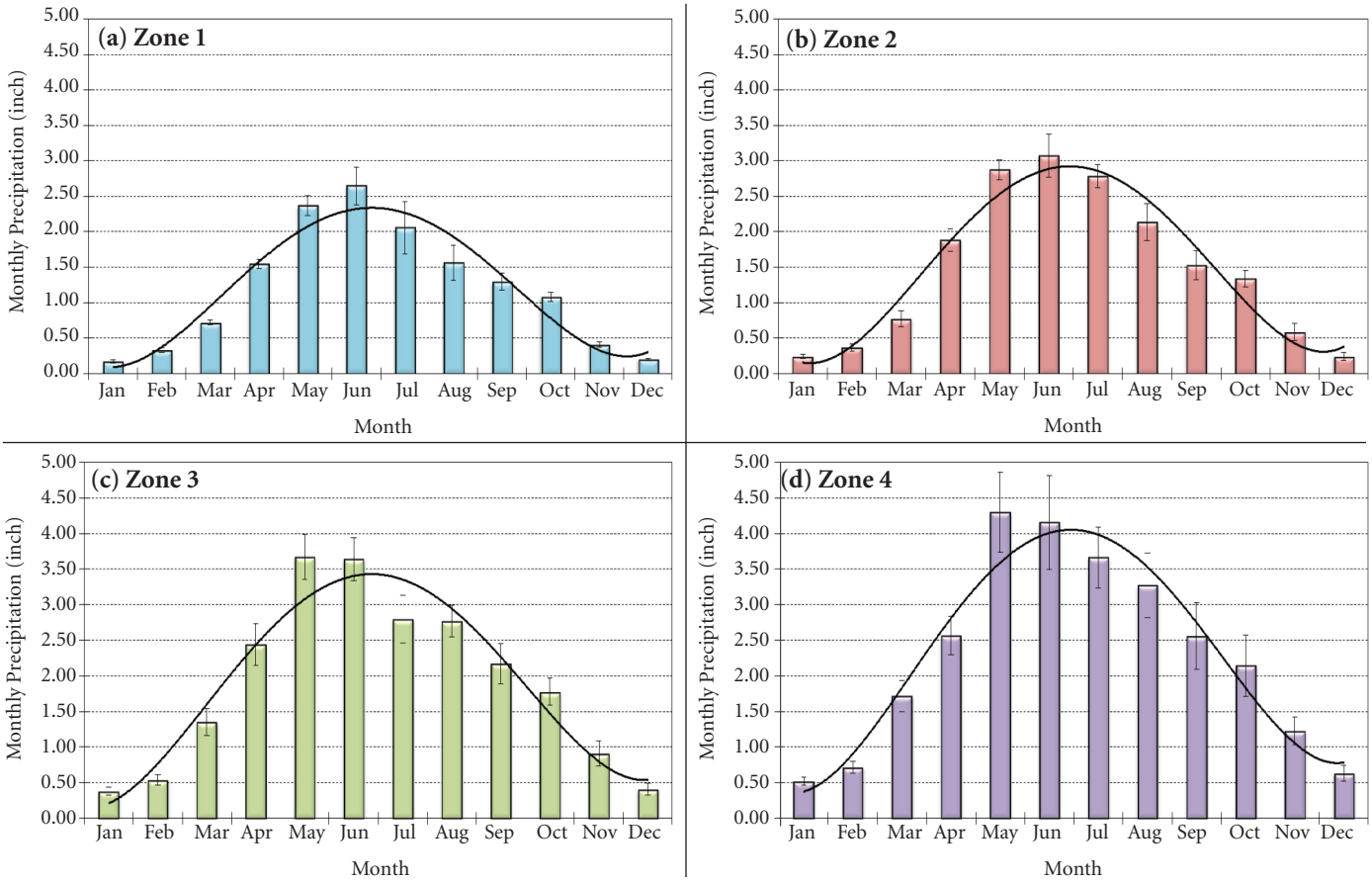

Figure 3. Long-term average monthly precipitation for Zone 1 (a), Zone 2 (b), Zone 3 (c), and Zone 4 (d). Each bar represents the average of 27 years (1986-2012) of monthly total precipitation. Vertical lines on each bar represent the standard deviation (SD) in each zone for a given month. Dark black line represents the annual trend in precipitation for all zones.

