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From Too Much to Too Little: How the central U.S. drought of 2012 evolved out of one of the most devastating floods on record in 2011

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From Too Much to Too Little:

How the central U.S. drought of 2012 evolved out of one of the most devastating floods on record in 2011

NIDIS
NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM

National Drought Mitigation Center

AASC
AMERICAN ASSOCIATION OF STATE CLIMATOLOGISTS

HIGH PLAINS REGIONAL CLIMATE CENTER

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

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Midwestern Regional Climate Center

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Cover photo: Remains of a corn field near Sigel, Illinois, taken on July 1, 2012. Photo courtesy of Aaron Greuel.

Central U.S. 2012 Drought Assessment

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Section 1: Introduction

Brian Fuchs, National Drought Mitigation Center

The drought of 2012 will be remembered in many ways. Not only was this the first drought since 1988 that impacted almost the entire Corn Belt, it also was unique in how it developed and intensified and how quickly it took place. The 2012 drought occurred a year after epic floods throughout the Plains and Midwest. To capture the attributes associated with this drought event, an assessment of the drought on a regional and state level was conducted. This assessment is composed of contributions from state officials and university researchers, and it was made possible through funding from the National Integrated Drought Information System (NIDIS) Program Office and the National Climatic Data Center and their program for state climatologists. The aim of this drought assessment was to help identify what was actually taking place meteorologically and climatologically, especially after the floods of 2011. The assessment documents how 14 states (Wyoming, Colorado, Kansas, Nebraska, South Dakota, North Dakota, Minnesota, Missouri, Iowa, Illinois, Michigan, Indiana, Ohio, and Kentucky) responded to the drought, and how the drought progressed locally. Each state is represented in its own report, discussing what was important to that state and how it was impacted, and a regional synopsis is also included. The assessment examines the response of the region and the individual states to the drought with regard to local climate, agriculture, water supply, impacts, and other areas of interest, and provides a better idea of how drought impacts the various climate regimes being studied. By and large, the drought of 2012 caught many by surprise as there was very little in the way of an early warning signal that drought was going to develop or that it would be as intense as it was after the first signs of drought appeared. It is hoped that we can learn from this event to help better plan and prepare for the next drought.

One intriguing question that surrounded the drought of 2012 (and all drought events) is, Why did this drought develop and occur, especially after the historic floods of the year before? Four types of drought have been identified (meteorological, hydrological, agricultural, and socio-economic), and the contributing factors are distinctive to each type, but in essence all droughts are due to a lack of precipitation at some point in time. The spatial extent and intensity of the 2012 drought in the central United States did have some unique and interesting characteristics, many of which are touched on in this assessment. Not only did the lack of precipitation contribute to the drought, but the above-normal temperatures were also key. For more on why the drought developed as it did, please see "An Interpretation of the Origins of the 2012 Central Great Plains Drought," which was put together by a NOAA drought task force led by Martin Hoerling and co-leads Siegfried Schubert and Kingtse Mo and released on March 20, 2013. For many, this was the first drought of significance since the 1988 drought, and the way it developed caught many unprepared. Assessing what happened, how the drought developed, what impacts were experienced, and how states responded will all help in mitigating the impact of future drought events.

Photo by Martin N. Culik

Drought stressed corn in Jefferson County, Illinois on June 28, 2012.

Section 2: Regional Drought Perspective

Natalie A. Umphlett, High Plains Regional Climate Center
Michael S. Timlin, Midwest Regional Climate Center
Brian Fuchs, National Drought Mitigation Center

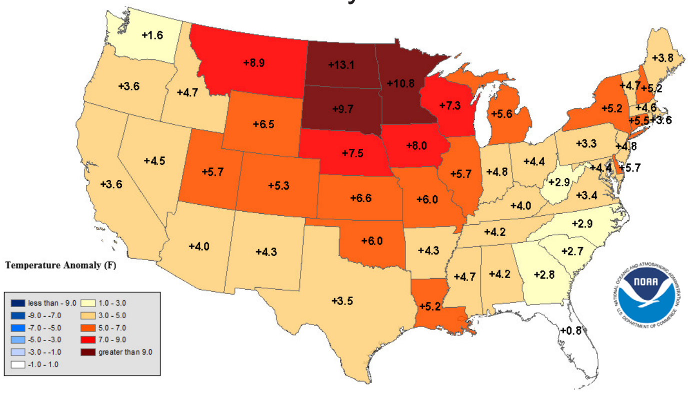
Conditions leading into 2012 gave scant indication of what was to come for the central United States, a 15-state region extending from Colorado, Wyoming, and North Dakota on the west to Kentucky, Ohio, and Michigan on the east. Extreme drought (D3) was limited to some counties in southwest Kansas, the northernmost border of the southern Plains drought of 2011. Severe drought (D2) also extended westward into southeast Colorado and eastward into a few southeast Kansas counties. Another pocket of severe drought (D2) had emerged in northwest Iowa and parts of Minnesota because of dry conditions in the latter half of 2011. Some moderate drought (D1) surrounded the areas of severe drought, but much of the remaining region was free of drought. In fact, the Ohio River Valley states (Indiana, Ohio, and Kentucky) all recorded statewide annual precipitation records in 2011. Some locations along the Ohio River received 60 to 70 inches (1,524 to 1,778 mm) of precipitation. Soils in the southeastern half of the Midwest were saturated. Much of the High Plains (extending northward from northern Kansas and northeast Colorado) also recorded above-normal precipitation in 2011. Record snowfall in the Rockies coupled with extremely heavy rainfall contributed to the Missouri River flooding that lasted for months into the summer of 2011. Drought conditions at the end of 2011 and into 2012 were not widespread in the region. In January 2012, only 15.82% of the study area was experiencing drought, according to the U.S. Drought Monitor. The majority of the drought was in two main areas, the first including Iowa, Minnesota, Nebraska, South Dakota, and North Dakota. The second region was in Kansas and Colorado. The only extreme drought (D3) identified at this time was in extreme southern Kansas and only represented a little more than 1% of the region.

Photo by Jim Angel

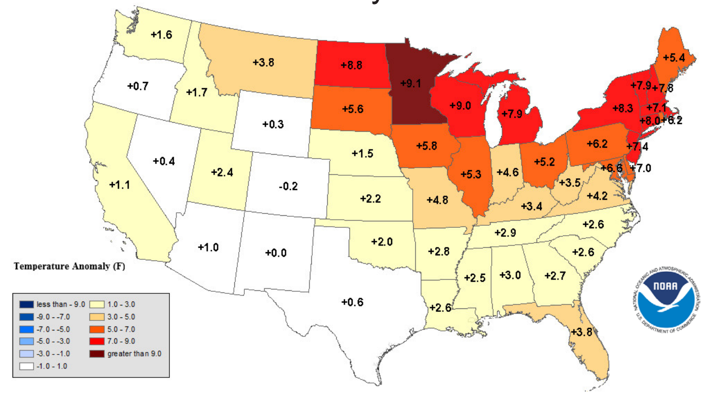
Lake Decatur in Illinois August 24, 2012.

Statewide Temperature Anomalies

January 2012

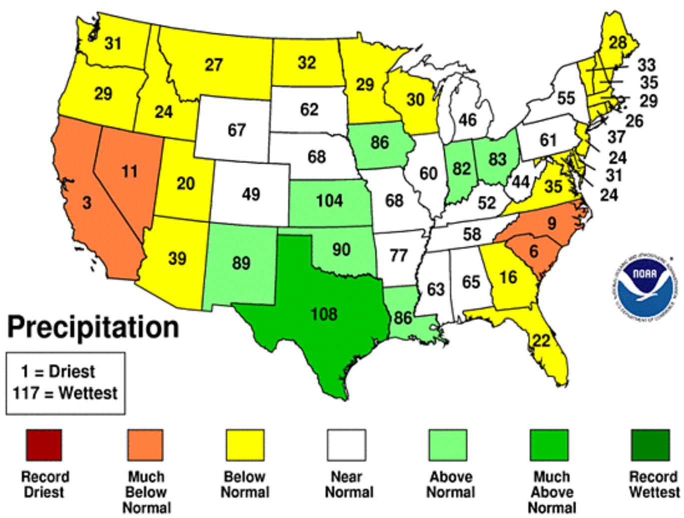


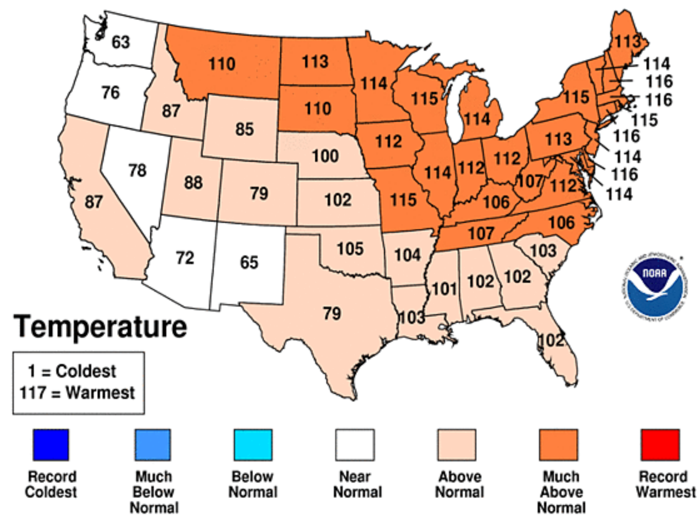
February 2012



Courtesy National Climatic Data Center

Dec 2011 - Feb 2012 Statewide Ranks

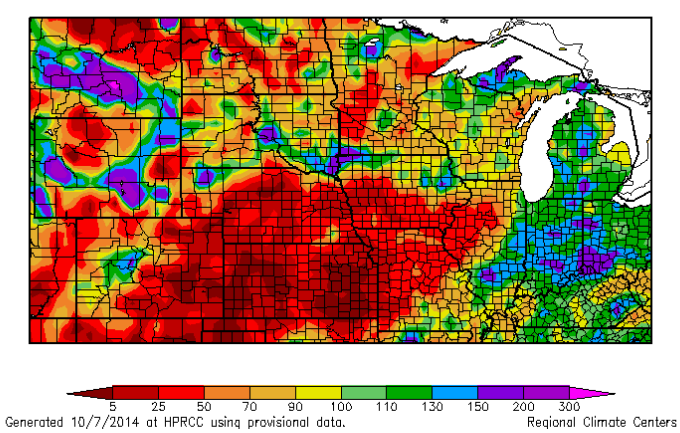




Courtesy National Climatic Data Center

Percent of Normal Precipitation

1/1/2012 - 1/31/2012



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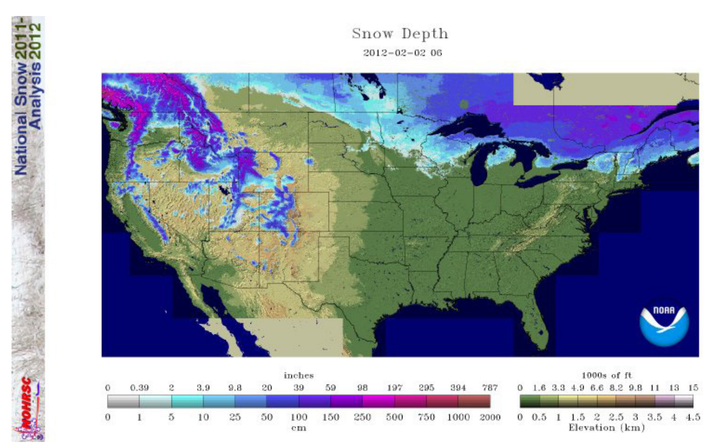
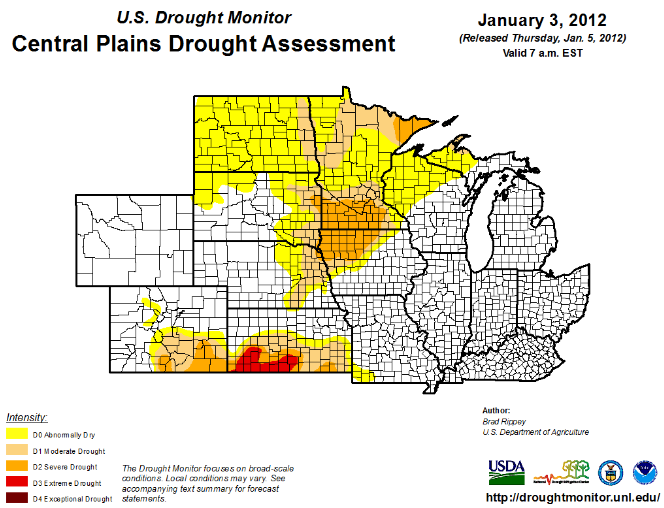


Courtesy National Operational Hydrologic Remote Sensing Center

The winter season of 2011-2012 was strongly influenced by a positive Arctic Oscillation, which is correlated with warm winter conditions. After a warm start to the winter in December, the pattern continued in January, with statewide temperatures ranking among the top 25% of years on record dating to 1895. The warmth was most pronounced in the Plains and western Midwest, where rankings were among the warmest 10%. Minot, North Dakota (with records extending back to 1948), recorded its warmest January temperature on the 5th, when the mercury hit 61°F (16.0°C). Temperatures were as much as 12-15°F (6.7-8.3°C) above normal in parts of the Dakotas. Precipitation was above normal to the east of the Mississippi River, generally below normal to the west, and well below normal in Kansas and Nebraska. With warm temperatures in December and January, especially in northern areas, the snow totals and snowpack were below normal. Near the Great Lakes, many locations were up to two feet (61 cm) below normal for December and January snow totals. January did have a slight expansion of drought in the region. The month ended with 21.69% of the area in drought compared to 15.82% at the beginning of the month. The increase in coverage was mainly over portions of Wyoming, Colorado, and Minnesota.



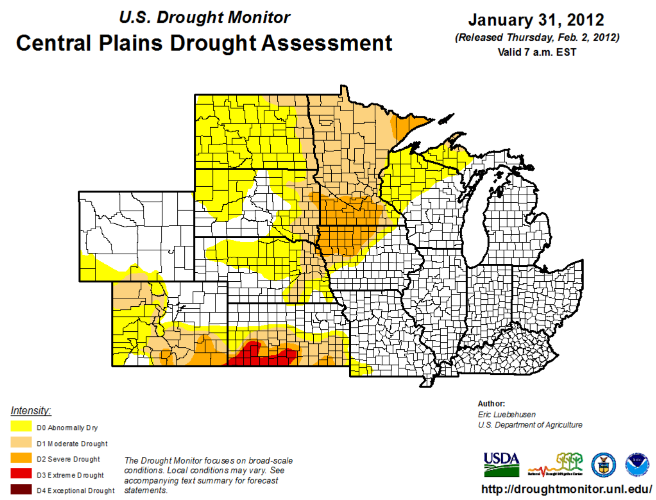


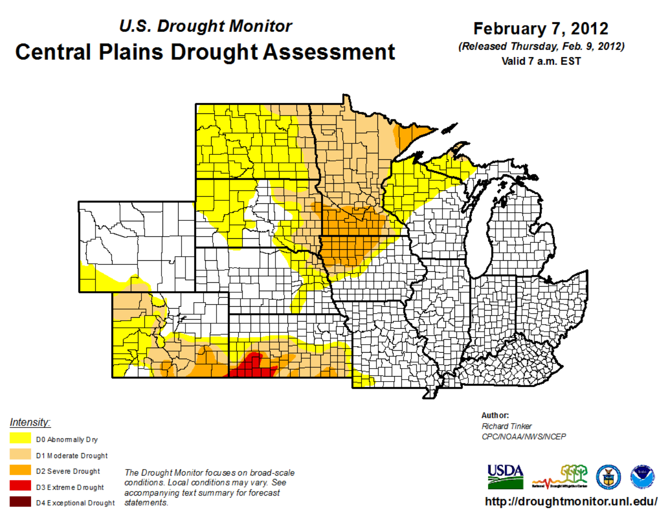
Photo by Martin N. Culik

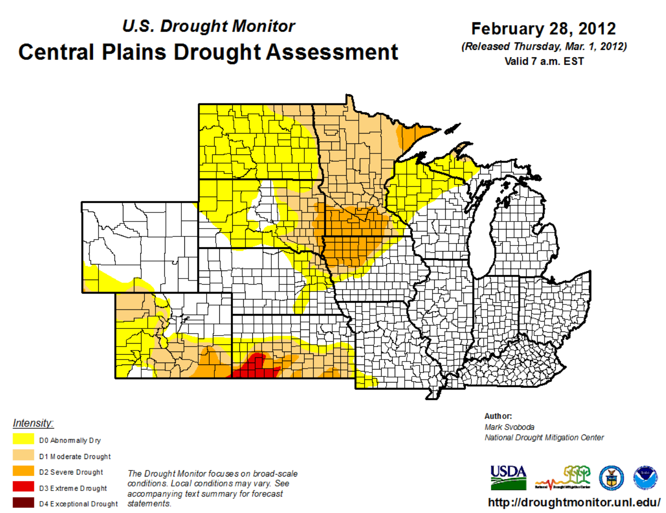
Drought stressed corn with leaves burning and rolling in Jefferson County, Illinois on July 11, 2012.

Photo by Jim Angel

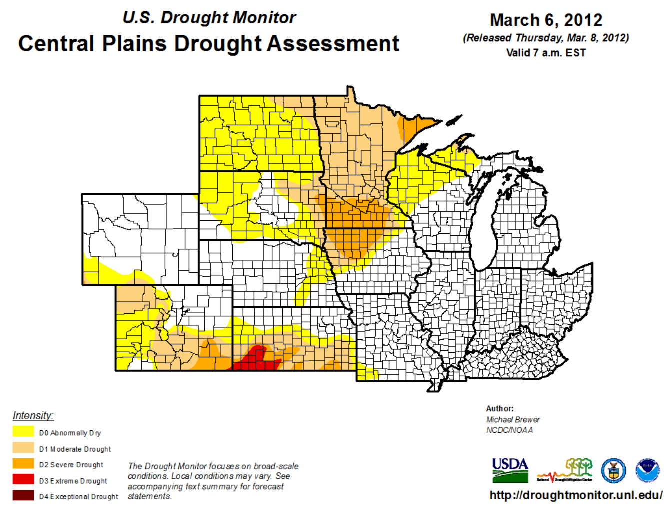
Farm pond drying up August 9, 2012.

February 2012 brought some welcome snow to the northwest of a Colorado-to-northern-Wisconsin line. However, snow totals for the winter of 2011-2012 in the contiguous United States still ranked as the lowest in more than 20 years. Warm conditions in February were centered on the Great Lakes, with near-normal temperatures in Colorado and Wyoming. The states east of Colorado and Wyoming all were continuing a string of 3 or more months of above-normal temperatures. Thin ice on lakes that are typically frozen solid led to incidents in the upper Midwest where people or vehicles fell through the ice. Precipitation patterns in February flipped the January pattern, with above-normal precipitation, including several winter storms, west of the Mississippi River and drier-than-normal conditions east of the river. The season wrapped up with much warmer than normal temperatures extending across nearly the entire region, excluding only four states in the southwest part of the region that still recorded above-normal temperatures. Precipitation was a mixed bag from month to month, with winter totals running the lowest along the Canadian border and increasing for some of the states farther to the south. The overall drought situation of the area stayed the same in February. February began with 21.01% of the region in drought and ended with 20.99% in drought.





March 2012 was most notable for the extremely warm temperatures across the region. A strong ridge formed and persisted over the eastern part of the continent mid-month, bringing record warmth to the eastern two-thirds of the United States. Statewide records (1895-2012) were set in 13 of the 15 states in this study. Only North Dakota and Colorado, which recorded their second warmest March, fell just short of their records. Statewide temperatures were more than 10°F (5.6°C) above normal in each state in the region except Colorado and Wyoming. Cities across the region also set new March records and in many cases broke old records by significant margins. For example, Madison, Wisconsin (with records extending back to 1871), broke the old city record by 4.9°F (2.7°C) and set several daily records. Record highs during the mid-month peak of the heat wave were set on eight of nine days, and on March 21, temperatures peaked at 83°F (28.3°C), which was 38°F (21.1°C) above normal for that date. Thousands of daily records were set across the region during the month. The unseasonable warmth brought conditions similar to late April or early May, causing trees and other perennial plants to break dormancy as much as a month early. The warmest stretch was March 14-24 and was centered over the Great Lakes. Temperatures averaged up to 30°F (16.7°C) above normal for the eleven-day period. During this period, 19 stations in the region, mostly in Minnesota and Michigan, had days where the low temperature topped the previous record high temperature for the day. Records that were set often obliterated the previous record. For example, Bismarck, North Dakota (with records back to 1874), set a new record of 81°F (27.2°C) on March 16, topping the old record by 17°F (9.4°C). Crop insurance rules kept farmers from widespread planting during March despite the favorable soil temperatures. Much of the region had below-normal precipitation, with the driest areas in the Plains. However, even areas in the Midwest that received slightly more rain were subject to drying soils. March is often a time of soil moisture recharge from melting snow, spring rains, and little plant demand for water. March 2012 saw soil moisture levels drop because of scant snow, below-normal precipitation, enhanced plant water demand, and direct evaporation from exposed fields to the warm and windy conditions. Stream flows began dropping in March in response to the declining soil moisture conditions. Overall, the drought status of the region did not change much during the month, actually improving slightly. March began with 20.20% and ended with 19.46% of the region in drought.