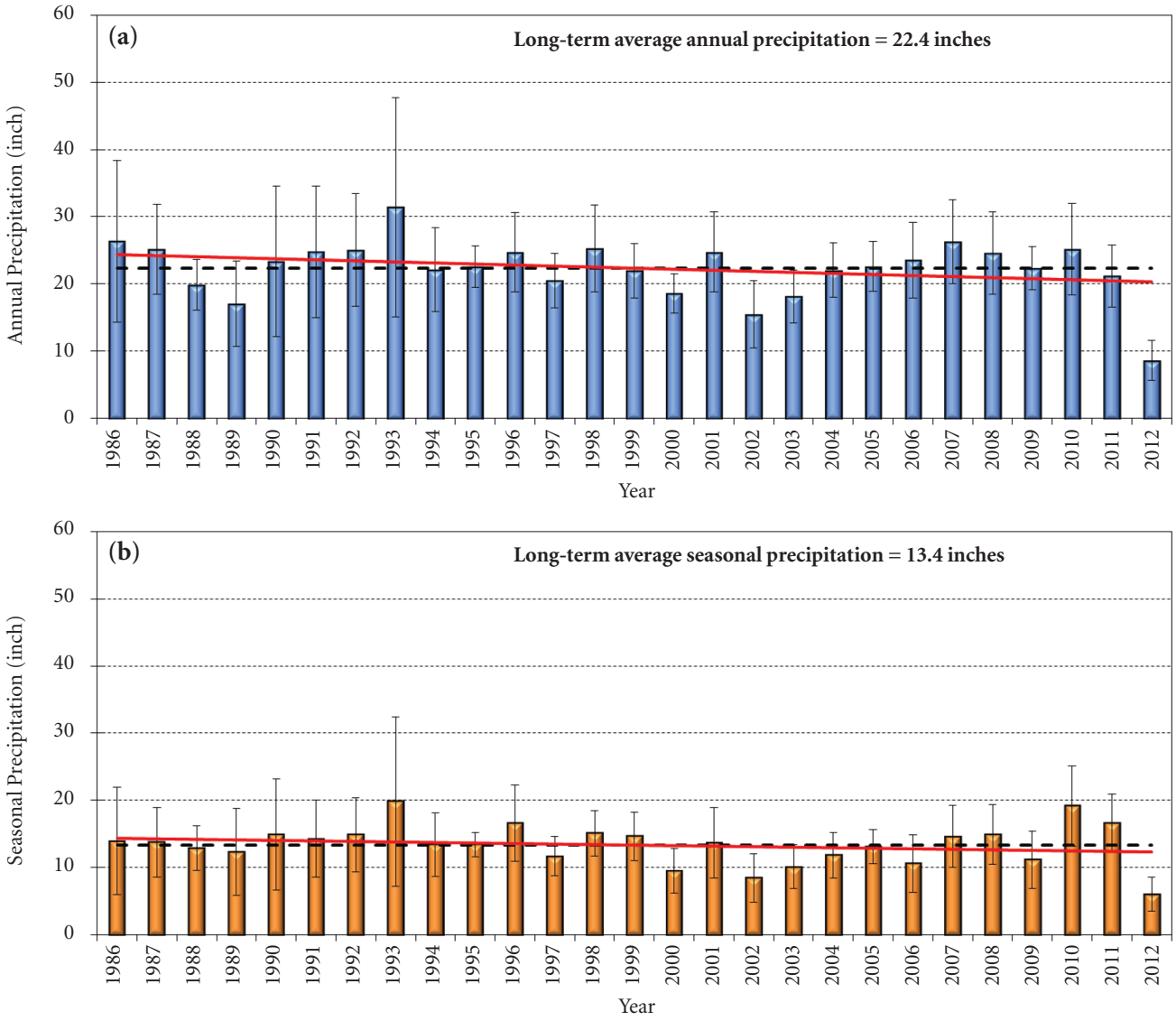

Figure 4. Average statewide (a) annual (Jan. 1 to Dec. 31) and (b) seasonal (May 1 to Sept. 30) temporal precipitation trends from 1986-2012 across Nebraska. Dotted black and red line represents the long-term average value and precipitation trend from 1986-2012.

inch (January) to 4.30 inches (May) for Zones 3 and 4, respectively. The maximum of 4.30 inches (Burt County) and 5.33 inches (Nemaha County) and minimum of 0.26 inch (Keya Paha County) and 0.45 inch (Nuckolls County) was observed for Zones 3 and 4, respectively. On an annual average basis, Zone 4 precipitation was about 48 percent, 35 percent, and 17 percent more than the precipitation in Zone 1, Zone 2, and Zone 3, respectively.

Temporal Variation of Precipitation

Figure 4a and *4b* represent the statewide variation of annual and seasonal precipitation from 1986-2012. Overall, a decreasing trend was observed in both annual and seasonal precipitation totals over this 27-year period. On average, there was about 20 percent and 15 percent reduction in annual and seasonal precipitation totals from 1986-2012, respectively. The maximum annual and seasonal precipitation of 31.4 inches (SD = 16.3 inches) and 19.8 inches (SD = 12.6 inches) was observed in 1993, which was one of the wettest years on record in Nebraska. The lowest amount of annual and seasonal precipitation was observed in 2012, with a statewide average of 8.64 inches (SD = 2.95 inches) and 6.1 inches (SD = 2.51 inches), respectively, which is 61 percent and 54 percent lower than the long-term annual and seasonal precipitation amounts.

Figures 5 and *6* represent the annual (Jan. 1-Dec. 31) and seasonal (May 1- Sept. 30) precipitation from 1986 to 2012 for each zone. In each figure, the dotted black line represents the long-term average line and the red line shows the precipitation trend over the period of 27

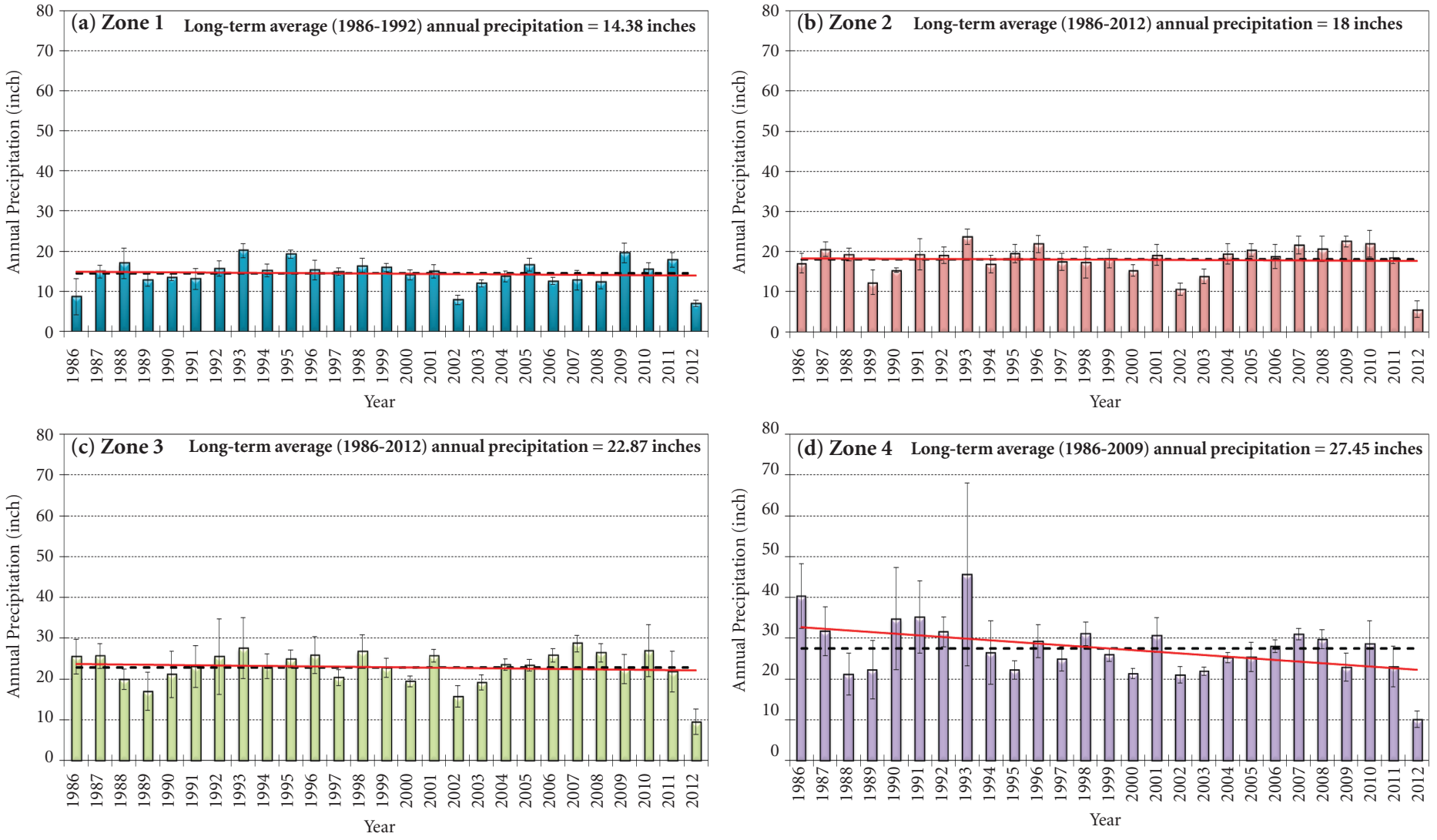

Figure 5. Long-term average (1986-2012) annual (Jan. 1 to Dec. 31) trends for Zone 1 (a), Zone 2 (b), Zone 3 (c) and Zone 4 (d). The vertical lines on each bar represent the standard deviation in annual precipitation in a given year. Dotted black and red line represents the long-term average value and precipitation trend from 1986-2012.