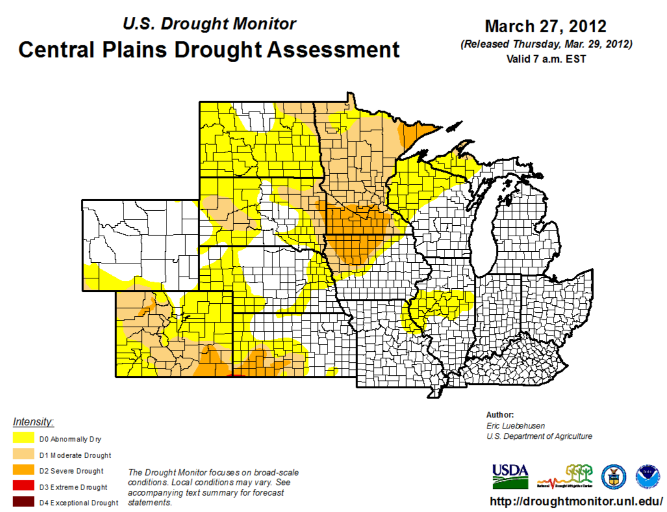
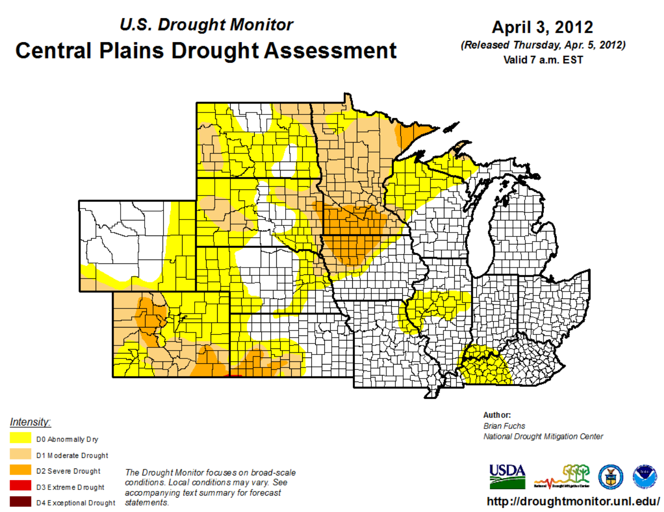
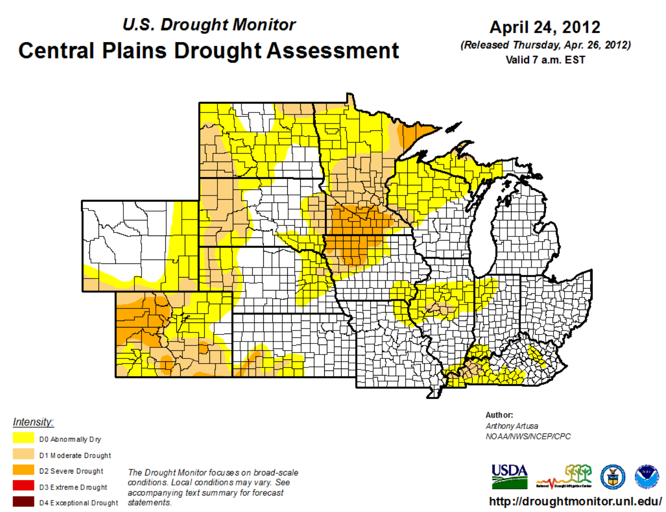


Photo by Wendy Ryan

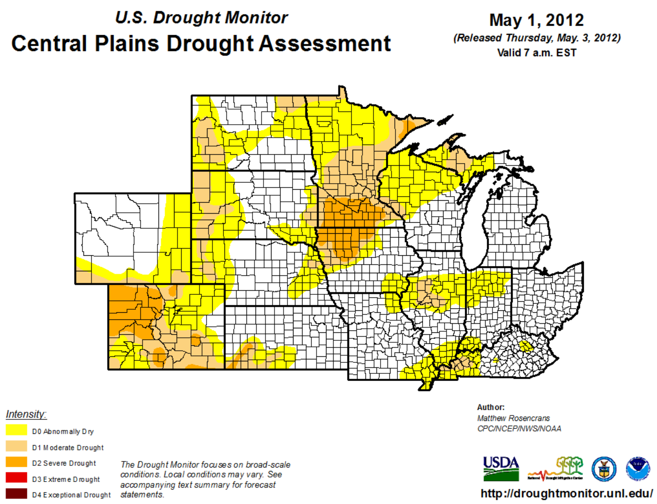
High Park fire from Horsetooth Reservoir west of Ft. Collins, Colorado June 10, 2012.

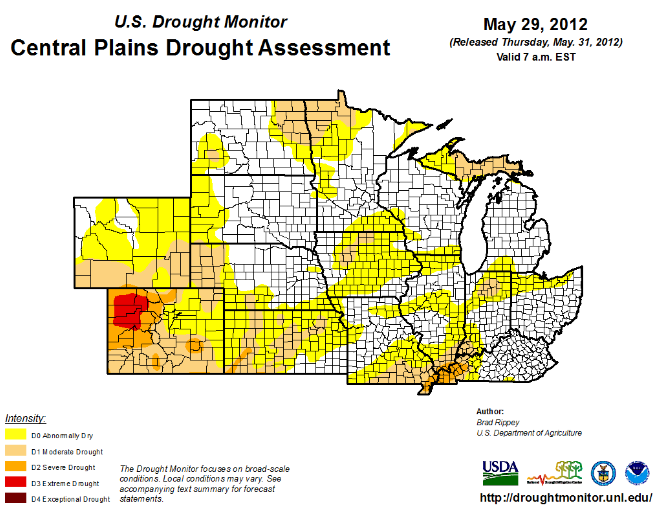
April saw a return to more seasonable temperatures as the ridge weakened, though all states in the region remained above normal. The area of warmest temperatures shifted from the upper Midwest to the Plains. In the six easternmost states, temperatures actually dropped below March's extreme temperatures, reversing the normal seasonal progression, while to the west, temperatures ranked among the top 10% of April values dating back to 1895. Precipitation was above normal in April from Kansas northward to the Dakotas and Minnesota, but precipitation totals fell more than an inch (25 mm) short of normal in the eastern parts of the Midwest. Freezing temperatures spread across the region April 8-12, sparing only Kansas and Missouri. The freeze was not late in the season climatologically, but it was damaging because of the extreme accumulations of degree days much earlier in the season than normal. The seasonality of the climatological conditions did not lead to much change in the overall drought status of the region during April. The month ended with no extreme or exceptional drought (D3-D4) in the region. April began with 21.44% of the area in drought and ended with 21.02% in drought. Some areas of Iowa, Minnesota, and Colorado were being hampered by severe drought (D2) conditions, but it only made up 5.84% of the region by the end of the month.





May marked the third month in a row that all states in the region recorded above-normal temperatures. In fact, only Colorado and Wyoming had below-normal temperatures in February, while all other statewide average temperatures were above normal for the first five months of 2012. The warmest areas in May extended from Kansas to Ohio, with temperatures at

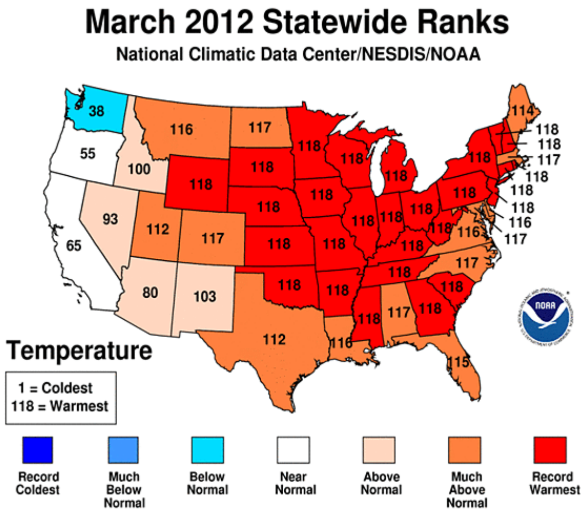


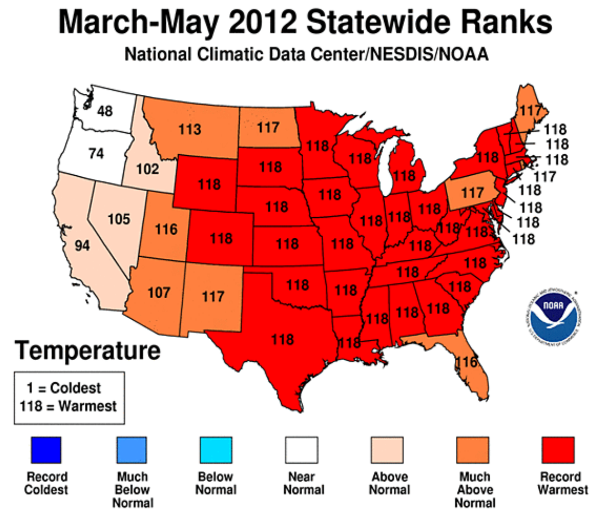


least 5°F (2.8°C) above normal. Only the states in the northwest part of the region (Wyoming, Nebraska, North and South Dakota, and Minnesota) fell outside the top 10% of the warmest Mays on record. The earliest 100°F day (37.8°C) on record for Scottsbluff, Nebraska (period of record 1893-2012), was recorded on May 22. Typically the first such day is in early July. The ridge of warm temperatures pushed most of the precipitation to the north as systems tracked over the ridge. Plentiful rains extended from northwest Iowa across Minnesota and into parts of Wisconsin.

Elsewhere, rain totals dropped off significantly. Colorado, Kansas, and Missouri ranked among their driest 10% for May precipitation on record. Precipitation totals in much of this area were less than 50% of normal for the month. The continued warmth and relatively dry conditions over much of the region continued to diminish available soil moisture. Drought conditions worsened, especially in Colorado and near the confluence of the Ohio and Mississippi rivers. There was some improvement in northwest Iowa and southern Minnesota where the May rains were concentrated. The U.S. Drought Monitor started to show degradation and intensification during May. The month began with 18.97% of the region in drought and ended with 21.55%. Extreme drought (D3) was also introduced into the area during May in northwestern Colorado, representing a little more than 1% of the region as a whole.

Spring 2012 (March to May) was most notable for the extreme warmth across the region. March was a record breaker, with records being obliterated on time scales ranging from daily to monthly. April and May were more moderate but still recorded above-normal temperatures in all states in the region. The persistent and widespread warmth along with the intensity of the March warmth led to spring temperature records for 14 of the 15 states in this study. North Dakota recorded its second warmest spring season and was within 1°F (0.6°C) of its record. The remaining states ranged from tying the old record (Colorado and Wyoming) to topping the old record by 3.8°F (2.1°C) (Kansas). Precipitation totals in the spring ranged from above normal in the north to below normal in the south and east. Minnesota recorded its third-wettest spring while Wyoming (third), Colorado (fourth), and Indiana (ninth) all ranked among the ten driest on record. The pattern of wet and dry areas was a reversal of the pattern seen in the winter. Spring snowpack was below normal across the region for March, April, and May. The warmth and early spring emergence contributed to the drying soils throughout the spring. Many records were set for the earliest dates on record for specific temperatures as well as the number of days above a threshold. Chicago, Illinois (period of record 1871-2012), set a record for the most 80°F (26.7°C) days in March with eight days. This easily topped the old March record of two days and even matched the record for April in Chicago. Another 14 days in May topped the threshold, ranking it second most for a spring as well. Chicago's March temperatures would even have ranked as the seventh warmest April on record.





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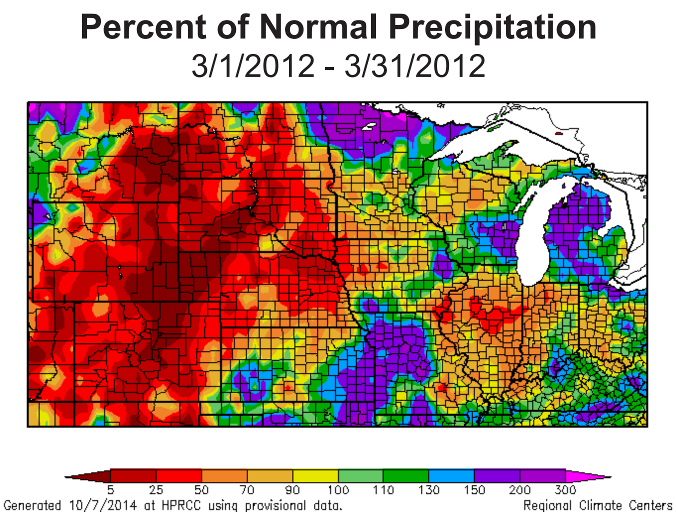
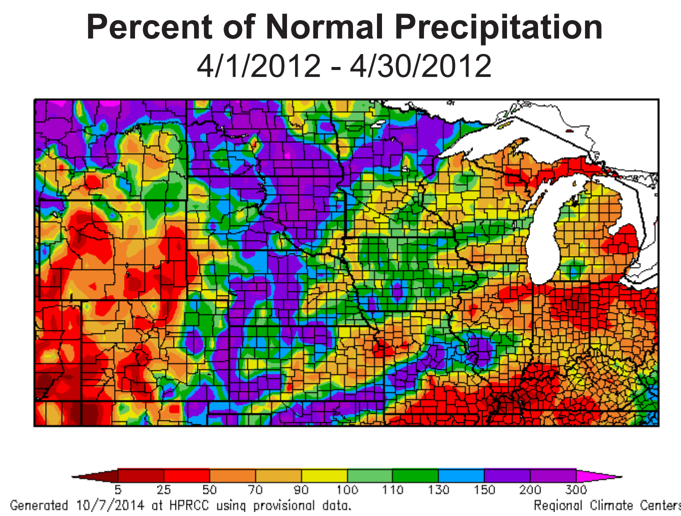
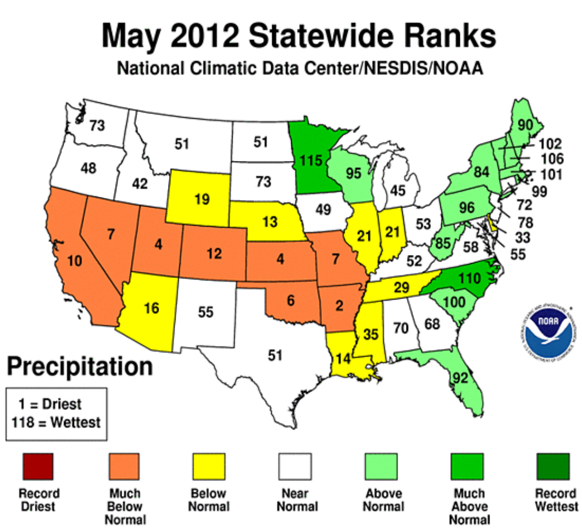




Courtesy High Plains Regional Climate Center



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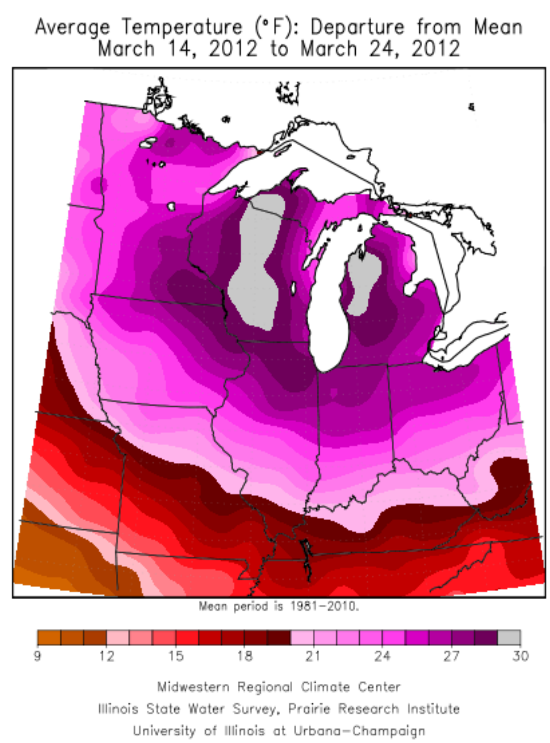
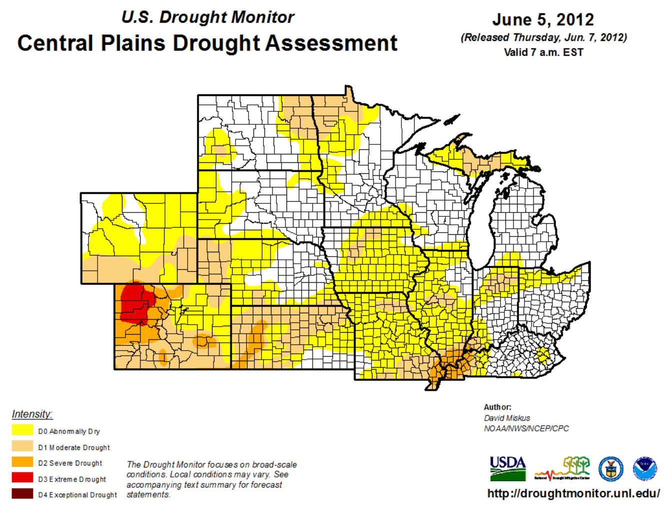
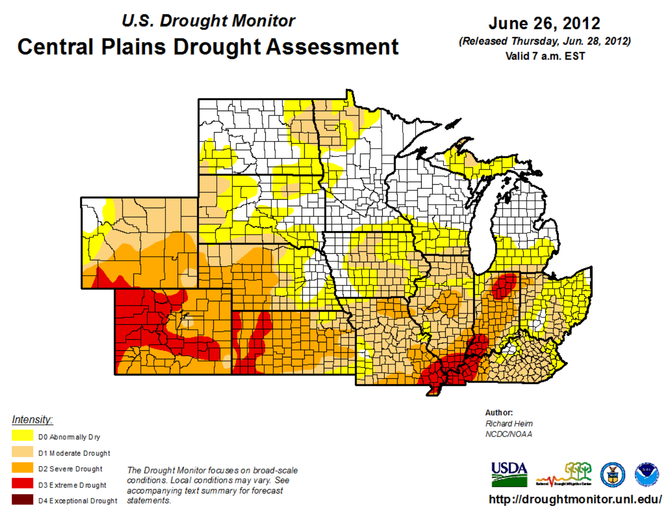


The persistent ridging pattern allowed for a continuation of hot and dry conditions into June. Extreme heat really took hold toward the end of the month as the strong ridge caused an extreme heat wave to form over the Plains. This heat wave subsequently expanded into the Midwest, bringing some of the hottest temperatures recorded in decades (and in some cases, of all time). More than 1,500 new record daily high temperatures were set in June in the central U.S. For example, McCook, Nebraska, recorded an all-time high of 115°F (46.1°C) on June 26. The old record of 114°F (45.6°C) was set on July 20, 1932 (period of record 1909-present). These hot and dry conditions also caused the drought to expand and intensify in both the Plains and the Midwestern states. By the end of the month, extreme drought conditions (D3) had either expanded or developed throughout Colorado, western Kansas, northeastern Indiana, the area around the bootheel of Missouri, southern Illinois, southern Indiana, and western Kentucky. In the end, average monthly temperatures were 6.0-8.0°F (3.3-4.4°C) above normal in the west to near normal in the east. Colorado had its warmest June on record, while surrounding states ranked in the top 10 warmest. Although there was a clear contrast in monthly average temperatures between the eastern and western parts of the region, the precipitation rankings showed that the majority of the region was dry. Wyoming had its driest June on record, while Colorado (second), Nebraska (fourth), Missouri (sixth), Illinois (eighth), Indiana (third), and Kentucky (fourth) all ranked in the top ten driest. Many impacts of the emerging/intensifying drought were becoming clear in June. Dangerous fire weather conditions were present in Colorado, Wyoming, South Dakota, and Nebraska, and the most destructive wildfire in Colorado's history occurred when nearly 350 homes burned in the Colorado Springs area. Corn and pasturelands began to take a hit when continuing soil moisture reductions were combined with the extreme heat. The drought that had been slowly developing really took over across the region in June. The month began with 24.65% of the area in drought and ended with 56.24% in drought. The drought intensification was also notable as June ended with a little more than 9% of the region in extreme drought (D3), mainly centered over portions of Colorado, Kansas, Wyoming, Missouri, Illinois, Kentucky, and Indiana.





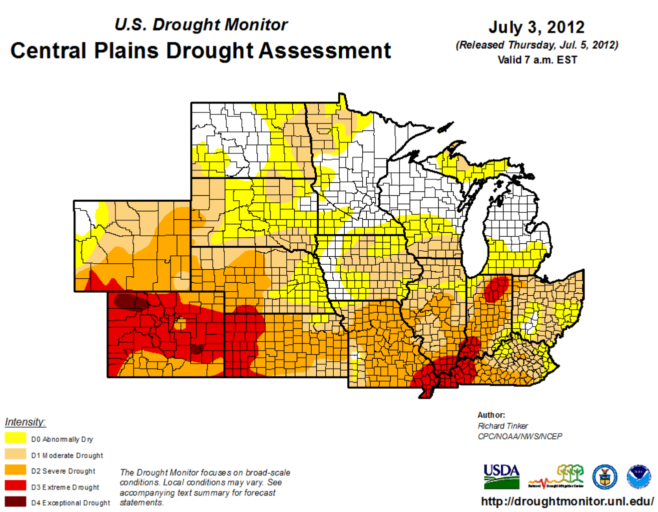
July was another hot and dry month as the ridging pattern continued and led to rapidly expanding drought conditions. The dominating high pressure prohibited the formation of pop-up thunderstorms and kept cold fronts well to the north of the drought-stricken area. Temperatures were well above normal across the region, with large areas of Illinois, Indiana, Iowa, Kansas, Nebraska, South Dakota, and Wisconsin having temperature departures of 6.0-8.0°F (3.3-4.4°C) above normal. Every state in the region ranked in the top 10 warmest Julys on record and, just as in June, many individual locations had their warmest July on record. Denver, Colorado, actually had its warmest month ever recorded with 78.9°F (26.0°C)—hotter than any month during the Dust Bowl years. The old record occurred in July 1934 with 77.8°F (25.4°C). The dearth of precipitation also led to many record low

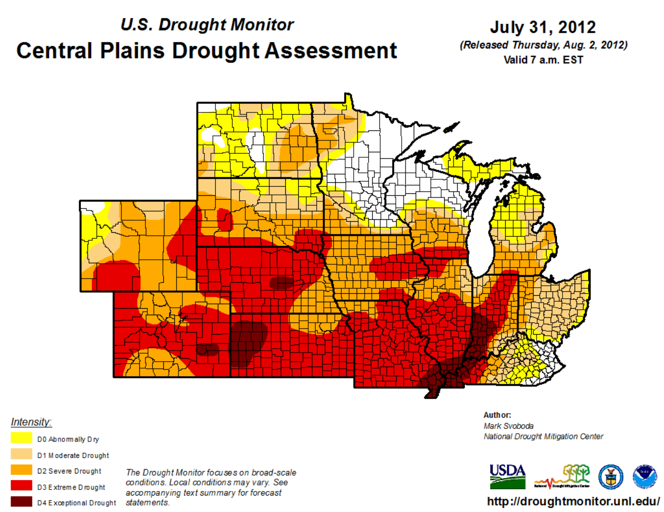
Photo by Tim Baker

Corn in the Grand River flood plain showing effect of drought east of Gallatin, Missouri on July 31, 2012.