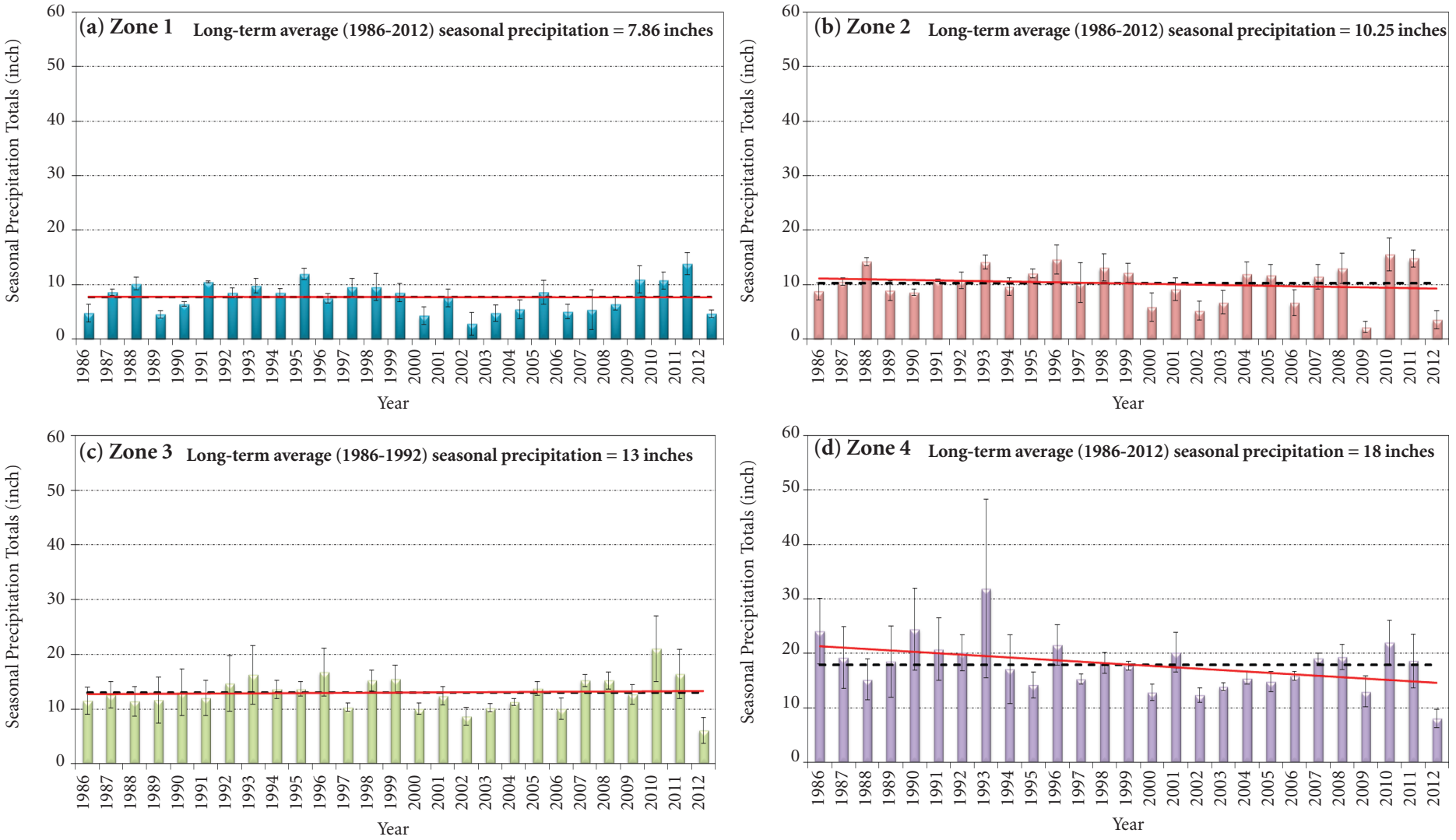

Figure 6. Long-term average (1986-2012) seasonal (May 1 to Sept. 30) trends for Zone 1 (a), Zone 2 (b), Zone 3 (c), and Zone 4 (d). The vertical lines on each bar represent the standard deviation in seasonal precipitation in a given year. Dotted black and red line represents the long-term average value and precipitation trend from 1986-2012.

years. The long-term average annual precipitation total was calculated as 14.4 inches (range: 6.9 inches to 20.1 inches) for Zone 1, 18 inches (range: 5.7 inches to 23.7 inches) for Zone 2, 22.9 inches (range: 9.6 to 28.7 inches) for Zone 3, and 27.5 inches (range: 10 inches to 45.6 inches) for Zone 4, respectively. For every year, except 1995, Zone 4 had the highest precipitation total. For all zones, the minimum precipitation was observed in 2012, which is 52 percent, 68 percent 58 percent, and 63 percent lower than the long-term average for each zone. Maximum precipitation in Zone 1, Zone 2, and Zone 4 was observed in 1993 (wettest year), while in Zone 3 the maximum precipitation was observed in 2007. In the 27-year period, there were 12 years (1986, 1987, 1990, 1991, 1992, 1993, 1996, 1998, 2001, 2007, 2008, and 2010) when the annual totals were greater than the long-term average in Zone 4. However in Zone 1, there were 15 years (1987, 1988, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2001, 2005, 2009, 2010, and 2011) where annual totals were greater than the long-term average.