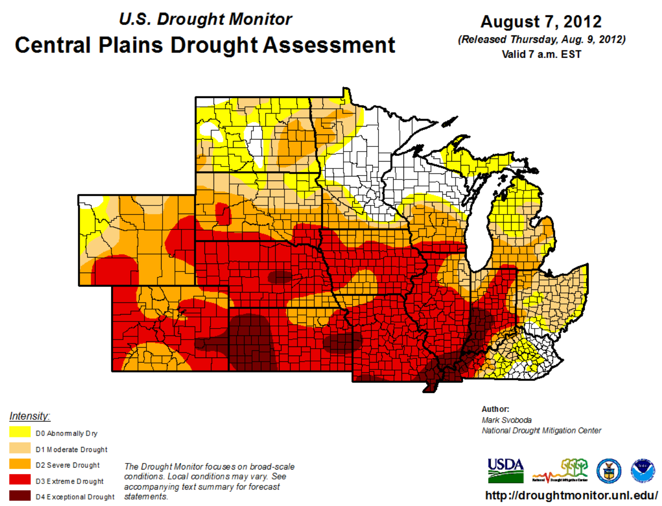
precipitation totals in July. Most of the middle portion of the study region barely picked up 50% of normal precipitation, which in most cases meant an added deficit of 3 inches (76 mm) or more. In addition, some stations did not receive any measurable precipitation. One such site was Atlantic 1 NE, Iowa, which only picked up a trace amount of precipitation and set its driest July on record (period of record 1893-2012). The old record was set in 1975 with 0.43 inches (11 mm). States in the core areas of the drought were much drier than normal, with Nebraska, Iowa, and Illinois having their second, third, and fourth driest Julys on record, respectively. July's extremely hot and dry weather led to various impacts across the region, including soil moisture depletions, fires, low stream flows, low pond and lake levels, and crop and pastureland degradation.

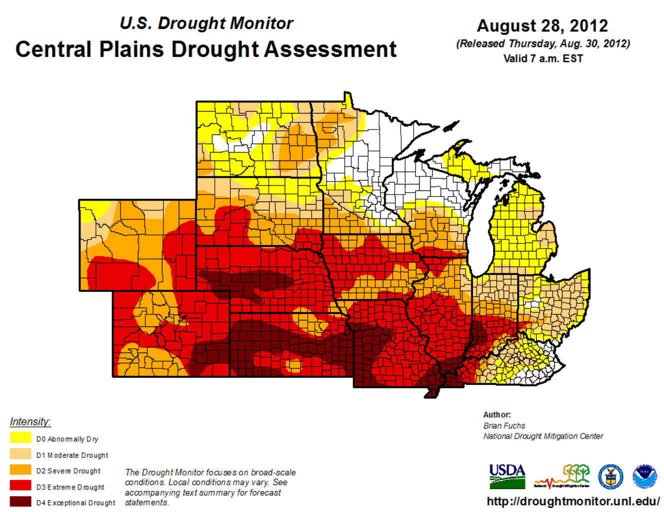
According to the USDA agriculture statistics reports, by the end of the month, 88% of all corn, 87% of all soybeans, 64% of all hay acreage, and 72% of all cattle in the United States were within an area experiencing drought—most of which was occurring in the central U.S. Drought conditions continued to develop and expand during July, with slightly more than 79% of the region in drought at the end of the month compared to 63.33% at the beginning of the month. The drought also intensified greatly during July as the area in extreme drought (D3) increased from 13% to 40.12% and exceptional drought (D4) increased from 0.57% to 4.48%. D4 drought was indicated in western Kansas, eastern Colorado, and along the Ohio River Valley and into the bootheel of Missouri.





August was the first month in nearly a year that average temperatures were below normal for a significant portion of the region. The persistent ridge finally started to break down a bit, which allowed for the cooler conditions. Unfortunately, precipitation continued to be sparse, especially across the western half of the study area, with some areas of Wyoming, northeastern

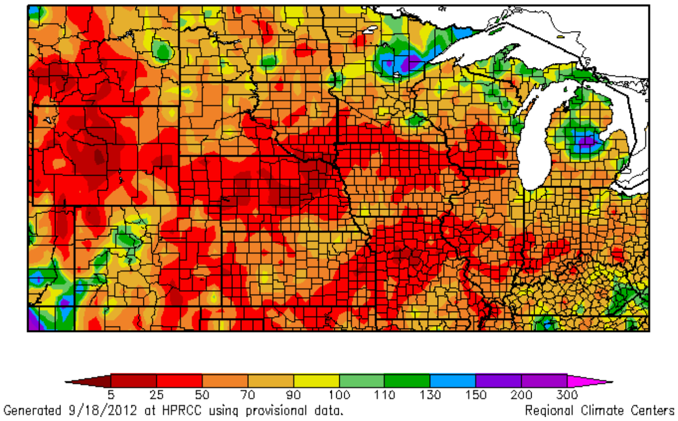




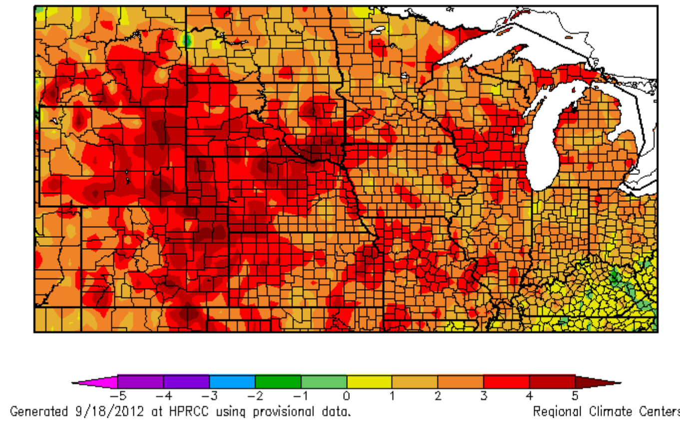
Colorado, and the panhandle of Nebraska receiving less than 5% of normal precipitation. Scottsbluff, Nebraska, and Colorado Springs, Colorado, recorded their driest August. Some areas did manage to pick up normal to slightly above normal precipitation during the month, including central North Dakota, central Kansas, and a swath running from southern Missouri to the northeast through central Michigan. Despite precipitation in these drought-stricken areas, the U.S. Drought Monitor only indicated slight improvements. Additionally, at that point in the growing season, many of the crops did not benefit from the precipitation. The overall drought status of the region improved slightly during the month as August ended with 76.84% of the region in drought, compared to 79.17% at the beginning of the month. The area in extreme drought (D3) stayed the same during the month, but exceptional drought (D4) increased from 6.86% to 11.07%.

Overall, the summer of 2012 was hot and dry across the region, and drought conditions developed and expanded quickly during this time. Two separate regions of extreme drought conditions (D3) developed early in the season—one in western Colorado and the other around the borders of Missouri, Illinois, Kentucky, and Indiana. As the summer progressed, conditions deteriorated and spread to eventually encompass an area of extreme to exceptional drought (D3-D4) stretching east/west from Utah all the way to Indiana and north/south from Texas to South Dakota. Every state in the region had above-normal average temperatures and most states had well below normal precipitation. Wyoming and Colorado had their warmest summer on record, but Wyoming and Nebraska had their driest summer on record. Many other states in the region experienced summers that ranked in the top 10 warmest and driest summers on record. As for individual stations, every single station across the region had above-normal temperatures, except for a few in eastern Kentucky that were slightly below normal. Thousands of records on all sorts of time scales, including daily, monthly, and seasonal, were set over the summer months. Some records were quite interesting, including one in Denver, Colorado, where a new record for number of days at or above 100°F (37.8°C) was set. Denver racked up 13 days at or above 100°F (37.8°C) this summer, which was nearly double the previous record of 7, set in 2005 (period of record 1872-present). In most years, Denver has none.

Percent of Normal Precipitation
6/1/2012 - 8/31/2012

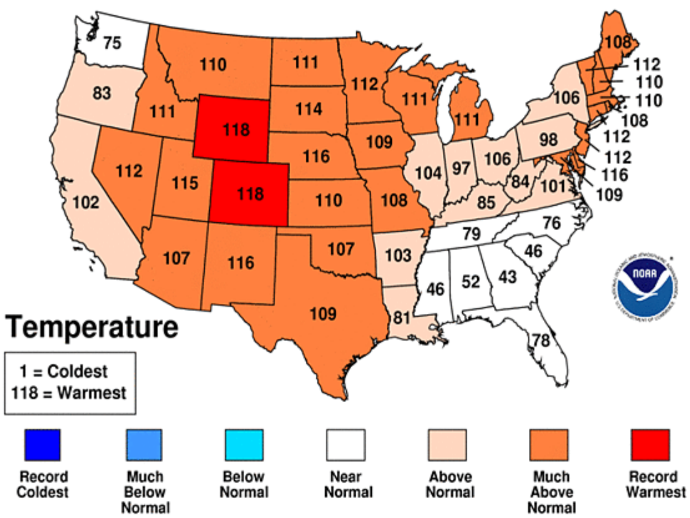


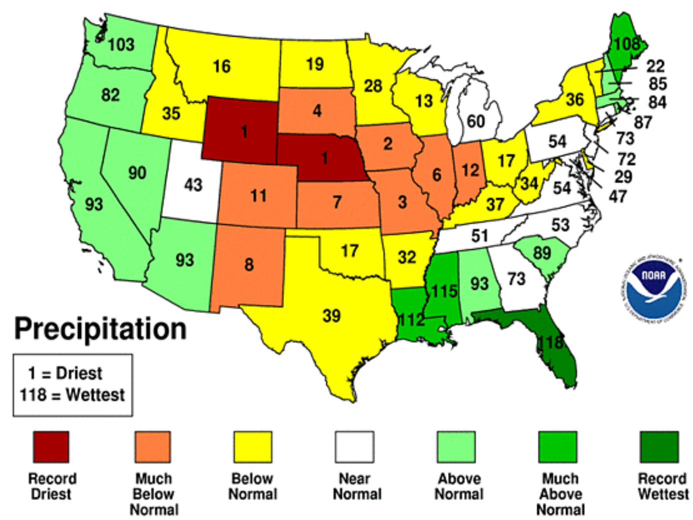
Departure from Normal Temperature
6/1/2012 - 8/31/2012



Courtesy High Plains Regional Climate Center

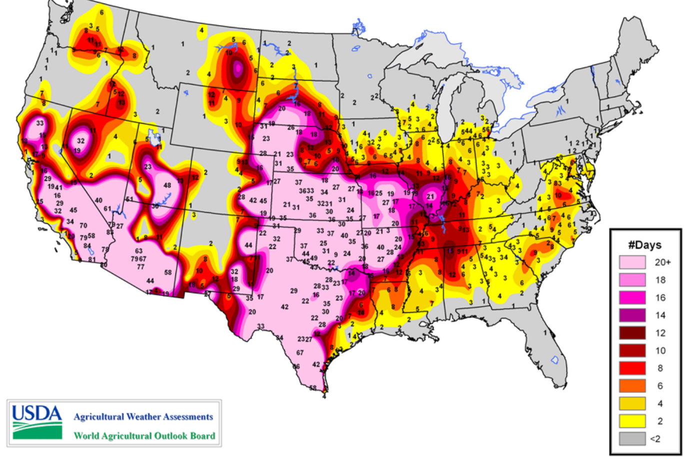
June-August 2012 Statewide Ranks
6/1/2012 - 8/31/2012





Courtesy National Climatic Data Center

Number of Days >=100ºF
6/1/2012 - 8/31/2012

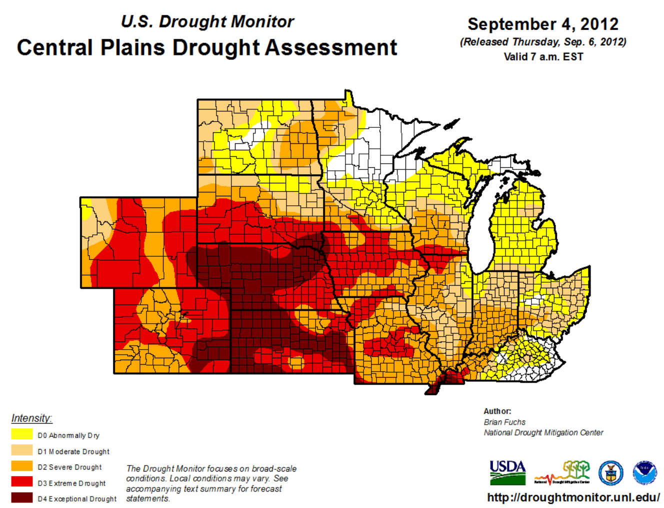


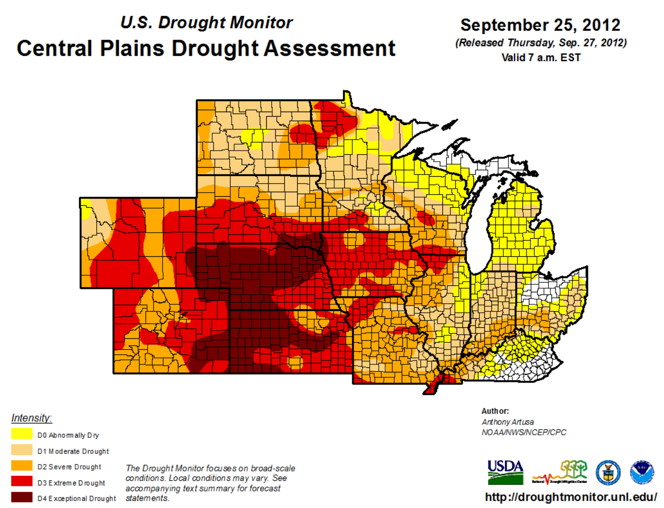
Courtesy U.S. Department of Agriculture

September brought major changes to the drought situation—some for better and some for worse. Hurricane Isaac made landfall on August 28 in Louisiana, and the remnants of this slow-moving storm brought heavy rains to the central Midwest over the Labor Day weekend. Because this storm was slow to exit the region, the rains were able to soak into the ground instead of just running off, which resulted in a significant improvement to the drought conditions in Illinois, Indiana, Kentucky, and Missouri. On a state level, the largest improvements occurred in Missouri, which went from 99% of the state in extreme to exceptional drought (D3-D4) coverage to a complete erasure of exceptional drought (D4) conditions. Only 17% of the extreme conditions (D3) remained at that time. Meanwhile, the situation in the Plains states was quite the opposite. The exceptional drought conditions (D4) in Colorado, Kansas, and Nebraska continued to expand and ultimately spread into eastern Wyoming and southeastern South Dakota. Nebraska was the hardest-hit state during this period as the exceptional drought coverage (D4) increased from 23% to 71% of the state in one week alone (August 28 to September 4). In the end, monthly average temperatures were generally near normal, with the western half of the study area at near to slightly above normal and the eastern half at slightly below normal. There was, however, quite a contrast in the precipitation totals across the region. Much of Illinois, Indiana, Kentucky, and Ohio had precipitation totals of at least 150% of normal. South central Illinois even had totals greater than 300% of normal. Meanwhile, a huge area encompassing most of Wyoming, Nebraska, the Dakotas, Minnesota, Iowa, Wisconsin, and a portion of Michigan had an extremely dry month, with the vast majority of locations receiving less than 50% of normal. Statewide rankings indicated that Minnesota, North Dakota, and South Dakota had their driest September on record. In addition, Nebraska had its third driest September. Meanwhile, Kentucky and Ohio ranked in the top ten wettest. The drought continued to expand as 83.36% of the region was in drought at the end of September compared to 77.74% at the beginning of the month. Extreme drought (D3) increased slightly, from 37.88% to 38.32% of the region, while exceptional drought (D4) decreased slightly.

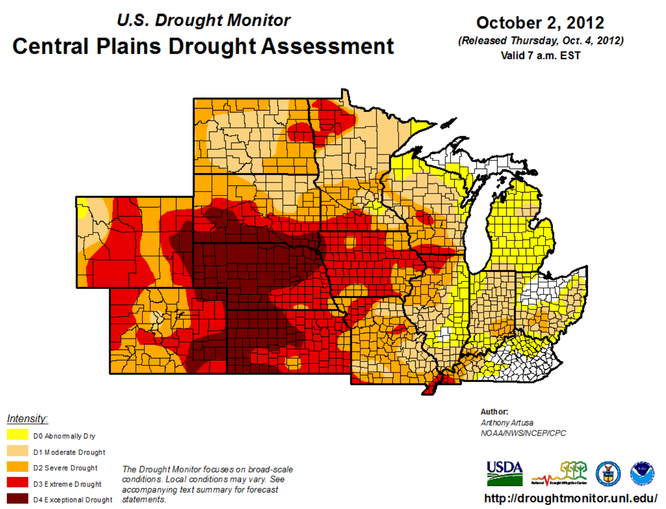
Photo by Mark Nunnery

Dewitt County, Illinois cornfield, September 6, 2012





In October, the core area of the drought continued to be over the western part of the study region, including Colorado, Kansas, Nebraska, South Dakota, and Wyoming, while areas to the east continued to improve. October temperatures were below normal for the majority of the region except for portions of Colorado and Wyoming. Precipitation, however, was quite varied. Above-normal precipitation was found in northern North Dakota and also a swath running from Iowa and Missouri into Illinois, Wisconsin, Indiana, Michigan, and Ohio. This precipitation helped improve the drought conditions in those states. Most notably, Indiana made tremendous improvements in October. At the beginning of the month, 77% of that state was in the moderate to severe drought categories (D1-D2), but by the end of the month, all severe drought conditions (D2) had been eliminated and only 7% of the state remained in moderate drought (D1). Likewise, all extreme drought conditions (D3) were downgraded in Illinois and Wisconsin. Even with the precipitation, drought impacts were still being realized as the levels of Lakes Michigan and Huron dropped to near-record lows this month and a dust storm across the panhandle of Nebraska, eastern Colorado, and eastern and central Kansas closed three interstates. Drought conditions elsewhere in the region persisted with little to no change in coverage. In October, the spatial extent of the drought actually peaked during the first week of the month when 84.89% of the region was now experiencing some level of drought. This did decline slightly by the end of the month to 77.26%.



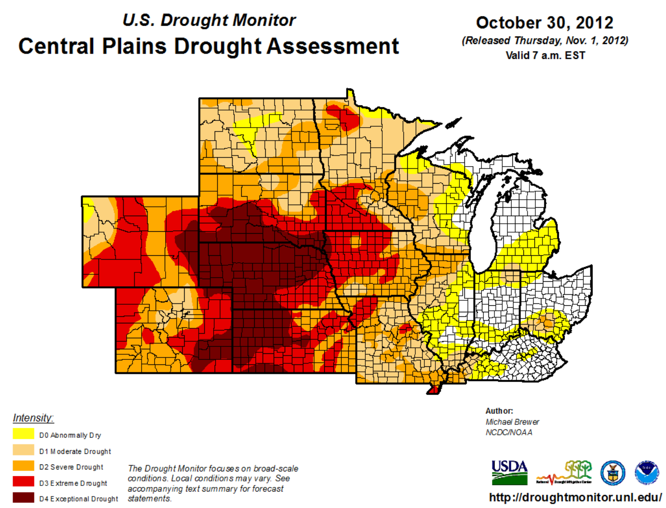
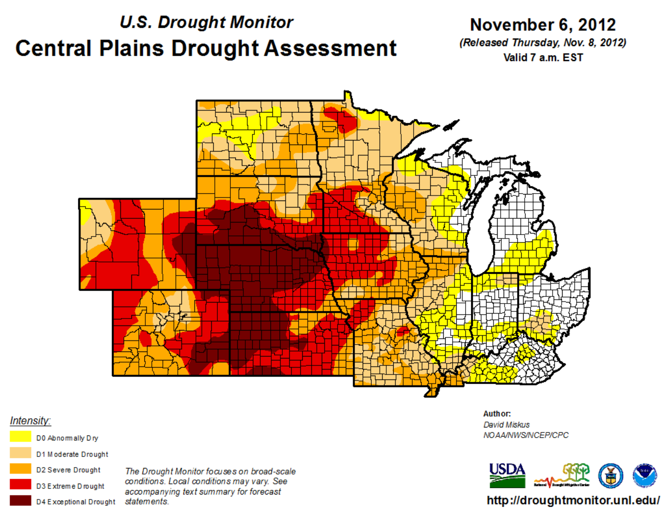


Photo by Douglas Todey

Des Moines River, October 6, 2012

November was largely a dry month across the central U.S. The majority of the region received less than 50% of normal precipitation, and the only areas to receive at least 150% of normal precipitation were northern North Dakota, central Wyoming, and a small section of northern Minnesota and the Upper Peninsula (UP) of Michigan. Temperatures were generally warmer than normal in the west and cooler than normal in the north and the east. Statewide rankings indicated that Colorado had its third warmest November on record, while Wyoming had its ninth warmest. Because of the varying conditions, there were both degradations and improvements in November. Some precipitation fell across an area stretching from central Kansas to the northeast through the UP of Michigan and also from southern Missouri into Illinois and Indiana, which led to one-category improvements. Cooler and wetter conditions also allowed for improvements in North Dakota. Meanwhile, the main area of degradation in the region occurred in Minnesota and northwestern Wisconsin, where rapid declines in soil moisture and stream flow were observed. Even though the harvest season had come to a close, the dry weather continued to have various impacts across the region. Major concerns included the condition of the winter wheat, the replenishment of soil moisture, and fires. The spatial extent of the drought in the region did improve slightly in November and the overall intensity levels also came down a bit. November ended with 74.97% of the region in drought, compared to 76.17% at the beginning of the month. D3 and D4 declined to 33.69% and 13.57%, respectively, compared to 34.42% and 14% at the beginning of November.



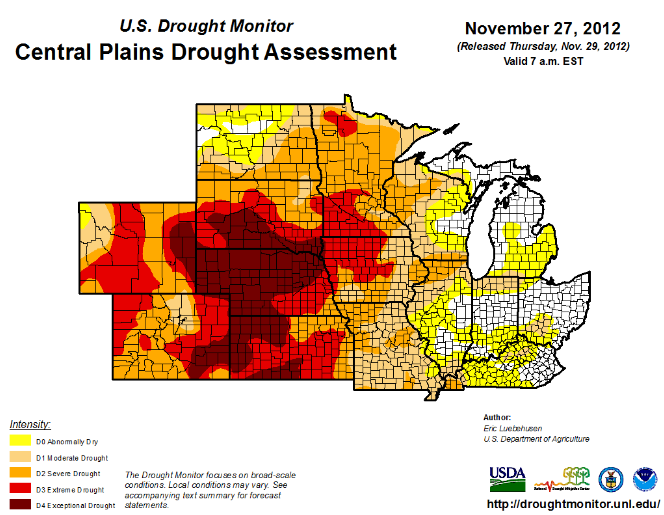
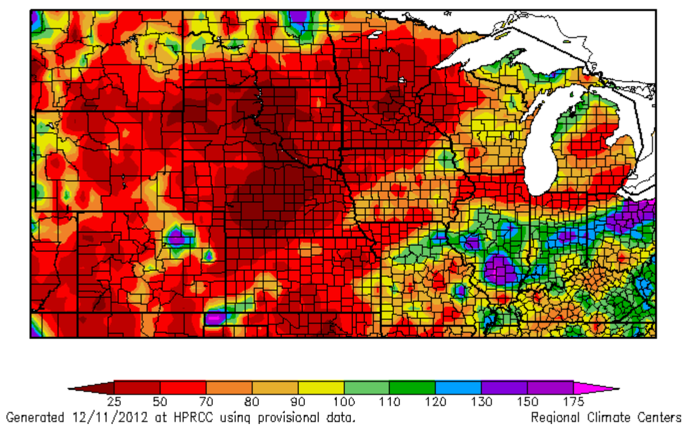


Photo by Ryan Flickner

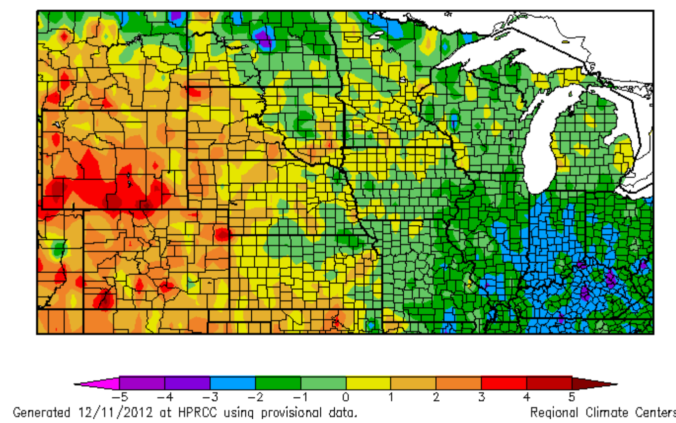
Drought ravaged corn field near Moundridge, Kansas July 19, 2012.

Overall, the fall was a time for improvement in the east and persistence in the west. The region finally experienced relief from the blistering temperatures of the summer and some drought-stricken areas received beneficial precipitation. Average fall temperatures were below normal for much of the northern and eastern areas of the region, while areas to the west were near to above normal. After the remnants of Hurricane Isaac lessened drought conditions in eastern parts of the region, the core of the exceptional drought conditions (D4) remained in Colorado, Kansas, and Nebraska. Improvements were also made in North Dakota where ample precipitation fell. Fall statewide rankings indicate that Nebraska, South Dakota, and Minnesota had their second, fifth, and sixth driest fall on record, respectively. Impacts were varied across the region, especially in the agricultural sector. The dry weather during the fall months provided for an early maturity of crops and resulted in a rapid harvest season, but drought also caused slow winter wheat emergence. According to the USDA, by the end of November, the worst winter wheat ratings since 1985 were taking shape.

Percent of Normal Precipitation
9/1/2012 - 11/30/2012

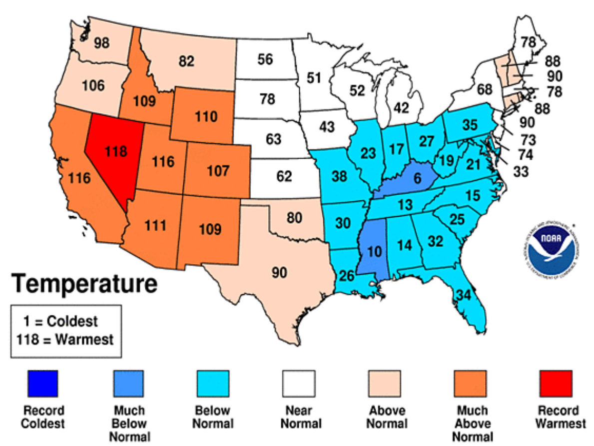


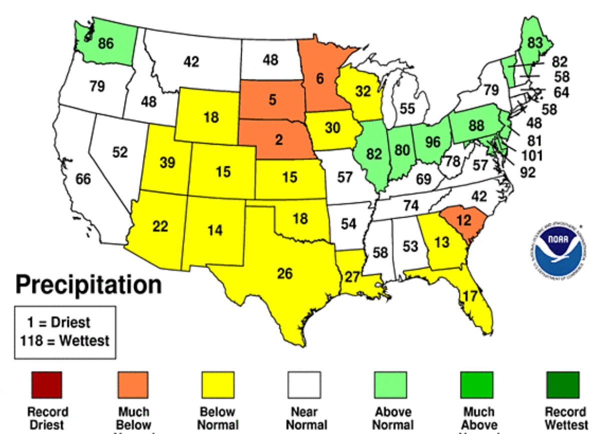
Departure from Normal Temperature
9/1/2012 - 11/30/2012



Courtesy High Plains Regional Climate Center

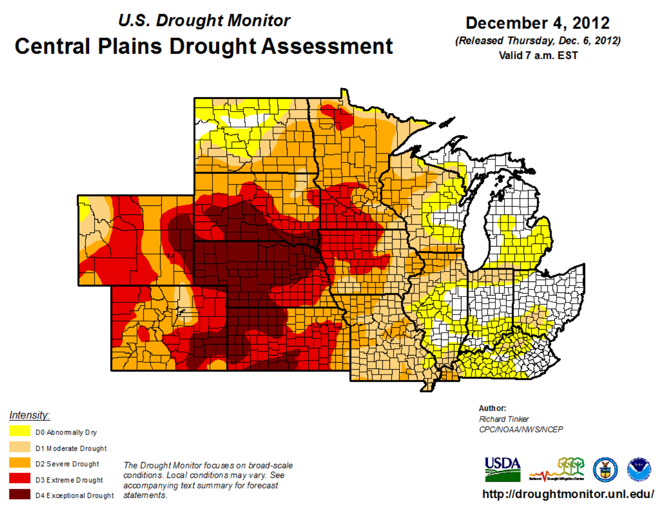
September-November 2012 Statewide Ranks





Courtesy National Climatic Data Center

December brought little change to the drought situation. Impacts to winter wheat and stream flow were still being monitored. The Mississippi River reached a near-record low in December, greatly affecting the shipping industry. Overall, temperatures were generally near normal in the Plains and much above normal in the Midwest, with Illinois (sixth), Indiana (sixth), Kentucky (ninth), Michigan (eighth), Missouri (seventh), and Ohio (ninth) ranking in the top ten warmest Decembers on record. Precipitation was quite varied across the region, although at this time of year (the winter months) even normal or above-normal precipitation is not likely to change drought conditions. As such, few or no changes were made during December and the early part of 2013. The drought status improved only slightly during December, from 75.10% to 74.17%. The year ended with 34.34% of the region in extreme or exceptional drought (D3-D4), mainly over Nebraska, Kansas, Colorado, Wyoming, South Dakota, Iowa and Minnesota.



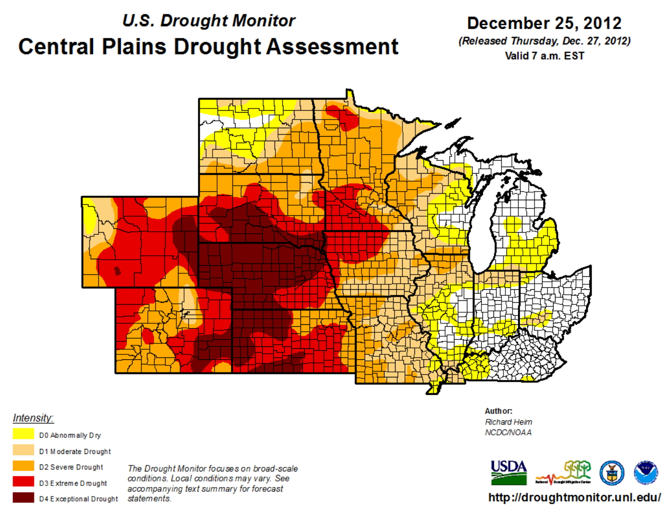


Photo by Jeni Fuchs

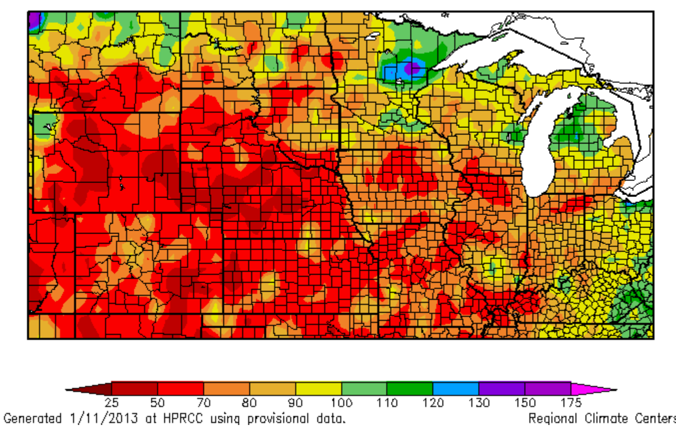
Platte River dried up south of Columbus, Nebraska August 11, 2012.

Photo by Jim Angel

Mississippi River near St. Louis, Missouri July 30, 2012.

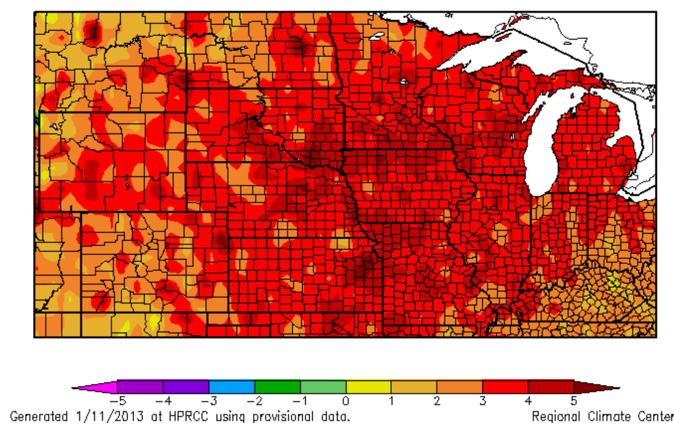
Percent of Normal Precipitation

9/1/2012 - 11/30/2012



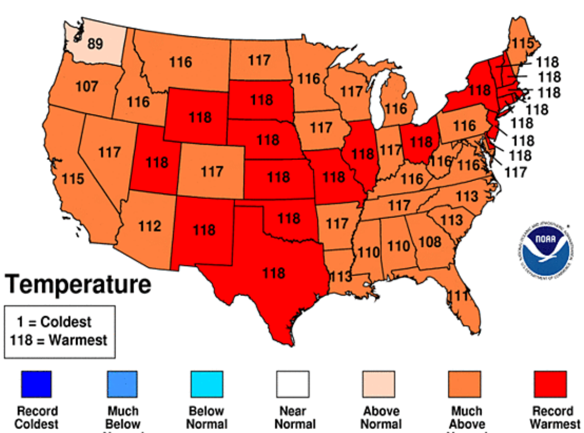
Departure from Normal Temperature

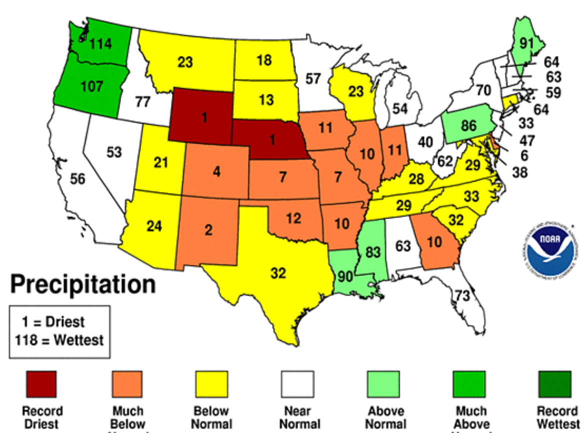
9/1/2012 - 11/30/2012



Courtesy High Plains Regional Climate Center

January-December 2012 Statewide Ranks





Courtesy National Climatic Data Center

Section 3: State Drought Perspectives

Section 3.1: COLORADO

Wendy Ryan and Nolan Doesken
Colorado Climate Center

Introduction

As 2012 began in Colorado, about 50% of the state was already designated in drought, based on the U.S. Drought Monitor. Most of the dry areas were in the Rio Grande and Arkansas basins in south central and southeastern Colorado. These areas had shared in the extreme drought of 2011 experienced over Texas, New Mexico, and Oklahoma. Conditions then gradually deteriorated statewide as winter snow accumulation in all of Colorado's mountainous areas fell well below normal. Starting in February (mainly on the west slope) and March (for much of the rest of the state), temperatures soared well above average and precipitation totals were persistently much below normal. A tenuous situation quickly worsened. April and May also brought widespread above-average temperatures and below-average precipitation. Snowpack melted much earlier than usual, and stream flow response was limited.

By the end of May 2012, all of the state was in classified in drought, including the mountainous areas that supply roughly 80% of the state's water supply. Despite very wet weather in 2011 across northern Colorado and high stream flows just one year before, river levels all dropped precipitously. Stream flows were only slightly better than during the extreme drought years of 1934, 1954, 1977, and 2002. The timing of these conditions in the spring created large deficits at the worst possible time of year and dried out soil moisture during the critical planting time of year. A dry spring on the plains coupled with low snowpack in the mountains set the stage for the widespread drought experienced in 2012. By June, vegetation was already brown. Temperatures soared in June, especially over the eastern half of the state, to levels not seen since the extreme drought and heat waves of two notable historic drought years, 1954 and 1934. Temperatures climbed well over 100°F on many days. Denver and Colorado Springs both set daily and all-time records, and the all-time state record high temperature of 114°F was matched at Las Animas, in southeastern Colorado. Reference evapotranspiration rates measured by our agricultural weather network, CoAgMet, were the highest ever observed in the network's 20-year history. Forests were incredibly dry by June. The table was set for two of Colorado's most destructive wildfires, the High Park fire in northern Colorado and the Waldo Canyon fire near Colorado Springs, both of which ignited in June.

Colorado Drought Impacts

Wildfires

The devastating Colorado wildfire season of 2012 was the most publicized impact from the drought of 2012 and was responsible for five fatalities and an estimated $450 million in insured losses. This does not include the costs of fighting the fires. The cost for fighting the High Park fire alone was around $40 million. In total, 12 major wildfires were reported, starting with the Lower North Fork fire in March 2012 and continuing straight into October with a wildfire in Rocky Mountain National Park. The Fern Lake fire, as it was called, burned through the fall and doubled in size at the end of November, with 70-mph winds fueling the fire in inaccessible terrain. This fire burned into January; it was finally extinguished by a blanket of snow, but not until it had burned nearly 3,500 acres. This was a strong indication of the extremely dry forest conditions observed in 2012.

The High Park and Waldo Canyon fires were the most explosive and destructive, burning 87,284 and 18,247 acres, respectively. The proximity of these fires to large population centers and the large number of homes burned or threatened set these fires apart from

typical Colorado wildfires. On June 26 alone, 350 homes were lost to the Waldo Canyon fire, making it the most destructive fire in Colorado's history. That title had been given to the High Park fire just a few weeks earlier for burning 259 homes. The High Park and Hewlett Gulch fires burned the "backyard" of the Colorado Climate Center. Smoke, flames, and pyrocumulus clouds were visible from the Climate Center nearly all summer, but finally ended when the southwestern monsoon arrived in early July, bringing much-needed precipitation and high dew points to help fire crews extinguish the flames.
Wildfire was also a major problem across Colorado's eastern plains. Spring grass fires are not uncommon, but in 2012 the fire hazard continued into the summer. The Last Chance fire, which ignited June 25, was the second-largest wildfire of the year by acreage, next to the High Park fire. It burned 45,000 acres and 23 structures, including 5 homes. The cause of this fire was thought to be a few sparks from a tire blowout. With conditions as dry as they were, just a few sparks were responsible for 45,000 acres of burned landscape in just two days, in contrast to the High Park fire, which burned for several weeks.

Agriculture

After being hit with drought in 2011, the southeastern portion of Colorado experienced its second consecutive year of severe drought conditions. In 2012, the Arkansas and Rio Grande basins were not alone as the rest of the state started feeling the effects of agricultural drought as well. The most extensive agricultural producing areas in Colorado are on the Eastern Plains in the South Platte, Republican, and Arkansas basins. The rest of the state is known for ranching and hay production while the Western Slope near Grand Junction is well known for fruit growing. None of these areas were spared by the drought of 2012, with the state reporting 98,086 failed and 124,461 prevented planting acres. Where irrigation water supplies were adequate, some crops did well. For example, western Colorado's fruit growers experienced very early blossoming similar to the fruit areas of the Midwest and Great Lakes, but Colorado escaped the April freezes that so damaged fruit crops east of here.

Rangeland and the extensive irrigated pasturelands of Colorado were especially hard hit. By August of 2012, only 3% of the total pasture and rangeland acres in Colorado were rated good condition or better while 81% were rated poor or very poor. Hay prices soared to two to three times their recent levels, and supplies were scarce. Production was limited to 10-50% of average. Since drought also encompassed all neighboring states, there was no easy option for purchasing hay. Buyers were able to have hay trucked in from locations such as northern Montana and Idaho but also as far away as the Carolinas. In some areas, special provisions were required to exempt hay-hauling truckers from highway load size limits. This allowed some oversize loads to be delivered, making hay slightly more affordable.

With continued drought across the state, corn prices increased in 2012 to roughly $6.60 per bushel, up from 2010 corn prices of $3.79 per bushel, or a 43% increase in price over just two years. The increased price of corn was not isolated to Colorado as much of the Corn Belt of the United States experienced exceptional drought conditions in 2012, which led to the large increase in prices and reductions in supply. Increased prices offset decreased yields for some producers, and for the few farmers with full irrigation allocations, this was a financial benefit.

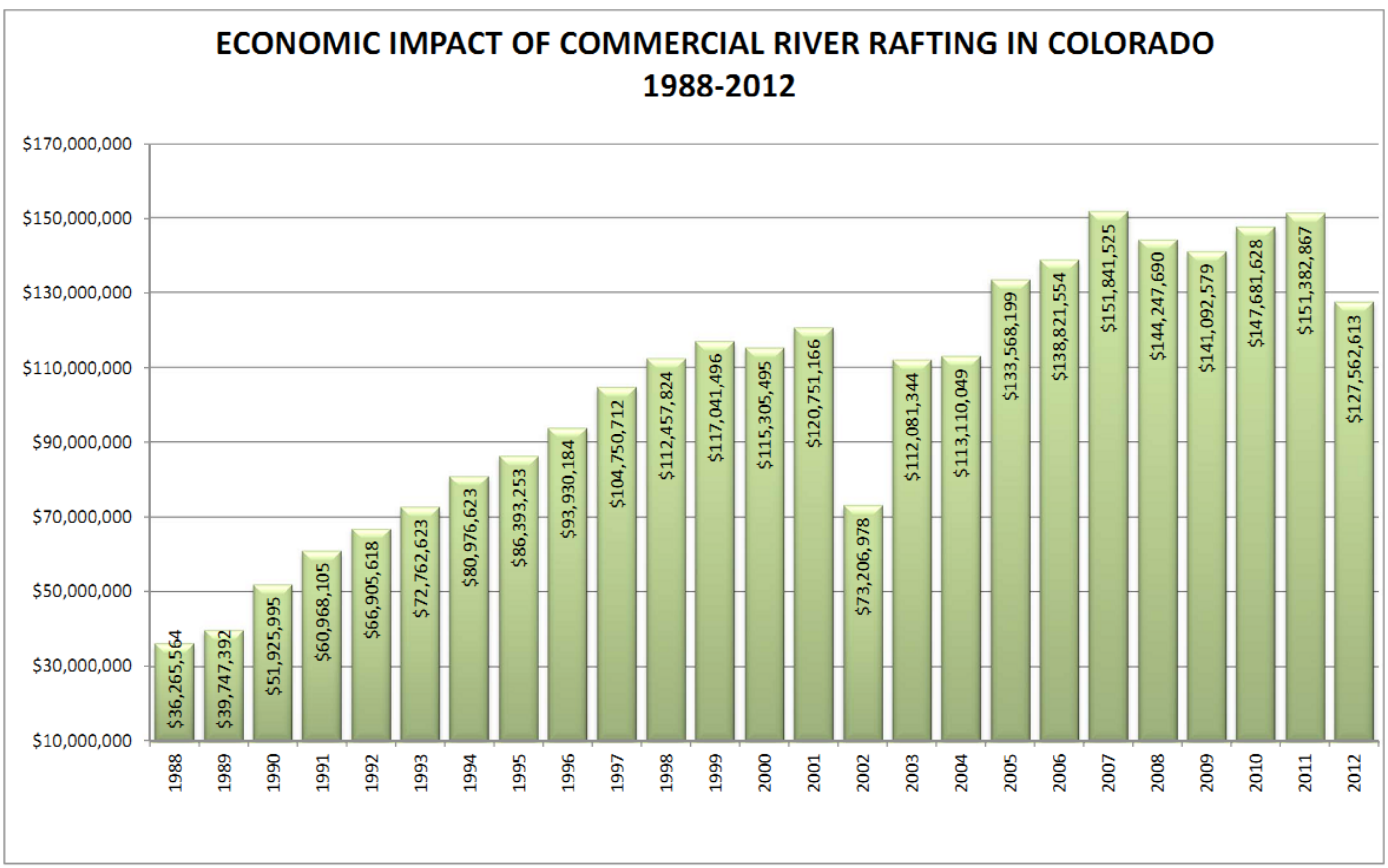
The Colorado Drought Mitigation and Response Plan establishes lines of communications to send information up the chain of command when drought hits our state. This plan identifies impact task forces for each sector of the economy. The agricultural impact task force met for much of 2012, bringing together Farm Service Agency personnel and state water managers to report failed and prevented planting acreages, updates on CRP (Conservation Reserve Program) grazing availability, and emergency loan status and disaster declarations status by county. Reports were also given (although hard numbers were rarely available) on cattle being sold, which mainly occurred in the Arkansas basin. These reports were integral for understanding impacts in different regions of the state.