The temporal trend shows the decreasing trend in annual precipitation for all zones (red line), however the maximum reduction in precipitation amount was observed for Zone 4, with 32 percent reduction in annual totals from 1986 to 2012. A maximum SD of 22.42 inches, 9.3 inches, 4.49 inches, and 3.89 inches of annual totals was observed in the 1993 for Zone 4, 1992 for Zone 3, 1986 for Zone 1, and 1991 for Zone 2, representing more variability of precipitation in these years in specific zones. For all years, higher SD was observed for Zones 3 and 4.

Similar to annual totals, *Figure 6* represents the seasonal precipitation totals over a 27-year period. The average seasonal precipitation in Zone 1, Zone 2, Zone 3, and Zone 4 was observed as 7.8 inches, 10.3 inches, 13 inches, and 17.9 inches, respectively. For all years, the highest seasonal precipitation was observed in Zone 4 and minimum was observed in Zone 1 except in two years (2009 and 2012), where minimum seasonal precipitation was observed in Zone 2. Seasonal precipitation shows the decreasing trend (red line) for Zone 4, Zone 2, and Zone 1. However, a slight increasing trend in precipitation was observed in Zone 3, which might be due to recent high precipitation totals. The seasonal average precipitation amounts of 15.21 inches, 15.2 inches, 21.1 inches, and 16.4 inches were observed in 2007, 2008, 2010, and 2011, which are higher than the statewide long-term average value of 13.4 inches.