Recreation and Tourism

It is no secret that drought brings impacts to the recreation and tourism industry, but it seems that this sector has done much in recent years to make their industry more resilient when drought strikes. One impact from the Colorado River Outfitters Association report for 2012 was a 17% decline (from 2011 figures) in rafting visitation in the state. This decrease in visitors was caused by a combination of low water flows and inaccessibility of river reaches due to wildfire. The Cache la Poudre visitation dropped 40% from 2011 because the river was closed for several weeks. The report shows that the industry's statewide profits were down 15.7%, from $151.4 million in 2011 to $127.6 million in 2012. Although numbers were down, they were not as bad as 2002's rafting season, and that was largely attributed to changes in marketing and getting the word out that the rivers were open for rafting. Some outfitters changed to targeting more family-oriented trips with the lower water levels being ideal for beginners. Figure 1 shows the time series of economic impact by the rafting industry.

The largest portion of Colorado's tourism sector is the skiing industry. Colorado Ski Country USA reported visitation for the 2011-12 season to be down 11.9% compared to the five-year average. The 2011-12 season proved to be challenging for many ski areas, especially with high temperatures and very little moisture in March, which essentially ended the ski season several weeks early. The ski industry has steadily prepared itself for the inevitable dry years by making large investments in snowmaking and slope grooming technology and diversifying their services to include more than just skiing. Similar to the river recreation industry, they have developed marketing strategies to compensate to some degree. But in this industry, a 12% drop is large.

Other summer recreation was affected, especially near publicized wildfire areas. Specific numbers are not available. Again, marketing strategies were aggressively employed to compensate to some extent for the national and international media coverage of the drought and wildfires. Overall, the impact on Colorado's huge recreation and tourism industry was modest but not severe.



Source: Colorado River Outfitters Association 2012 report

Figure 1. Time series of economic impact by the rafting industry

Water Storage

In Colorado, approximately 80% of the state's water supply comes in the form of runoff from mountain snowpack, which is captured as it melts in reservoirs for municipal water supply, irrigation water, power generation, and many other uses. Fortunately for reservoir operators, the 2011 water year in Colorado saw record-breaking snowpack in some river basins, which allowed reservoirs to fill. A longer-than-average runoff season resulted in more reservoir carryover into 2012, at least in the northern two-thirds of Colorado. But by May 2012, above-average reservoir storage changed courses to below-normal storage and has remained less than normal. Figure 2 shows the October 1 end-of-growing-season statewide time series of reservoir storage as a percentage of normal. Note how water year 2011 brought statewide storage up to 105% of normal and the large decrease in storage over just one year down to 67% of normal.

Another unique story about water supply in Colorado deals with in-stream flow rights. In 2012, the Colorado Water Trust launched the "Request for Water 2012" program and was able to purchase temporary water rights that were unclaimed in Stagecoach Reservoir. These rights were purchased within the Colorado water rights framework and used as in-stream flow to keep water flowing through the Yampa River near Steamboat Springs, Colorado, during the summer recreation season. This was an unprecedented contract that utilized the 2003 short-term water leasing statute and spurred many other water transfers. These types of transfers benefit stream flow, aquatic life and habitats, water users, fishermen, hydropower, and much more by keeping water flowing in the river for all to enjoy.

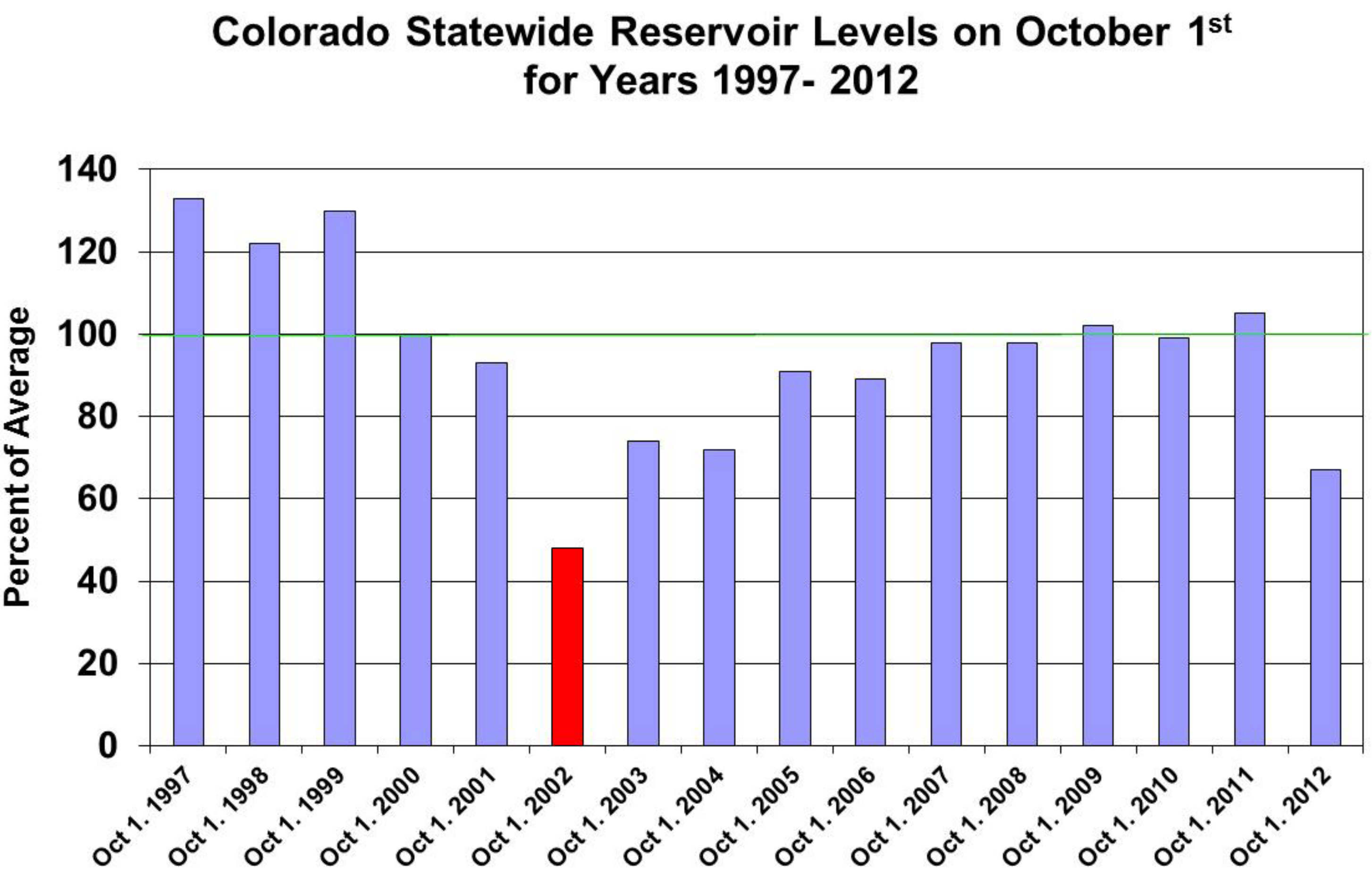


Figure 2. October 1 end-of-growing-season statewide time series of reservoir storage as a percentage of normal.

Lessons Learned

The Colorado Climate Center has had the privilege of being a part of the NIDIS (National Integrated Drought Information System) Upper Colorado River Basin Drought Early Warning System since 2009. Since that time, Colorado has experienced some level of drought across the state every year. This project allowed the state climate office to be much more involved in drought monitoring and communication efforts than they had been previously. Before this NIDIS pilot project, updates had been done monthly through the Colorado Water Availability Task Force (organized under the Colorado Drought Response and Mitigation Plan). Although these monthly meetings have continued, the NIDIS project has allowed for much more aggressive and timely weekly monitoring of conditions across the Upper Colorado River Basin and the rest of Colorado. This intense monitoring proved to be much more effective in identifying drought early enough so that water managers had more information sooner to help support decision making. Responses to exceptionally dry conditions in 2011-2012 in Colorado were much more coordinated than responses to the 2002 drought, which had a false sense of security that conditions would improve when in fact they did not. The 2002 drought was a wake-up call that conditions could deteriorate rapidly, and that is exactly what happened in 2012.

Increased monitoring was the key to closely tracking drought conditions and getting accurate changes made to the U.S. Drought Monitor, which people rely on heavily for tracking national conditions. This increased monitoring allowed for a more localized depiction of conditions in Colorado, which gave users of the USDM more confidence in the product for their location. Classifying drought is not cut and dried and takes into account a variety of perspectives. Consensus is not always easy and compromise is the key.

Real-time data and long-term observations are critical for putting current conditions into historical context. Recent satellite products are useful for depicting severity and spatial extent of drought, but have too short a history to provide perspective on the wide range of conditions experienced over the entire observed period of temperature and precipitation going back to the late 1800s. Those long-term observations, mainly from the National Weather Service Cooperative Observer Network, are the backbone of drought monitoring across the United States and critically important. In the western United States, SNOTEL stations maintained by the USDA Natural Resources Conservation Service are also critical for assessing and anticipating water supply conditions for the upcoming year. These stations provide early warning for reduced water supply by tracking snowpack in the high elevations of the western United States. Breakthroughs in remote sensing products, like VegDRI, are quite valuable for assessing drought conditions in data-sparse areas that provide little information alone. Preliminary evaluation of these products suggests that with good data inputs, these types of products provide a lot of value when few data are available to make decisions on a finer spatial scale. The reporting of drought impacts is fairly lacking. These data help us to understand how any categorization of drought relates to actual impacts seen—for example, what does "exceptional" drought look like, and what impacts does it trigger.

Understanding susceptibility to drought and developing mitigation plans is critical if we are to make it through long-term, widespread droughts. Several examples have been given in this report, from non-profit organizations buying in-stream flow rights to recreation outfitters investing in their infrastructure and diversifying their portfolios to keep business stable even during times of drought. These are just a few examples of the innovative solutions that can be developed. Drought is a frequent visitor to Colorado and being prepared for it is critical to mitigating the impacts from it.

Section 3.2: ILLINOIS

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Regional Environmental and Economic Impacts

For Illinois, the 2012 drought was the worst since the 1988 drought and in some ways rivaled the 1934 and 1936 droughts. The primary impacts of the 2012 drought in Illinois were agricultural. Corn yields were reduced to 101 bushels per acre, which is 64% of the yield in 2011. Soybean yields were reduced to 43 bushels per acre, which is 89% of the yield in 2011. The number of corn acres cut for silage doubled as it became evident that particular fields would not produce a measurable yield. Hay production was reduced as well. The lower yields and higher hay prices increased costs for livestock producers.

Photo by Aaron Greuel

Remains of a corn field near Sigel, Illinois, taken on July 1, 2012.

The hot, dry summer caused higher-than-normal levels of aflatoxin to be present in the corn crop. Aflatoxins are a group of chemicals produced by a certain family of mold fungi and can be harmful or fatal to livestock. In addition, they are considered carcinogenic to both animals and humans. As a result, the Illinois Department of Agriculture required extensive oversight in the handling and blending of corn containing aflatoxin.

The increase in livestock feed prices, coupled with diminished pasture production and hay shortages, created hardships for hog and cattle producers in Illinois. Many operators were forced to send breeding animals to slaughter to reduce the herd size. As a result, the subsequent increase in meat supply caused livestock prices to drop. Unlike corn and soybean producers, livestock producers typically do not have access to insurance to protect against financial losses caused by drought.

Several agriculture-related water issues arose during the 2012 drought. One of the earliest impacts at the farm level was the drawdown of shallow groundwater wells. As a result, many farmers resorted to hauling water from nearby municipalities at great expense. As the drought progressed, many municipalities restricted bulk water sales over concerns for their own water supplies. Agricultural irrigation increased in 2012. The combination of the drought and high commodity prices triggered a significant expansion of irrigation across Illinois that continued in 2013. There were several complaints of irrigation operations pumping hard enough to drop neighboring farms' well levels. In Illinois, agriculture relies heavily on the Mississippi and Illinois rivers as a source of reliable and economical movement of corn, soybeans, fertilizer, and other agricultural commodities. The low river stages on the Mississippi River below St. Louis in the fall and winter months were of special concern. One of the secondary impacts of the 2012 drought was that the poor crop growth, and in some cases total crop failure, resulted in the reduced uptake of nutrients, especially nitrogen. The concern was that these extra nitrates would make it into the rivers and streams by spring. On the other hand, more carryover of nitrates through the winter and following spring could mean reduced applications in the following growing season. Field measurements in the spring of 2013 indicate that the drought-related residual nitrates stayed in the field but moved deeper into the soil, making them unavailable for crops. As those nitrates moved out of the soil and into field tiles, nitrate levels on the Illinois River rose in March 2013 and remained high through June.

Most public water supplies in Illinois have adequate reserves to meet the demands of users. Water levels in most Illinois reservoirs dropped rapidly in the spring and summer before recovering with the fall rains. Drought conditions would have needed to continue unabated into 2013 before most water supply reservoirs would have reached critical low levels. Three water systems did experience serious problems during the drought. La Harpe, a small community in western Illinois, and Vienna, in southern Illinois, were of special concern. However, the biggest concern was Lake Decatur, which supplies water to approximately 87,000 people and is the primary source of water for industrial applications including Archer Daniel Midland (ADM). By August 2012, water levels on the lake were at a critical stage that required mandatory water restrictions. ADM was faced with the possibility of curtailing production activities. However, rains in September eased the situation. The city of Decatur is addressing the issue with the dredging of the lake to increase capacity and drilling new groundwater wells to supplement existing sources.

Photo by Jim Angel

Low water level on Lake Decatur, Illinois, in August 2012 threatened water supplies to the city of Decatur and to major industries such as Archer Daniels Midland.

The 2013 Illinois Drought Task Force report (http://www2.illinois.gov/gov/drought/Documents/The%20Drought%20of%202012.pdf) identified several additional impacts of the 2012 drought. These are noted in the following paragraphs. The drought resulted in several water-quality issues throughout Illinois, including high water temperatures and low dissolved oxygen levels, which stressed fish and other biota, sometimes resulting in fish kills. High water temperatures also impacted industrial and power plants with water intakes on rivers and lakes. Ongoing monitoring efforts by the Illinois Environmental Protection Agency (IEPA), Illinois State Water Survey (ISWS), U.S. Geological Survey (USGS), and other agencies served to document water-quality impacts of the drought. As a result of the drought, real-time temperature monitoring was added to USGS stream gauges at several power plants. In response to several reports of harmful algal blooms, a reconnaissance was conducted by the IEPA and the USGS during August through October 2012 to (1) confirm recent detections of high cyanotoxin concentrations, (2) assess the spatial extent, concentration, and characteristics of cyanobacterial blooms in Illinois, and (3) provide data to support state and local agencies in managing water resources to protect human, animal, and ecological health.

The coal industry depends on a constant water supply to suppress coal dust as coal is mined. These coal mine operations draw water from numerous sources, including local impoundments, rivers and streams, and federal reservoir allocations. A coal mine in Washington County experienced shortages of available water in August and requested access to water from state park lakes. The mine was able to obtain water to sustain their operations through their own initiatives.

Power plants depend on water supplies to provide cooling water, which is essential to the generation of electricity. Closed system plants are those that utilize cooling towers or maintain cooling ponds. Cooling pond plants maintain an adequate water supply to sustain operations for a limited time period. Cooling tower plants still need a small supply of make-up water. Open cycle plants require a continuous supply of cooling water from adjacent waterways, most of which is immediately returned to the water source.

Low flow conditions during 2012 resulted in the need to limit make-up flow and/or to decrease power generation at many power generating facilities in order to stay in regulatory compliance and maintain safe unit operation.

When Braidwood Station, a nuclear power plant that withdraws water from the Kankakee River, reached the low flow threshold specified in its DNR Public Water withdrawal permit, withdrawal of water was temporarily suspended. The Kendall 1200-MW combined cycle combustion gas turbine station draws water from the Illinois River and its withdrawal of that water was severely restricted when the Illinois and Kankakee river flows reached low flow limits set by permit. Three open-cycle fossil-fueled plants on the Chicago Sanitary and Ship Canal/Lower Des Plaines River and one on the Mississippi River were required to reduce power production during critical demand periods in response to extremely low river flow conditions, which were further exacerbated by frequent level manipulations by upstream entities.

Low river flows coupled with prolonged periods of above-average air and water temperatures also challenged power plants to stay within their National Pollutant Discharge Elimination System permits (NPDES) discharge temperature limits. Short-term site-specific thermal variances were granted by the Illinois Environmental Protection Agency, based on the showing of sufficient need by individual entities.

As flows in the rivers and streams of Illinois decreased during the drought, water temperatures rose and dissolved oxygen levels fell. These river and stream conditions contributed to a significant number of fish kills statewide. Additionally, several mussel beds dried up, leaving the mussels exposed to high temperatures and predators. The hazards of wildfire existed in natural areas as dry weather persisted. These natural areas are used frequently by campers and hikers. In many areas of southern Illinois, the dry conditions led to burn bans, which were implemented by most counties. Many communities curtailed firework displays over concerns about fire as well.

Regional Climate Services provided in Illinois

For Illinois, the state climatologist participated in the following activities.

- Prepared written material and briefings for the Illinois Drought Response Task Force (DRTF). The DRTF is a state-level group with representatives from state agencies including the Department of Natural Resources, Department of Transportation, and Environmental Protection Agency. This task force was activated with the governor's approval when drought conditions warranted a unified statewide approach.

- Kept the media informed about the drought on a daily basis. Although most inquiries were from media sources in Illinois, several national news services called as well, including Reuters, the Wall Street Journal, and CBS News. In addition, international news services in Korea, the United Kingdom, Denmark, and Germany contacted the office.

- Made presentations to a variety of groups, including farm and agriculture groups, the Mahomet Aquifer Consortium, regional water supply planning groups, the American Water Works Association, and other related agencies and associations. More than 50 talks were given in fall and winter 2012 and spring 2013 on the 2012 drought and its lingering impacts.

- Provided up-to-date information was provided on the Illinois State Water Survey website, the state climatologist blog (http://climateillinois.wordpress.com/), and Twitter feed JimAngel22. In fact, the blog was an excellent way to communicate the latest information on the drought. It received more than 82,000 views during 2012.

- Participated in regional and national meetings and webinars as either a panelist or presenter.

- Provided feedback to the authors of the U.S. Drought Monitor while working closely with the five NWS offices that cover Illinois.

Lessons Learned, Best Practices, and Next Steps in Illinois

Several lessons were learned and re-learned from the 2012 drought in Illinois. The number one lesson was that more drought planning is needed in Illinois. The state updated and revised its drought plan in 2011, but many communities in the state either had no drought plan or had plans that were out of date. Efforts are underway to perform more regional water supply planning.

The second lesson is that unlike many western states, Illinois has limited management authority for state governmental units to respond to drought, including (1) no regulation of limited groundwater resources, (2) no regulation of riparian water use, and (3) few identified alternative water supplies for municipalities. The Illinois Drought Response Task Force recommended a review of existing governmental authority to respond to drought emergencies and develop new authorities as needed.

The third lesson was the primacy of the U.S. Drought Monitor (USDM) in monitoring the ongoing drought. Although the USDM was used to some extent in previous droughts in Illinois in 1999-2000 and 2005, in 2012 it was widely used by state and federal agencies in Illinois for making decisions. It was widely referenced by the media and any economic sector impacted by drought.

The fourth lesson for the Illinois State Climatologist Office was the widespread use of social media for communicating the many aspects and issues of the 2012 drought. In previous droughts, information was passed on to the public by posting on the institutional homepage and occasional press releases. In the 2012 drought, a much wider audience was reached using the blog, Facebook, and Twitter.

The fifth lesson learned was that many more climate-related products were available to monitor drought conditions in Illinois. The multi-sensor precipitation estimator products provided by the NWS, in particular, were heavily used. The availability of high resolution precipitation data, the ability to choose time scales, and the presentation of totals and departures/percentages of normal made this the primary way of monitoring precipitation conditions around the state. Soil moisture models were useful products, and satellite-based products such as the NDVI were used as well. However, improvements are still needed in actual measurements of soil moisture. Illinois has a network of 19 soil moisture sites across the state. Unfortunately, they are located under grass. Another area of improvement is a better handle on the quantitative impact of drought on commercial crops. Right now, most monitoring consists of qualitative ratings like the percent of the crop rated poor or very poor.

Photo by Aaron Greuel

Dust blowing through a corn field near Sigel, Illinois, July, 2012.

Section 3.3: INDIANA

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Introduction

The 2012 drought affected a majority of the United States and reached historic levels rivaling the droughts of the 1930s, 1950s, and 1980s. It is most prominently attributed to the phase of the El Niño Southern Oscillation (ENSO) as quantified by the Oceanic Niño Index (ONI) from May 2010 to August 2012. The ONI Index is the three-month running mean of sea surface temperature anomalies in the Niño 3.4 region (5°N-5°S, 120°W-170°W). In Indiana, La Niña was the predominant ENSO phase from January until late summer 2012. La Niña conditions tend to cause dry and warmer-than-normal conditions in spring and summer. In addition to the La Niña phase, a large high pressure system established itself over the central United States from late spring into summer, providing little moisture and few weather systems to pass through Indiana. Despite Climate Prediction Center (CPC) seasonal outlooks and ENSO phase projections, the drought of 2012 reached levels of severity beyond forecast ability to predict it, resulting in natural disaster area declarations, water restrictions, burn bans, and catastrophic crop loss across a majority of the country, with Indiana being heavily impacted.