To further investigate the increasing and decreasing trends in precipitation totals, trend analyses are presented in *Figures 7a* and *7b* for each county. Red circles in each figure represent the counties with decreasing precipitation trends; blue circles represent the counties with increasing trends in precipitation. The increasing size of the blue circles represents increasing annual precipitation trends; the increasing size of the red circle represents decreasing trends in annual precipitation. About 75 percent of Nebraska counties show a decreasing trend in annual precipitation. The maximum decreasing trend was observed in Zone 4, with about 56 percent, 52 percent, and 50 percent reduction in annual precipitation in Nemaha, Richardson, and Sarpy Counties, respectively. For seasonal precipitation, about 63 percent of Nebraska counties show a decreasing trend. A maximum decrease of 60 percent in seasonal precipitation was observed in Nemaha County. Contrary to the decreasing trends, maximum increasing trend was observed in Gosper County (Zone 3), with an increase of 21 percent in annual precipitation. However for seasonal precipitation a maximum increasing trend of 51 percent was observed in Stanton County (northeastern Nebraska).

Summary

This Extension Circular discusses and analyzes the long-term (1986-2012) average annual (Jan. 1 to Dec. 31), seasonal (May 1 to Sept. 30), and monthly spatial and temporal variation in precipitation for Nebraska. The state of Nebraska is divided into four climatic zones according to differences in environmental characteristics, climatic conditions, soil, and topographic characteristics. Annual, seasonal, and monthly precipitation exhibit similar spatial patterns. Precipitation gradually increased from the northwest (Zone 1) corner to the eastern part (Zone 4) of the state. The statewide long-term average annual precipitation was 22.9 inches with maximum and minimum values of 34.99 inches and 12.61 inches observed in Nemaha and Scotts Bluff Counties. Significant variation was observed over the state with average precipitation of 27.45 inches (SD = 3.62 inches), 22.87 inches (SD = 2.00 inches), 18.01 inches (SD = 0.97 inch), and 14.38 inches (SD = 1.07 inches) in Zone 1, Zone 2, Zone 3 and Zone 4, respectively.

Average statewide seasonal precipitation ranged from 6.36 inches to 23.02 inches with a statewide average of 13.39 inches (60 percent of total annual precipitation). According to the annual and seasonal average precipitation data, there was approximately an 1.2 inch and 0.85 inch decrease in annual precipitation for every 25 miles going from east to west in the state. Monthly maximum and minimum precipitation amounts ranged from 0.62 inch to 5.33 inches, and from 0.13 inch to 2.26 inches, respectively, with minimum values observed in January and maximum values in June. The SD of daily precipitation increased gradually from January toward the summer months and decreased again gradually toward