Although the 2012 drought affected the Great Plains and Midwest, this report will focus on Indiana. Indiana is a rich agricultural state with predominant crop production in corn and soybeans. Indiana has a high water table with numerous aquifers, rivers, and reservoirs, but the scale of the 2012 drought resulted in significant drops in soil moisture levels. By the time recovery from the drought began in August 2012, damage from the drought had impacted the local economy, agriculture, energy and infrastructure, recreation, wildlife, and the everyday lives of Indiana residents.

National Drought Data

Indexes

Drought monitoring is primarily completed using three indexes: the Palmer Drought Severity Index (PDSI), or "Palmer Index"; Palmer Hydrological Drought Index (PHDI); and Palmer Z Index (PZI). An additional drought monitoring tool is the U.S. Drought Monitor (USDM). It is a nationwide drought monitoring tool that is produced by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United State Department of Agriculture, and the National Oceanic and Atmospheric Administration. The USDM is based on broad-scale conditions, and is a synthesis of precipitation information from federal and academic scientists that is spatially displayed to serve as a tool for decision makers, the National Weather Service, state water agencies, state natural resource agencies, specialized media, general media, and the general public.

Although all the tools just noted provide crucial information during a drought, the USDM appears to have been the most widely used and recognized drought monitoring tool during the 2012 drought. Broadcast meteorologists used it widely in Indiana to help convey the degree of drought to the public. This report will review the most significant months of the 2012 drought with the USDM, PDSI, PHDI, and PZI. Hydrological drought assessment for the 2012 drought impacts in Indiana will be reviewed through other sources that directly measure river levels, reservoir levels, and groundwater levels such as NOAA's Advanced Hydrological Prediction Service (AHPS). River level and flow information in Indiana for 2012 will be briefly reviewed.

Crop and Agricultural Information

Weekly Weather and Crop Bulletins are published jointly by the National Oceanic and Atmospheric Administration (NOAA), National Agricultural Statistics Service (NASS), and World Agricultural Outlook Board. Each bulletin provides a national summary, state stories and summaries, current weather, temperature and precipitation data, and news on international agriculture and international agricultural weather. Pertinent information regarding the impacts of the 2012 drought in Indiana will be reviewed in brief. The full bulletins are available online.

Drought Mitigation—State Agencies and Additional Resources

State agencies and organizations that contributed to the monitoring and dissemination of drought information across Indiana during the 2012 drought include the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRSC) at the state level, Indiana State Department of Agriculture (ISDA), Indiana Department of Homeland Security (IDHS), United States Geological Survey (USGS) National Drought Watch website, and Indiana Department of Natural Resources (DNR). Additional state resources include the Purdue Extension Disaster Education Network on drought and Purdue Agronomy Center for Research and Education (ACRE) farms across Indiana. Each organization developed websites devoted to drought education, monitoring, and news, which are available to the public. The most pertinent information regarding the progression of the drought and economic impacts provided by these websites will be reviewed as well in the following state summary.

2012 Drought Impacts in Indiana

National Drought Indexes

Archives of the PDSI, PDHI, PZI, and USDM provide different information regarding the 2012 drought. The USDM will be reviewed in a separate paragraph, as it was reviewed, discussed, and disseminated differently to the public than the PDSI, PHDI, and PZI. All Palmer Indexes categorize spatial drought severity by climate division level.

The PDSI and PDHI showed very similar trends in the drought progression each month during 2012. From January through March 2012, drought conditions were not a real concern. April saw the onset of the drought in climate divisions 1 and 2 as moderate drought in both indexes, with May showing climate division 2 in severe drought and remaining divisions in a moderate drought or mid-range wet/dry (1.99 inches above/below normal). By August, both indexes have a majority of the state in severe to extreme drought (7 of 9 climate divisions). In September, the PDSI and PHDI show a slight subsidence in the drought severity, with most climate divisions in moderate drought and east central and southeast climate divisions back to midrange levels; however, climate division 2 remains in a severe drought. In October, there is a slight shift back to moderate drought for climate divisions 1 and 7, while 2 remains in severe drought status. November and December show climate divisions 2 and 3 in severe drought status, 1 and 8 in moderate drought status, and the rest of the state in recovery mode.

The PZI index shows the departure from normal (DFN) of moisture and is a good indicator of short-term drought. As to which index suggested the intensity of the developing 2012 drought, the PZI is the index that identified the 2012 drought the quickest, showing by March that Indiana's 9 climate divisions were already in moderate drought (divisions 5 and 6), severe drought (3, 8, and 9), or extreme drought (1, 2, 4, and 7). By August, the PZI rankings of drought severity by climate divisions matched those of the PDSI and PHDI, with agreement between all indexes until the end of the year. By December, the PDSI, PHDI, and PZI showed that climate divisions 2 and 3 were still in severe to moderate drought, with climate divisions 1 and 8 in the PDSI and PDHI in moderate drought. The 2012 drought entered Indiana from the northwest and west, and retreated from the south and southeast toward the north and west upon entering the fall season. The fall brought a shift toward neutral ENSO conditions, helping alleviate drought conditions. However, climate divisions 2 and 3 remained in drought status entering 2013.

Photo by Curran

Corn pointing near Campbellsburg, Indiana, June 30, 2012.

The USDM is presented via a national map of land area to the general public but can be individualized to a specific state. At the state level, Indiana felt the greatest severity of the 2012 drought during the month of August. In July, an average of 81.62% of the area in the state was classified as D2-D4 (severe to exceptional drought). The next most affected month was August, during which (on average) 79.18% of the land area in Indiana was categorized as D2-D4. In August, the total percentage of land area classified in extreme to exceptional drought peaked at 47.79%. Table 1 shows the severity of the drought through time in Indiana by percentage of land area classified by a specific drought ranking.

USDM: Indiana January 2012-December 2012

Percentage land area classified by drought quantification interval

	Category					
Month	**Nothing**	**D0-D4**	**D1-D4**	**D2-D4**	**D3-D4**	**D4**
Jan.	100.00	0.00	0.00	0.00	0.00	0.00
Feb.	100.00	0.00	0.00	0.00	0.00	0.00
March	100.00	0.00	0.00	0.00	0.00	0.00
April	86.75	13.25	0.00	0.00	0.00	0.00
May	67.31	32.69	5.42	0.00	0.00	0.00
June	15.35	84.52	55.80	27.86	7.17	0.00
July	0.00	100.00	97.40	81.62	44.73	8.76
Aug.	0.00	100.00	98.31	79.18	47.79	15.80
Sept.	0.00	100.00	86.97	33.15	0.00	0.00
Oct.	19.86	80.54	31.48	2.93	0.00	0.00
Nov.	54.77	45.23	8.84	0.00	0.00	0.00
Dec.	57.12	42.88	16.01	0.00	0.00	0.00

Where: D0 = Abnormally dry; D1 = Moderate drought; D2 = Severe drought; D3 = Extreme drought; and D4 = Exceptional drought

Table 1. Average percentage land area by month classified by category according to the USDM. Please note these values are averages derived from the percentage of area determined weekly in the USDM for the given month.

Photo by Jennifer Stewart

Drought stressed corn curling in Tippecanoe County, Indiana, July 5, 2012.

Stream Flow

The USGS provides U.S. maps of monthly average stream flow data where river basins and watersheds are color-coded by percentile class above or below normal to represent stream flow as "much below normal (<10); below normal (10-24); normal (25-75); above normal (76-90); and much above normal (>90)." Monthly maps for January and February 2012 show that Indiana stream flow was above normal for January 2012 and normal for February 2012. March 2012 still had a majority of stream flow categorized as normal, with small pockets of below-normal levels in northwest central Indiana and southeast Indiana. By April 2012, most of Indiana's watersheds had stream flow levels below normal and much below normal. Stream flow levels remained normal in only a small area along the Ohio River in southeast Indiana and along the northern state border east of Lake Michigan. May 2012 saw a rise in stream flow levels, with only areas north and west of the Wabash River categorized as below normal or much below normal for stream flow. Far southern Indiana along the Ohio River and west of Louisville fell into the much below normal category as well. By June 2012, Indiana was predominantly categorized by much below normal stream flow, with only a small fraction of the state in the far southeast at normal levels. July 2012 was just as bad as June, with stream flow levels in almost the entire state categorized at much below normal (Figure

1). By August 2012, the severity of the drought began to diminish, with stream flow levels rising slightly so that most of the state was at below-normal to normal stream flow levels. September 2012 had most of the state returning to normal stream flow levels, with only two pockets of below-normal stream flow in far northeast Indiana and west central Indiana. Stream flow levels climbed to above-normal levels across much of the state in October 2012, while remaining areas had returned to normal levels with only far northeast Indiana still below normal. November and December 2012 showed normal stream levels present across the state except in the far north and northwest portions of Indiana, where drought conditions continued into 2013.

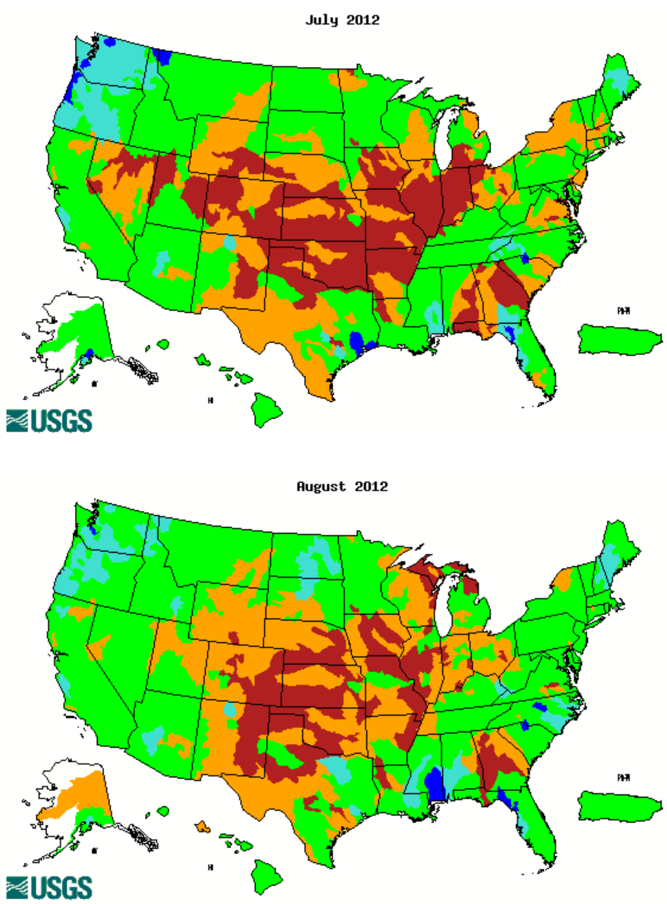

Figure 1. U.S. monthly stream flow maps for July and August 2012. A large percentage of land area in Indiana had stream flow classified as much below normal, coinciding with the peak time of the 2012 drought in July. August 2012 showed improvement as much-needed rain began to fall intermittently with storm systems across the state.

NASS State Weekly Weather and Crop Bulletins

Because January and February 2012 began warmer than normal with mid-range to slightly wetter than normal soil moisture, many farmers planted earlier than normal across the state. Upon sprouting and the onset of the heat wave and drought, conditions were optimal for the development of the aflatoxin Aspergillus Ear Rot. Weekly Weather and Crop Bulletin State Summaries (WWSS) provided by the USDA and NASS state that the warmer-than-normal temperatures (15.1° above normal during March) sped up the tilling, fertilizing, and planting process throughout Indiana, with a small percentage of farmers having already planted by the end of the month. However, most producers waited for crop insurance replant guarantees and did not plant until mid- to late April, once the chance for frost subsided. The WWSS for April 24, 2012, noted the record pace of planting in Indiana for corn and soybeans. The warmer-than-normal temperatures led winter wheat to break dormancy quickly and caused concern for frost damage to fruit and berry crops due to early blooming (WWSS March 2012).

By the first week of May, corn planting was 31 days ahead of the previous year, and 24 days ahead of the 5-year average. Dryness in March and April, along with frosts, resulted in the reduction of winter wheat yield and significant damage to fruit and berry crops (WWSS, May 8 and 15, 2012). By mid- and late May, planting still remained well ahead of 2011 and the first fields of corn and soybeans began to emerge. However, dry conditions had already set in, and emergence was slow and uneven (WWSS, May 22, 2012).

Drought conditions entering June resulted in farmers having to replant soybeans because of low plant growth caused by the hot and dry weather during plant emergence. Rainfall totals remained minimal (if any precipitation fell at all), providing short-lived drought relief with some spot replanting occurring. Spider mites began appearing in soybean crops, and pasture conditions began to show signs of rapid decline. By the end of June, 55 counties in Indiana had been placed under burn bans because of the 48% of normal rainfall from May through June. Corn pollination had become a concern by this time, as corn had begun to tassel under the dry heat. Continually deteriorating pasture conditions from lack of rainfall had caused a shift to hay for livestock. June 2012 was recorded as the third driest in Indiana, falling behind 1988 and 1933.

July WWSS reported corn moving into pollination stage from the extreme heat and dry conditions, with farmers and crop insurance representatives discussing the possibility of harvesting corn for forage or destroying the crop completely. By mid-July, 80% of the state had reached severe to exceptional drought, with farmers in 55 counties qualifying for assistance once the Farm Service Agency (FSA) declared 36 counties natural disaster areas. Spider mites continued to be a large problem in soybean crops, and corn had begun to be chopped for forage to help relieve shortage of forage supplies. By July 24, 2012, most corn crops had moved past pollination stage, and thus any additional rainfall would yield improvement to the crops. The FSA declared 14 additional counties natural disaster areas in late July, with 74 counties now eligible for low-interest emergency loans to help recover from financial losses stemming from the ongoing drought. By the end of the month, 20% of Indiana was in extreme drought conditions according to the USDM, larger-than-normal numbers of cattle were being sent to market because of lack of pasture and forage, and water supplies had become an additional concern, as creeks and ponds had begun to dry up across the state.

The first week of August had some slight relief from drought conditions with rainfall from severe weather events in some parts of the state. However, surface water supplies remained an issue. Continued rainfall into mid-August helped to slightly alleviate drought conditions, with less than half of the state in extreme drought conditions compared to the 70% reached on July 31, 2012. Some corn harvest had begun by this time, with soybeans having been planted later in the spring benefitting from the rainfall. Rainfall in August also helped quell spider mites and the amount of aflatoxin in the corn crop. The end of August resulted in corn harvest beginning in west central and southern districts, with widely varying yields being reported.

Hurricane Isaac remnants had the potential to bring more drought relief to Indiana the first week of September. Unfortunately for Indiana, a majority of the rain fell across Missouri and Illinois. Increased precipitation with the shift in ENSO brought more rain to Indiana during the first two weeks of September; this slowed harvest progress but helped to recharge topsoil moisture. Reports of aflatoxin and other molds arose with the onset of crop harvest, and pastures improved from the increased rainfall. By mid-September, harvest increased and corn yields were reported as varying greatly from field to field. Soybean fields had reached maturity at this time. Much-needed rain hampered harvest rates toward the end of the month.

The beginning of October saw soybean and corn harvest in full operation, with other crops in the state nearly 90-100% harvested. Despite improved rainfall over the last month, deep soil profiles remained dry across Indiana. Harvested corn by mid-October had an average moisture content of 19% and harvested soybeans had an average moisture content of 13%. In early November, the corn harvest was nearly complete in western counties, and the emergence of winter wheat crops was doing well. By mid-November, harvest of corn and soybeans had been nearly completed, with remaining corn in the north central division and eastern counties. Rainfall amounts returning to normal coupled with moderate temperatures allowed for the growth of cover crops and hay heading into winter.

Photo by Zach Osowski

Dying evergreen trees at Goebel Farms, Evansville, Indiana, August 5, 2012.

Economic Impacts of the Drought

Indiana is predominantly a corn- and soybean-based state that practices crop rotation; thus, the drought drastically impacted the 2012 growing season. A simple analysis of NASS statistics of the 2012, 2011, and 2010 corn yields shows the impact of the 2012 drought on crop yield (Figure 2). Three years of data was utilized to account for decreased corn yield the following year resulting from crop-rotation practices.

Aflatoxin/Aspergillus Ear Rot

The Food and Drug Administration limits the amount of detected aflatoxin in corn, as the corn is used in feed for swine, poultry, beef cattle, breeding cattle, and dairy cows. As the risk of aflatoxin development in the 2012 corn crop grew worse, discussions arose about modifying the allotted amounts of aflatoxin detected in feed. On September 25, 2012, an aflatoxin relief letter from the U.S. Department of Health and Human Services approved temporary relief to Indiana. Permission was granted for farmers to blend corn contaminated by aflatoxin with corn testing negative for the toxin to reduce parts-per-billion (ppb) concentration below the 20 ppb limit for contaminated corn used for feed on mature animals (100 pounds or more). However, upon blending contaminated corn, the feed had to be tested for the toxin once more to certify that levels were below 20 ppb, and farmers had to provide a copy of certification to the purchaser and clearly mark the mixed feed "For Animal Consumption Only." Corn with aflatoxin concentrations greater than 500 ppb was not allowed to be blended (McChesney, 2012).

Corn and Soybean Yields

The August 10, 2012, USDA crop production report estimated corn yields for the 2012 growing season at an average of 605 million bushels on yields averaging about 100 bushels an acre. This is a per-acre decrease of 46 bushels from 2011, and 57.4 bushels from the 5-year average. Soybean yields dropped by 8 bushels an acre to 29, and dropped down to 9.7 bushels from

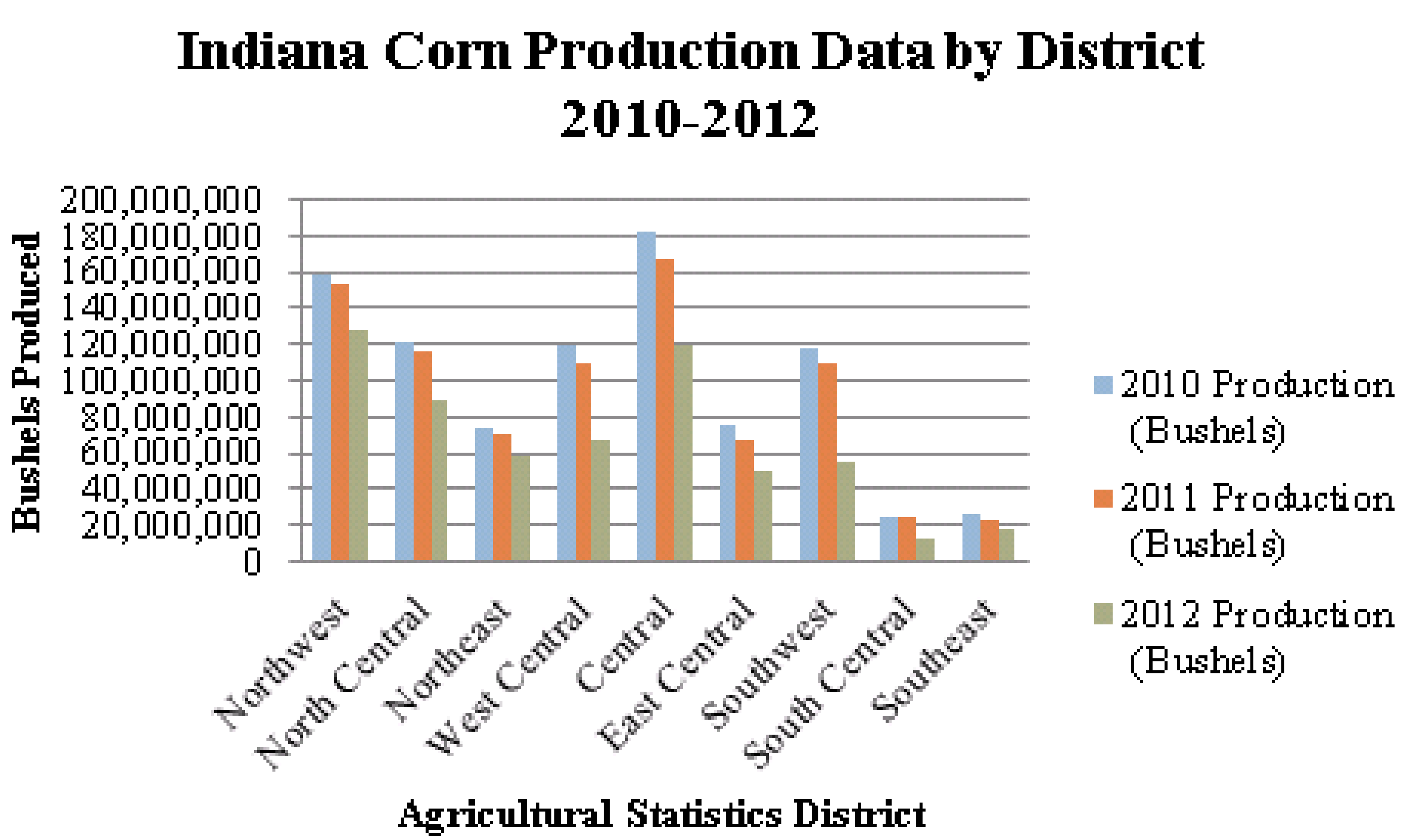

Figure 2. Corn yield in Indiana by climate division 2010, 2011, and 2012. By district, the percentage decrease from 2010 to 2012 (assuming a crop rotation occurred during 2011): Northwest: 18.78%; North Central: 26.70%; Northeast: 20.08%; West Central: 44.68%; Central: 34.08%; East Central: 34.30%; Southwest: 52.97%; South Central: 49.23%; and Southeast: 32.79%. West Central, Southwest, and South Central districts saw the greatest crop loss from the 2012 drought.

the 5-year average. Although initial hopes early in the 2012 season were for bumper crops because of the abnormally warm weather and earlier planting season, the 2012 drought crushed all hopes. Three-fourths of Indiana's corn crop and one-half of the soybean crop were in poor to very poor condition the first week of August 2012, leading to a USDA estimate of Indiana's corn crop to be ~38% below trend yields. This low yield is the lowest departure from trend in the last 75 years, inclusive of the 1988 growing season. The warm and dry weather had a greater impact on the corn crop as it leads to a faster maturation of the crop, whereas soybeans are more resilient to heat and moisture stress. Regardless, an early harvest season due to poor crops occurred. The September 12, 2012, USDA Crop Production report showed little variation from the August 10, 2012, report.