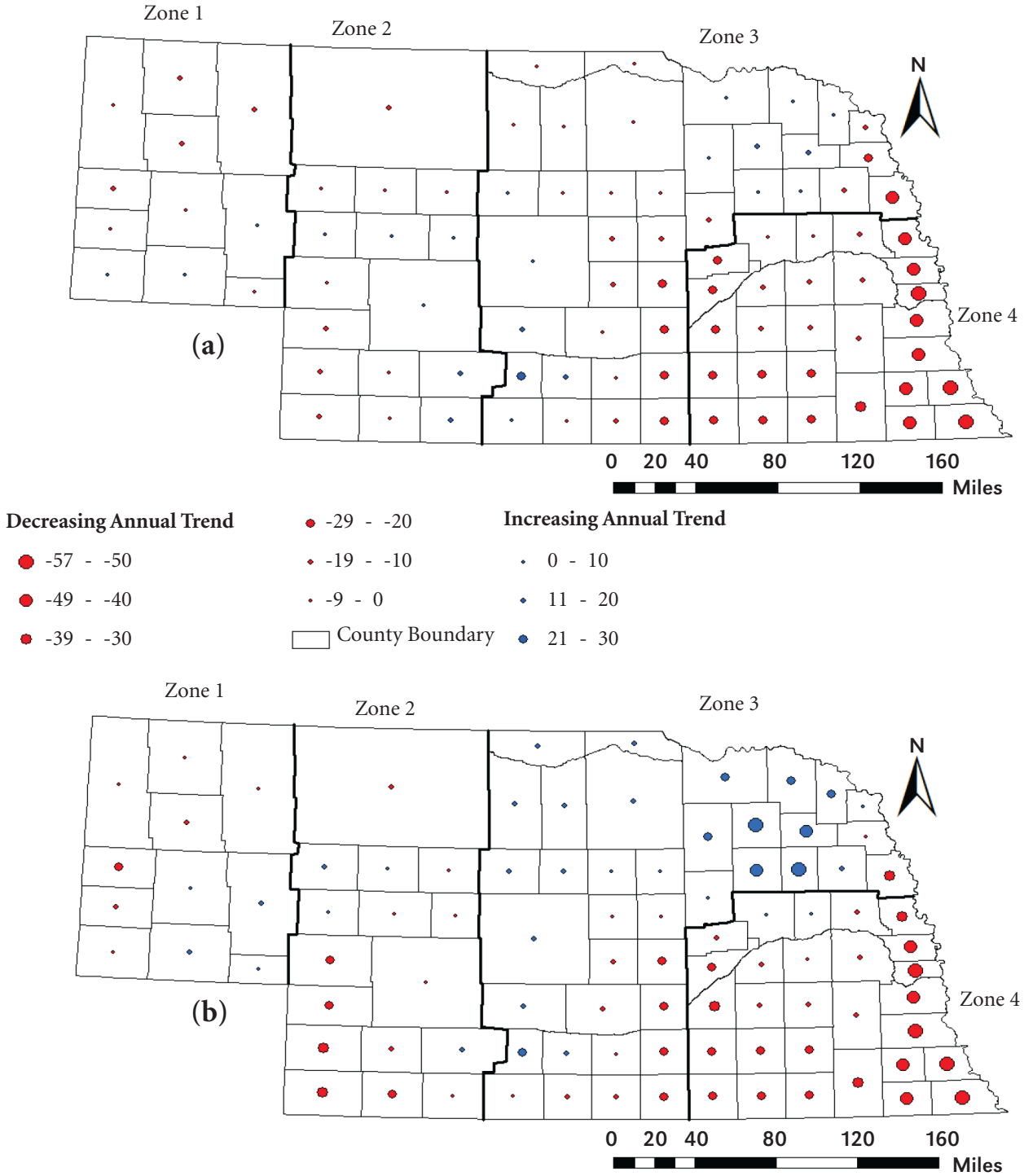

Figure 7. Long-term average (a) annual (Jan. 1-Dec. 30) and (b) seasonal (May 1-Sept. 30) precipitation trends from 1986 to 2012 in Nebraska. Blue circles in each county represent increasing trends and red circles represent decreasing trends. The size of the circles represents the magnitude of increase or decrease.

November-December, with maximum (0.75 inch) and minimum (0.13 inch) precipitation observed in the months of May and January, respectively.

Overall, a statewide decreasing trend was observed in both annual and seasonal precipitation totals from 1986-2012. On average, there is about a 20 percent and 15 percent reduction in annual and seasonal precipitation totals from 1986-2012, respectively. The maximum annual and seasonal precipitation of 31.4 inches (SD = 16.3 inches) and 19.8 inches (SD = 12.6 inches) was observed in 1993, which was one of the wettest years on record in Nebraska. The lowest amount of annual and seasonal precipitation was observed in 2012, with a statewide average of 8.64 inches (SD = 2.95 inches) and 6.1 inches (SD = 2.51 inches), respectively, which is 65 percent and 53 percent lower than the long-term annual and seasonal precipitation amounts.

The zone-wise temporal trend shows the decreasing trend in annual precipitation from 1986 to 2012, with an overall reduction of 5.8 percent, 3.6 percent, 6.76 percent, and 32 percent in Zone 1, Zone 2, Zone 3, and Zone 4, respectively. For all zones, the minimum precipitation was observed in 2012, which is 52 percent, 68 percent, 58 percent, and 63 percent lower than the long-term average for each zone. Maximum precipitation in Zone 1, Zone 2 and Zone 4 was observed in 1993 (wettest year), while in Zone 3 the maximum precipitation was observed in 2007. Similar to annual trends, a decreasing seasonal trend was observed in all zones except Zone 3, where small increasing trend was observed. About 75 percent of Nebraska Counties show the decreasing annual trend in precipitation from 1986-2012. The maximum reduction of 56 percent was observed in Nemaha County. For seasonal precipitation the maximum reduction of 60 percent was observed for Nemaha County, and maximum increasing trend of 51 percent was observed in Stanton County.

Resources

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