Crop Insurance

On August 10, 2012, Purdue Extension corn specialist Bob Nielsen reported that an estimated 65-75% of Indiana's corn and soybean crops were insured. However, the revenues for corn and soybeans were up in August by about 24%. This provided a chance for profit if crop yields were sufficient and crop insurance payments also came through. A Purdue University Extension Disaster Education Network news article issued on March 12, 2013, notes that Indiana crop insurance payouts topped $1 billion from the 2012 drought impacts on corn, soybeans, and wheat, breaking the state record of $522 million set in 2008. Of the $1 billion in payouts, $900 million was for corn losses, which averaged 99 bushels per acre in 2012, a 40% decrease from normal. The 2008 crop payout for corn was only $269 million. Soybean loss resulted in the second largest amount of insurance payout at $138 million, with not as much loss because of rainfall in August and September before harvest (Robinson, 2013).

Societal Impacts

With the peak of the drought felt in July and August 2012, the time of year when cookouts, green lawns, and water-based social activities are also at their peak, a drastic change of pace occurred for many Indiana residents. Water restrictions were implemented in major metropolitan areas such as Indianapolis, whose municipal water sources came from reservoirs such as Eagle Creek Reservoir and Morse Reservoir. Lawn-watering restrictions were put into place along with requests to limit the number of times individuals washed their cars per week. Law enforcement began to issue citations for throwing cigarettes from vehicles. County burn bans were implemented across the state, with 31 counties already under burn bans by June 18, 2012. By July 4, 2012, burn bans were in effect in 84 of Indiana's 92 counties, and many counties implemented firework restrictions.

State Agency Efforts

State agencies such as the NRSC, ISDA, IDHS, USGS National Drought Watch, and Indiana DNR provided the public with information regarding the 2012 drought via drought web pages. Topics included burn bans; water use restrictions; health issues; air quality alerts; water shortages; educational information regarding droughts; and information for farmers regarding aflatoxin treatments, crop insurance, crop prices, and loans. Websites also provided news releases such as the declaration of all 92 counties in Indiana as primary or contiguous natural disaster areas on August 15, 2012, and the NRCS announcement of $5 million in grant opportunities to help farmers adapt to drought. Readers can visit the following agency websites for more detailed information.

- *USGS Indiana Drought Watch:* http://in.water.usgs.gov/drought/
- *ISDA Drought Information:* http://www.in.gov/isda/2533.htm
- *USDA NRCS 2012 Indiana Drought Information:* http://www.in.nrcs.usda.gov/drought.html
- *Indiana FSA:* http://www.fsa.usda.gov/Internet/FSA_File/in_fsa_drought_factsheet_rev_5.pdf
- *Indiana DNR:* http://www.in.gov/dnr/water/4858.htm

Conclusion

A persistent La Niña phase ENSO pattern led to a moderate winter at the beginning of 2012, providing hope to farmers for a bumper crop year and an early spring to Indiana's citizens. However, the mild 2012 spring would give way to one of the worst droughts seen in Indiana since the 1980s and 1930s. Crop insurance payouts exceeded $1 billion dollars to compensate farmers for their corn and soybean losses, breaking the previous state record. Corn was the most heavily impacted grain because of its sensitivity to soil moisture deficits and heat stress. Soybeans are more resilient to heat and were able to survive better despite increased reports of spider mites across the state. Corn yields for 2012 were 30-50% less in certain districts than prior years, resulting in a ~40% decrease from normal, on average. In addition to decreased yields in general, the drought resulted in a higher incidence of aflatoxin levels in fields.

The drought affected Indiana farmers, citizens, law enforcement agencies, nurseries, parklands, watersheds and associated ecosystems, groundwater tables, stream flow, and reservoir levels. Water restrictions were implemented in major metropolitan areas where municipal water supplies are provided through reservoirs. Restrictions were also placed on when and how often homeowners could water their lawns, and if families could light fireworks for the Fourth of July. Groundwater levels decreased with little recharge from rainfall to the point that wells near streams and retentions ponds ran dry. Ecosystems along watersheds saw shifts in the types and amount of vegetation growing, which further trickled down the food web, limiting food sources for herbivores. Although the 2012 drought was significant in nature, another drought of the same magnitude should not occur in the near future. The return period of such droughts is roughly 25-30 years.

References

McChesney, Daniel (2012): Indiana aflatoxin relief letter 2012. *United States Department of Health and Human Services, Food and Drug Ad ministration.* September 25, 2012. April 14, 2013 <http://www.in.gov/isda/files/Indiana_aflatoxin_relief_letter_2012.pdf>.

National Agricultural Statistics Service: Crop Progress – State Stories. 2012 Weekly Summaries. April 14, 2013 <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1574>.

Robinson, Keith (2013): Indiana crop insurance payouts top $1 billion – a state record. *Purdue Agriculture: Extension Disaster Education Network*, March12, 2013. April 14, 2013 <https://ag.purdue.edu/extension/eden/Pages/drought-archive-p23.aspx>.

Section 3.4: IOWA

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The beginning of Iowa's drought of 2012 was in the summer of 2011. A cool and wet spring and early summer in 2011 quickly transitioned to a warm and dry pattern in late June. What at first was a welcome dry period began on June 27, with above-normal temperatures becoming prevalent on June 30. Warm and humid weather intensified in July, with Iowa recording its warmest July since 1955 and warmest calendar month since August 1983. At Fairfield in southeast Iowa, July 2011 brought only 0.20 inch of rain (5% of normal). This was their seventh driest July in 132 years of records and followed what had been the seventh wettest May-June period of record. The heat index climbed to 110°F or higher on nine dates among the ASOS network, with maximum readings of 117°F at Spencer on July 18 and 117°F at Iowa City on August 2 (NOTE: The Iowa AWOS network has a strong warm bias and high dew point bias compared to the ASOS network, leading to unrealistically high heat indices). Actual temperatures peaked at 106°F at Fairfield on August 2, Iowa's highest official temperature since 2006. Relatively dry conditions became more widespread in August (with the exception of far southwest Iowa), with Burlington recording their driest August since 1920 with only 0.44 inch of rain. Crop yields were reduced in parts of southeastern Iowa in 2011, but for the state as a whole, production was good thanks to abundant soil moisture reserves in most areas and the relatively late start to the drought.

Drier-than-normal weather spread to nearly all of the state during September 2011. Sioux City recorded their driest September since 1950. The statewide average pasture and range condition deteriorated to only 28% of Iowa reporting good to excellent conditions, the lowest percentage since August 2006. Stream flow levels were also becoming quite low in southeastern Iowa. The dryness intensified in October. Onawa (west central) reported only 0.04 inch of rain for the month. At Carroll (west central) and Lamoni (south central), the month ranked behind only 1953 and 1975 as the driest October in more than 100 years. By the end of October 2011, the condition of the state's pastures (19% good to excellent) declined to the lowest level since November 2003. On the positive side, dry weather allowed the harvest to proceed about two weeks ahead of the normal pace, with only 13% of the corn and 2% of the soybeans remaining in the field by October 30.

A series of storms brought abundant precipitation to southeast Iowa during November 2011 and erased all drought conditions in that area. However, very dry weather intensified over far northwest Iowa, where Orange City recorded only 0.01 inch of precipitation for the month.

The winter season, particularly in northwestern Iowa, is easily the driest season of the year. Thus, while evaporation rates decline to near zero and prevent any worsening of drought over the winter, the odds of having significant precipitation in mid-winter to improve the drought situation are slim. The winter of 2011-2012 was a mild one, with temperatures for the December-February period averaging the 9th highest since 1895. Snowfall was infrequent, with the 13th lowest statewide average amount among 125 years of records. The minimal snowfall resulted in the common perception that lack of snow was a major factor in the development of the drought. However, several mid-winter rain events more than made up for the lack of snowfall as the statewide average winter precipitation was actually the 14th highest total since 1895.

Concern regarding potential water supply issues led to creation of the Iowa Hydrology Working Group (HWG) in the winter of 2011-2012. The HWG was led by the Iowa Department of Natural Resources (IDNR) and included representatives of the IDNR, Iowa Department of Agriculture & Land Stewardship (IDALS), the Iowa Dept. of Transportation and the U.S. Geological Survey. An outgrowth of these HWG meetings was the creation of a periodic report, the Iowa Water Summary Update, which debuted in April 2012 and contains brief summaries of precipitation, stream flow and groundwater conditions, as well as drought impacts across the state.

An unseasonably heavy late winter precipitation event brought widespread rain to northwest Iowa on February 28-29, 2012. Thanks to the mild winter, much of this moisture was able to soak into the ground (which typically would be frozen well into March) and provide a much-needed boost to soil moisture levels in this driest corner of the state.

March 2012 began with four days of cool, snowy weather. However, this would prove to be the last measurable snow of the winter in Iowa. An exceptionally mild period of weather began on March 10 and persisted into early April. The statewide average daily minimum temperatures were higher than normal maximums every day from March 14 through March 22. Numerous daily high temperature records were set, such as at Cedar Rapids, where records were set for seven consecutive days (March 14-20) among 120 years of records. The month went on to be the warmest-ever March, in terms of statewide average temperature, at 51.1°F, 15.2°F above normal and 2.4°F above the previous March record set in 1910 (and 2.2°F warmer than the typical April). This

Photo by Dennis Magee, WCF Courier

Grass growing on the bottom of a dried out pond in Black Hawk County, Iowa, July, 2012.

warmth accelerated vegetation growth to about one month ahead of usual, with two major repercussions. First, it set the stage for a very damaging freeze event when seasonable cold returned on April 9. Second, the one-month early start to the growing season resulted in an extra month of evapotranspiration and further depleted low soil moisture reserves.

April 2012 precipitation was near seasonal averages but would later prove to be the wettest month of the year. April temperatures averaged from 1° above normal in the northeast to 5° above normal in the southwest. Nevertheless, over much of eastern Iowa, April averaged cooler than March.

May 2012 appeared destined to finish among the 10 warmest Mays of record until a brief turn to very cool weather the last two days of the month. Statewide temperatures averaged 5° above normal while rainfall was much below normal except over far northwest Iowa. The month began with frequent rainfall, but very dry weather developed during the second week of May. Some south central and east central Iowa locations recorded 19 consecutive days without rain and the focus of the drought moved from northwest to east central Iowa.

June brought temperatures averaging about 2° above normal while drought intensified over all but the southwest corner of the state. Several northwest Iowa locations experienced a record dry June, such as Sibley, where their 0.36 inch total was well below their previous June record of 0.96 inches (set in 1888) among 113 years of data at that location. The season's first triple-digit heat arrived on June 27 with 101°F at Des Moines, Little Sioux, and Sioux Center. The month's highest reading came at Keokuk on June 28 with 104°F, Iowa's highest June temperature since 1988.

July is known as the single most critical month for Iowa's row crops, and July 2012 will long be remembered for extremely hot and dry weather. Every reporting point in the state recorded below-normal precipitation. No measurable rain was recorded for 39 consecutive days at Underwood (southwest) from June 29 through August 7. Numerous locations (mainly in the southwest) saw record low July rain totals, such as Atlantic, where a trace easily beat the previous record low of 0.43 inch set in 1975 (among 125 years of data). All but 4 days in July brought above-normal temperatures, with daytime highs of 90°F or higher recorded on 28 days at Atlantic, Mount Ayr, Osceola, and Shenandoah. The state saw an average of 21 days of 90°F+ temperatures and 3 days of 100°F or higher during July while a typical year brings 23 days of 90°F heat and 1 day in the triple digits. Highest official temperatures were 107°F on July 23 at Donnellson, Fairfield, and Keokuk. These were Iowa's first 107°F readings since July 29, 1999.

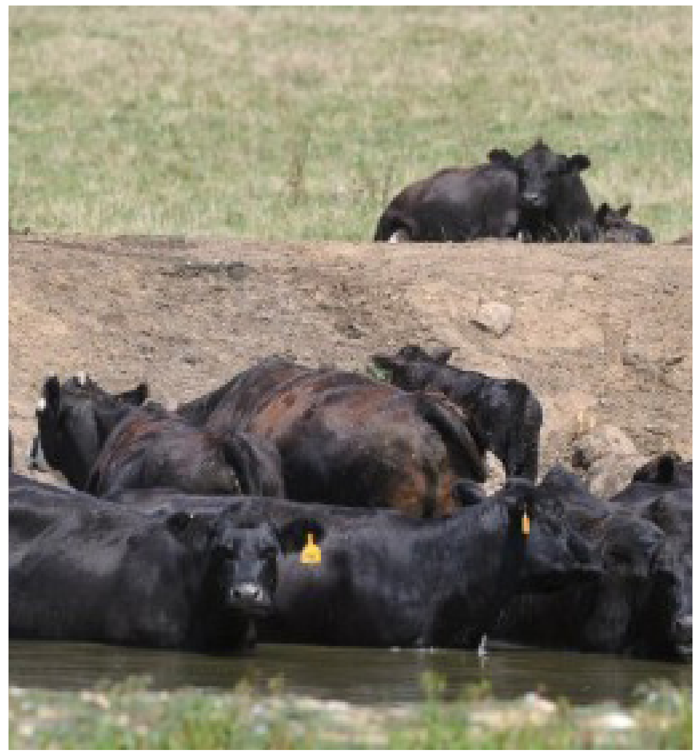

Photo by Dennis Magee, WCF Courier

Cattle suffering through the drought in a farm pond in Black Hawk County, Iowa, August, 2012.

The excessive heat continued into the first four days of August. A strong, but brief, cool down on August 5-6 brought a few daily record low temperatures on the morning of August 6, with Belle Plaine (east central) falling to 43°F. The heat quickly returned, with Keosauqua soaring back to 103°F on the August 7. However, a very welcome period of much cooler weather brought below-normal temperatures August 9-21. Daily record low temperatures were set in some areas on August 11, 17, 18, and 19, with Battle Creek (west central) and Sibley (northwest) reporting 38°F on the morning of August 17. These were Iowa's lowest temperatures for so early in the season since 1978. However, the heat was not done as above-normal temperatures returned for the final ten days of August. A few daily record high temperatures were set on August 29-30, with Hawarden reaching 104°F on August 30. Precipitation was more frequent than in July but remained well below normal over most of the state. The somewhat cooler and wetter weather slowed the rate of decline in crop conditions but did not improve conditions. Crops and pastures were generally rated the worst for the season since at least 1989.

Photo by Rick Chase

Dried out corn field near Waterloo, Iowa, July 30, 2012.

September's weather began with temperatures mostly above normal, but cooler-than-usual weather dominated most of the remainder of the month. There were scattered freezes in northwest Iowa on the mornings of September 18 and 22. However, a widespread freeze came on the morning of September 23, when 70% of the state reported temperatures of 32°F or lower. Sheldon and Spencer reported the lowest temperatures, with 22°F readings. This was Iowa's most widespread freeze for so early in the season since September 22-23, 1983. An additional 10% of the state (mostly in eastern Iowa) recorded a freeze the next morning, with additional scattered light freezes September 26-28. Typically, freezes occurring this early in the fall could potentially cause significant crop damage, but the very warm growing season pushed the maturity of all vegetation well ahead of the usual pace, and thus no freeze damage was reported. September precipitation continued to be well below normal in most of Iowa. The dry weather and early maturity of crops led to a very early completion of the corn and soybean harvest. A few farmers were even harvesting corn in August, with more than half the corn and soybeans harvested by the end of September, compared to typical progress of 8% of the corn and 21% of the soybeans by October 1. Overall, the harvest was completed three to four weeks earlier than usual in 2012. The very long and warm growing season allowed crops to dry down naturally in the field, thus requiring virtually no expenses in artificially drying grain to allow for long-term storage.

Overall View. A common question received during the development of the drought was, How does this compare to previous droughts? And when was it last this dry? Given the multitude of factors that combine to create drought conditions, it is never easy to accurately place a drought in historical perspective. This is compounded by the fact that when the drought is occurring we do not know the ultimate course it will take. Will this be a long-lasting drought or is relief perhaps just around the corner? In Iowa, continual comparisons were made between the 2012 drought and that of 1988, which was the last time Iowa experienced a combination of prolonged excessive summer heat and substantial precipitation shortfalls (frequent drought in the 1999-2003 period largely took place without unusual heat). The 1988 drought began with very dry conditions in the spring while that of 2012 was initially characterized by a very dry second half of 2011 and a warm spring in 2012. July 2012 went on to be much hotter and drier than July 1988, and thus more frequent comparisons began to be made with earlier droughts, such as the mid-1950s and the 1930s. However, the worst of the heat in 1988 came in August while in 2012 the worst of the heat was over by the end of July. Overall, the two years compare somewhat similarly. In 1988 Iowa recorded its 4th hottest and 14th driest summer while in 2012 it was the 5th driest and 14th hottest summer. Precipitation for the calendar year of 1988 averaged about 5 inches less than in 2012, mainly thanks to a drier spring. Precipitation was also much more variable in 1988, with a few extremely dry locations (only 14.02 inches for the year at Blockton along the Missouri border in southwest Iowa) while parts of northwest Iowa received near-normal precipitation. In 2011-2012, the geographic center of the drought impacts seemed to be constantly on the move. In the beginning, southeast Iowa had the greatest impacts in late summer 2011. By the end of 2011 it was far northwest Iowa. By the beginning of the summer of 2012, the worst conditions seemed to be over east central Iowa, but by mid-summer, practically no rain was falling over parts of west central and southwest Iowa (which had been the wettest area of the state early on).

Photo by John Gaines

Local farmer shows an example of drought stressed corn to Iowa Governor Terry Branstad and Lt. Governor Kim Reynolds in Mount Pleasant, Iowa, July18, 2012.

Now that 2012 is well behind us, it is apparent that the drought was not a particularly long-lasting drought, and thus in terms of water supply issues, simply was not persistent enough to result in the types of water supply issues seen in droughts such as the 1930s and 1950s (and in fact the overall precipitation totals of the recent drought were not even as low as much more recent droughts in 1988 and 1976). In short, the 2012 drought was intense, with the particular misfortune of a very hot and dry July (fourth hottest and fifth driest among 140 years of data), but comparatively brief. Also, an important factor that limited hydrological impacts from the intense drought of 2012 is that Iowa experienced an exceptionally wet, and often unusually cool, period from December 2006 through June 2011. This was the wettest extended period in Iowa since at least 1860 (some indication of similarly wet weather in the mid-nineteenth century). Among 140 years of statewide average statistics, 2007 ranked as Iowa's sixth wettest calendar year, 2008 was fifth wettest, 2009 was twelfth wettest, and 2010 was second wettest. This, combined with a cool and wet spring season in 2011, meant that all of Iowa's aquifers were at or near historically high levels and soil moisture reserves were abundant at the onset of the drought.

Another difference between this and earlier droughts is that following the 1988 drought, a major effort was made to develop regional rural water associations. The rural water systems greatly mitigated the local water supply issues that were frequent in 1988 and 1989, when many municipalities and hundreds of rural farm families had no alternative to shallow wells for their water. However, the nature of water use also changed greatly between 1988 and 2012. Large livestock confinement operations were few and far between in 1988 and were commonplace in 2012. Thus, literally hundreds of relatively large rural water users in 2012 had a critical need for water. In some cases in 2012, even the rural water systems in parts of western Iowa were very close to not having enough water to meet the minimum daily water needs. Additionally, the recent development of the renewable fuel industry also created much greater water demand in those areas where it was located, a water need that simply did not exist in 1988. In most cases, the ethanol production facilities developed their own sources of water, independent of municipal or regional water systems. Production of ethanol also declined in 2012 owing to a drought-induced spike in corn prices, thus simultaneously decreasing the demand for water needed for that purpose. As the drought intensified, the Iowa DNR worked to identify water systems most at risk of being unable to meet water demand. Potential breakdowns in water treatment, or losses of water owing to water main breaks, became very important as many systems were just barely meeting water demand with 24-hour per day operations. Thus a sudden loss of storage or treatment capability would have immediate impacts. Water systems were strongly encouraged to be sure their water allocation priorities were set and that the public was made aware of the potential for implementing rationing policies.

The Iowa corn and soybean crops fared much better than most analysts expected in 2012. Preliminary data suggest that Iowa's corn yield averaged about 20% less than the previous four-year average, compared to a 33% decline in 1988. Similarly, the statewide average soybean yield in 2012 was 10% less than the most recent four-year average, compared to a 20% decline in 1988. Improved genetics and increased use of conservation tillage have been noted as possible factors explaining the relatively better yield in 2012 versus what was realized in 1988. For the state as a whole, higher grain prices in 2012 roughly offset the drought-reduced production. However, it was a much more difficult year for livestock producers as feed costs were very high, excessive heat reduced the efficiency of weight gain, and insurance to protect revenue was not available for livestock production as it was for grain production.

The Iowa Department of Natural Resources reported that the dry weather brought a large increase in the number of campers utilizing the state parks. Public swimming pools and water parks also enjoyed a brisk business. However, boating, canoeing, and kayaking activities were greatly curtailed owing to low water levels. A positive effect of the low water was the great fishing that anglers experienced due to the fish being concentrated into the remaining areas containing deeper water.

The drought provided very favorable conditions for the spread of epizootic hemorrhagic disease (EHD) in deer. Deer mortality was high in many areas in 2012 owing to EHD. Drought can also cause toxins to develop in corn, which can affect some wildlife species. However, in some instances, dry conditions can produce favorable conditions, such as for shorebirds by exposing additional mudflats used for foraging.

The low water conditions of 2012, combined with heavy spring rains and flooding in April 2013, resulted in poor production of Canada geese in 2013. Other effects of the drought are more difficult to assess. For example, the 2012 drought may have reduced the mast crop in 2013, which can affect wildlife dependent on hard mast. Additionally, 2012's drought resulted in reduced growth of native warm season grasses and forbs, and it appears that this may have reduced numbers of some butterfly and other prairie obligate insect species because of lack of production or over-wintering habitat. Any impact in insect numbers may result in unpredictable impacts up the food chain in animals such as birds and bats.

A positive impact of the 2012 drought: the zebra mussel population in Clear Lake, the largest natural lake in north central Iowa, decreased dramatically. Before 2012, surveys for adult zebra mussels sometimes gave results of more than 30 mussels per square inch and rocks that were frequently 75-100% covered with zebra mussels. Veliger samples during those years at times had more than 200 individuals per liter. The drop in water level during 2012 stranded many zebra mussels out of the water while ice action during the winter of 2012-2013 scoured off many more. In 2013, there were only 3 veligers per liter of water and less than 10% (usually 0%) coverage on all rocks collected. The rocks that had anything on them had 1-3 adults and/or juveniles.

Finally, 2012 was a very quiet year for severe weather in Iowa. Iowa recorded only 16 tornadoes during the year, which was the lowest annual total for the state since 1953 (when tornado records were far less complete than today). The drought-induced dearth of 2012 tornadoes, combined with a very cool spring in 2013, resulted in the longest tornado-free period known in Iowa (May 25, 2012, through May 18, 2013). Additionally, the state recorded a very long snow-free period during 2012. The last measurable snow of the 2011-2012 winter season was on March 4 (about five weeks earlier than usual) while the first widespread accumulating snow in the fall did not arrive until December 7 (about three weeks later than normal).

* Crop and pasture statistics are from data collected by the USDA National Agricultural Statistics Service; weather statistics are derived from raw data collected by the U.S. Department of Commerce National Weather Service. Finally, information regarding water supply issues and fish and wildlife impacts came from the Iowa Depatment of Natural Resources.

Section 3.5: KANSAS

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The drought of 2012 in Kansas had its roots in 2011. Extreme to exceptional drought covered much of southwest and south central Kansas, as the impact of a high pressure dome centered in Texas reached northward. The winter of 2011-2012 was actually much wetter than average across the state. Unfortunately, these benefits did not persist through the 2012 growing season (Figure 1). Although March and April were wetter than average, temperatures were also much warmer than average. March 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. By the end of April, vegetative growth in many locations was three to six weeks ahead of normal. During May, the heat continued but the precipitation did not. Vegetation quickly wilted under those conditions. As temperatures warmed and rainfall stopped, the normal production was severely limited. By June, most pastures were in extremely poor condition.

Changes in Vegetative Conditions during 2012 Growing Season

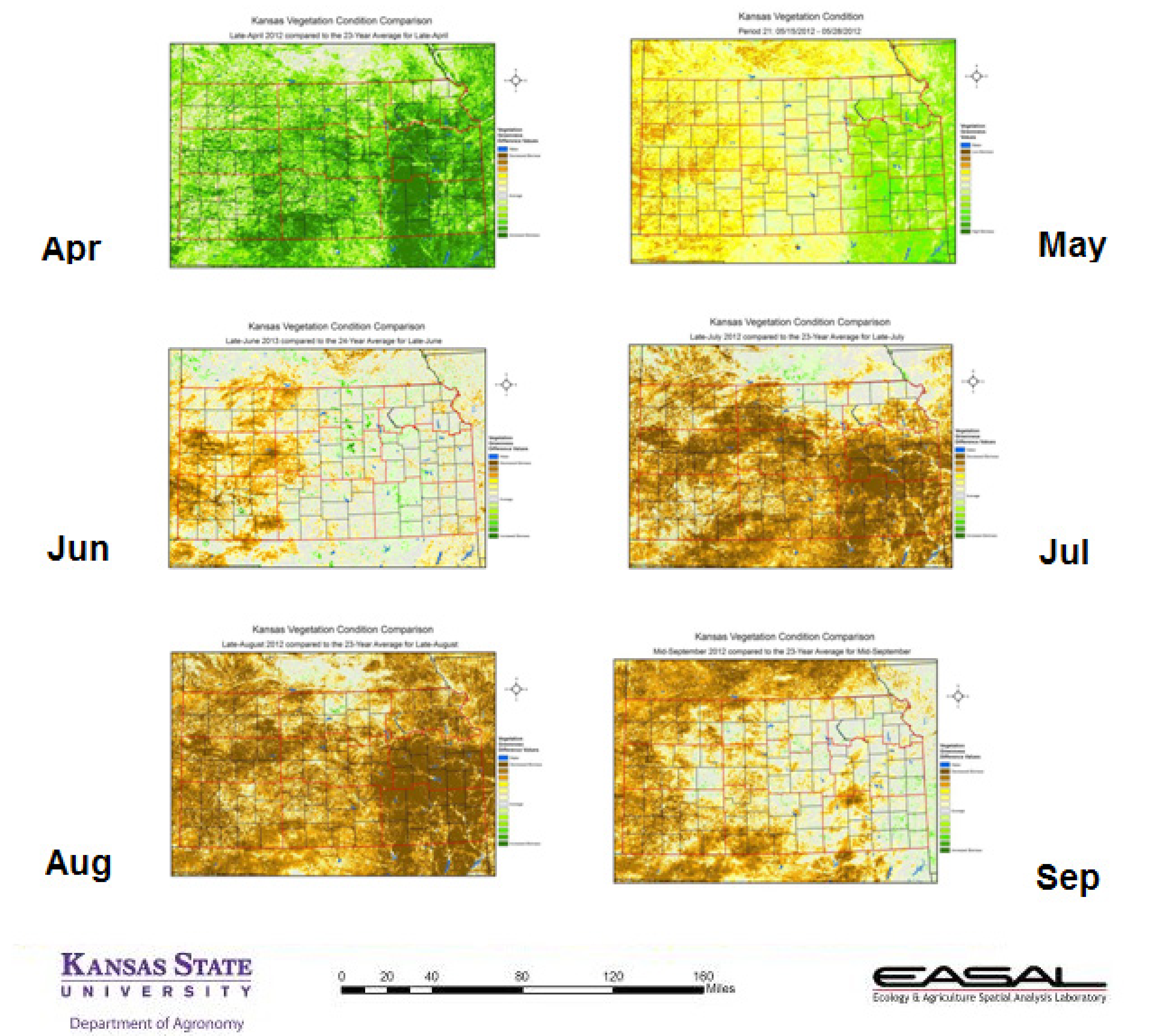

Figure 1. Vegetative health index maps from late April through late September, compared to 23-year averages.

This was particularly damaging to cow/calf operations and grazing in the Flint Hills of eastern Kansas, as May is a major stocking period in normal operations. In addition to the poor pasture conditions, surface water supplies were extremely limited. Many ponds were completely dry.

Hot dry weather continued through the summer. Many locations set records for number of days above 100°F. In a few locations, such as Garden City, the numbers exceeded the records established during the heat waves of 1934 and 1936.

Impacts

Precipitation

The extremely low precipitation, compared to long-term averages (as shown in Figure 2), fueled the impacts during 2012.

Agriculture

Winter wheat fared well. Mild temperatures and adequate moisture in fall 2011 allowed for ready establishment in the western third of the state. According to reports from the Kansas Wheat Commission, harvest in 2012 was surprisingly good. "In Wellington, the 'Wheat Capital of Kansas,' farmers are pleased with the 2012 wheat crop," said Curt Guinn, general manager of the Farmers Coop Grain Association in Wellington. "Sumner County farmers averaged 45 to 50 bushels per acre, with 60 pound test weights and a protein average of 11.3. Among the company's five locations, more than 4 million bushels were received, about 30% more than a typical year." In northwestern Kansas, one COOP reported taking in 1 million bushels in just 12 days. In addition to good yields, test weights, and protein content, another feature was the early finish to the harvest. By June 25, more than 95% of the state wheat harvested had been completed. This was well

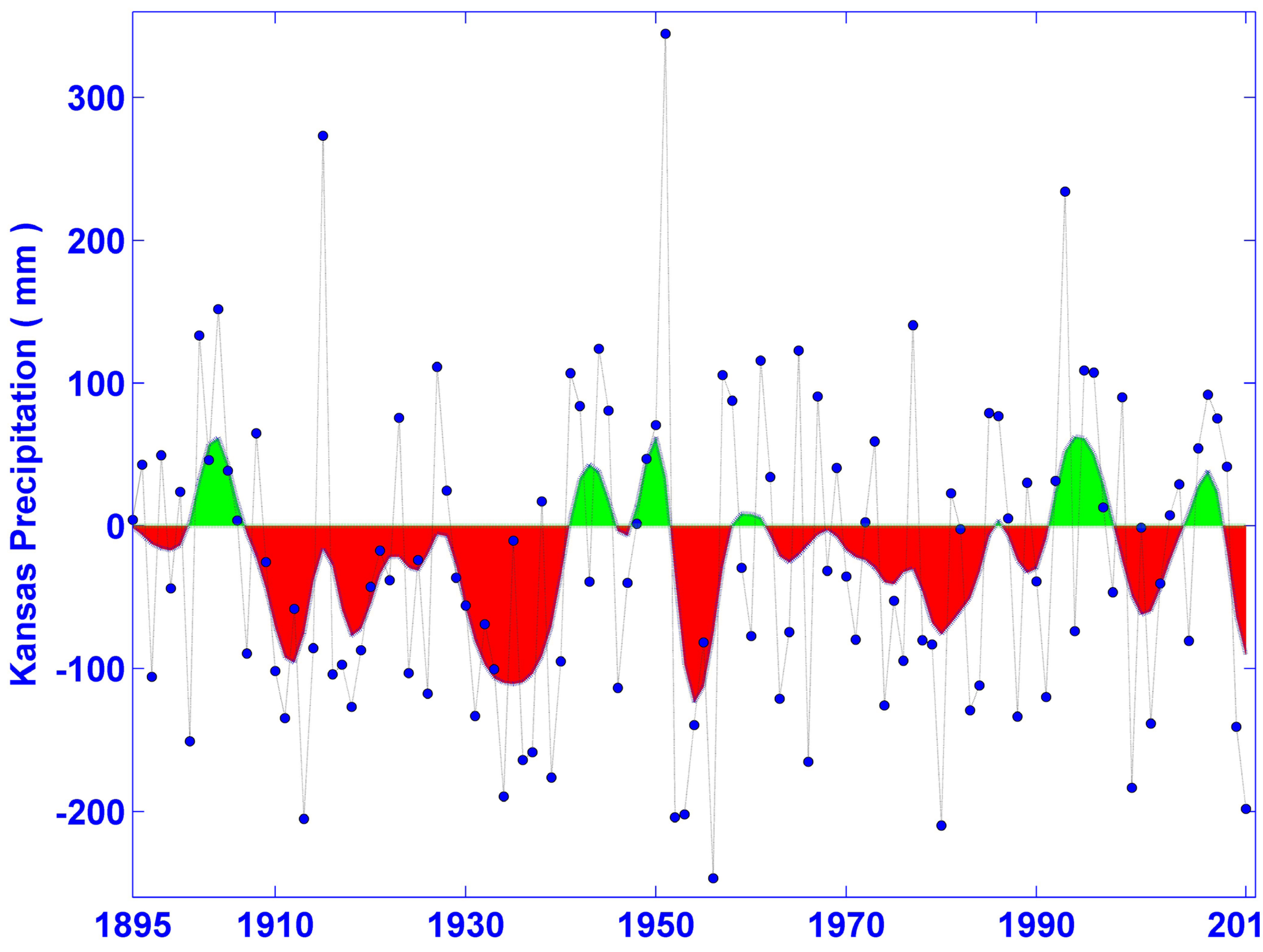

Figure 2. 118-year Kansas growing season precipitation

ahead of the average completion date in mid-July. Unfortunately, other commodities didn't fare as well. Production of sorghum, soybeans, and alfalfa were all below normal. Late-planted beans had the best production as temperatures moderated in August and spotty rains favored these late beans. Extremely dry conditions created some unique problems. In southeastern Kansas, a fire spread through five widely spaced stacks of baled cotton after one was ignited by lightning.

Livestock

Poor pasture conditions, high feed costs, and low water availability resulted in considerable loss in the livestock industry. Many operators reduced inventory, and others had much lower profit margins. Degradation to pastures will result in lower stocking rates for several years, even when drought conditions improve. In addition, during mid-July, a combination of high temperatures, high humidity, and low wind produced heat deaths in feedlot operations. The biggest impact was seen in an area from Ottawa County to Pratt County, with some losses as far west as Dodge City. These types of losses are relatively rare in the western areas of the state, because of the lower humidity that is typical in that region. Unfortunately, there is no official mechanism of reporting these losses in either the state programs or in industry reports. Losses of 0-1% of the inventory of particular operations were noted, but they do not convey overall totals and may or may not be representative of the losses experienced.

Water

Water continued to be a major issue. In March 2012, new legislation (Senate Bill 272) 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.

Stream flows were extremely low. Twenty-one USGS monitoring locations had record 7-day low flows. On August 2, 2012, the Smoky Hill gauge near Ellsworth reported a 7-day average stream flow of 0.81 f3 per sec. Within a 105-year record, the previous low was 1.01 f3 per second, set in 1957. On December 4, 2012, the Arkansas River gauge at Syracuse reported a 7-day average stream flow of just 0.05 f3 per second. The previous low flow in the gauge's 97-year record was 0.06 f3 per second, set in 1974. Figure 3 shows the Smoky Hill flow during 2012. The black line indicates the 2012 flow while the area shaded in brown represents the 10% flow level.

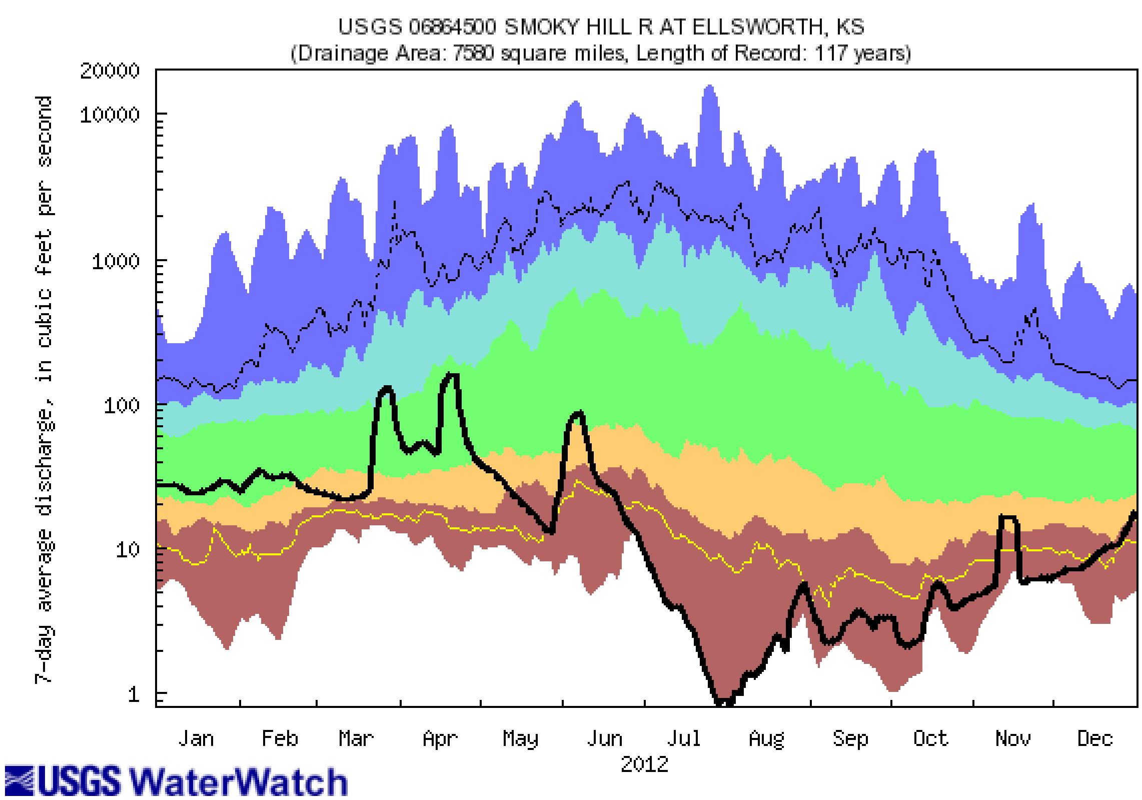

Figure 3. Smoky Hill flow during 2012

Photo by Ryan Flickner

Dying corn field in Mountridge, Kansas, July 19, 2012.

Water flow tells only part of the story. A water budget is the balance between the amount of rainfall received and the amount lost through evaporation and transpiration. By using an atmometer, a gauge that displays evapotranspiration, side by side with a rain gauge, it is possible to illustrate this point. Table 1 provides a comparison of water budgets for Manhattan and Lawrence during July 2012 using the CoCoRaHS atmometer and rain gauge.

Reports like this help users visualize the actual amount of water lost versus rainfall received during the period. Municipalities experienced additional problems with increasing numbers of water main failures. Lawrence reported a 200% increase in failure rates compared to 2010. Kansas City reported a record number of water main breaks in 2012 (about 1,800 across the metro region). Wichita reported a similar increase in water main failures. Shifting soils due to cold and drought were a significant factor in the failures.

Recreation

Fishing and boating activities were limited on many lakes and reservoirs because of the low water levels. Low stream flows also limited canoeing activities on the major rivers in Kansas (the Arkansas and Kansas rivers). Changes in fish populations are likely to result from the warmer waters. Also, alerts for blue-green algae limited access to various lakes over the summer.

State Climate Office activities

- Presented invited talks on droughts at the NOAA 2013 Drought Outlook and Assessment Forum, Kansas Water Office, and 'Tear Down the Walls' Annual meeting in 2013.
- Prepared written reports and briefings for the Kansas Drought Task Force, including weekly drought updates. These are submitted to the Kansas Water Office for inclusion in their drought updates.

Water Balance Summary

Station Number	Station Name	Water Balance in.	Total Precip Sum in.	Precip Coverage (Days)	Evap Amt in.	ET Coverage (Days)	First ET Obs	Last ET Obs
KS-RL-1	Manhattan 0.5 NE	-8.56	0.69	100% (30)	9.25	100% (30)	7/1/2012	7/30/2012
KS-DG-13	Lawrence 1.6 ESE	-4.41	2.78	100% (30)	7.19	100% (30)	7/1/2012	7/30/2012

Table 1. A comparison of water budgets for Manhattan and Lawrence during July 2012 using the CoCoRaHS atmometer and rain gauge.

- Provided documentation for disaster declarations. This ranged from providing county precipitation data for Natural Resource Conservation offices to helping farmers with monthly rainfall amounts and the normal monthly values for their area as they developed drought response plans.
- Regularly talked to the media and gave presentations to groups interested in drought. This included working with municipal water offices, groundwater management districts, irrigators, and livestock operators. Presentations were made to groups including the Kansas Water Conference, Wichita Municipal Water Suppliers Conference, and Kansas Grazing and Livestock Coalition. This also included talks throughout 2012 and into the spring of 2013 on the 2012 drought, its lingering impacts, and the possibility of recovery.
- Provided weekly feedback to the authors of the U.S. Drought Monitor.

Mitigation activities

- The legislature enacted regulations to increase flexibility of water right usage, while maintaining control of allocations.
- 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.

Section 3.6: KENTUCKY

Stu Foster
Kentucky State Climatologist

Historical Perspective

The drought of 2012 was remarkable for its rate of intensification, peak intensity, and duration. As highlighted in Figure 1, only four times dating back to 1895 has the Palmer Drought Severity Index (PDSI) recorded more intense drought conditions across Kentucky's western climate division during the month of May. In each of these cases, 1914, 1931, 1941, and 1954, severe to extreme drought conditions had persisted from the previous year. Only the droughts of 1941 and 1954 were more intense across the western climate division during the month of July, when the drought of 2012 reached its peak intensity of -4.52 on the PDSI scale. The droughts of 1930 and 2007 were similar to that of 2012, as they reflected a rapid reversal from unusually moist conditions to severe or extreme drought. While the return of above-normal rainfall by September helped to gradually improve conditions in 2012, the droughts of 1930, 1941, and 1954 persisted at the severe to extreme levels through the end of the respective calendar year.

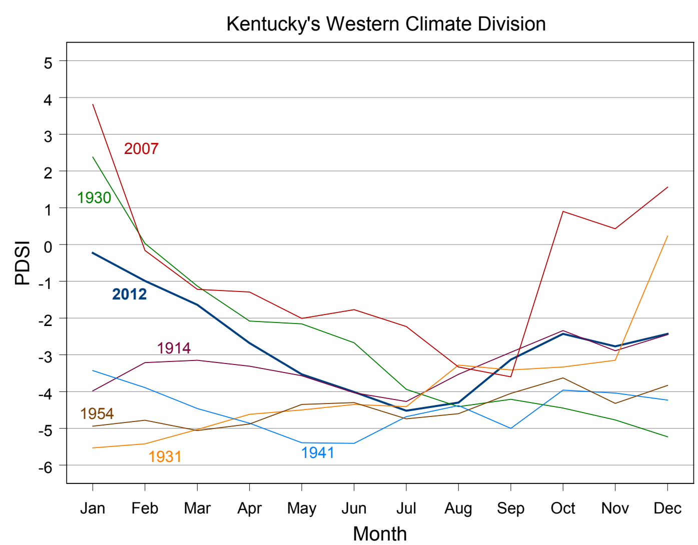

Figure 1. Historical context for the drought of 2012

The timing of the drought of 2012 broadly coincided with the growing season, creating particularly adverse impacts on agriculture. Figure 2, representing

Kentucky's western climate division, locates each year from 1895 through 2012 in terms of its cumulative precipitation over the first half of the growing season, defined as the months April through June (AMJ), and for the second half of the growing season, defined as July through September (JAS). The blue lines on the graph show the median cumulative precipitation for both periods based on 118 years of record. The year 2012 stands out as the driest on record for the period of April through June. Though cumulative precipitation for the period July through September was slightly above the historical median, much of that precipitation was recorded near the end of the period.

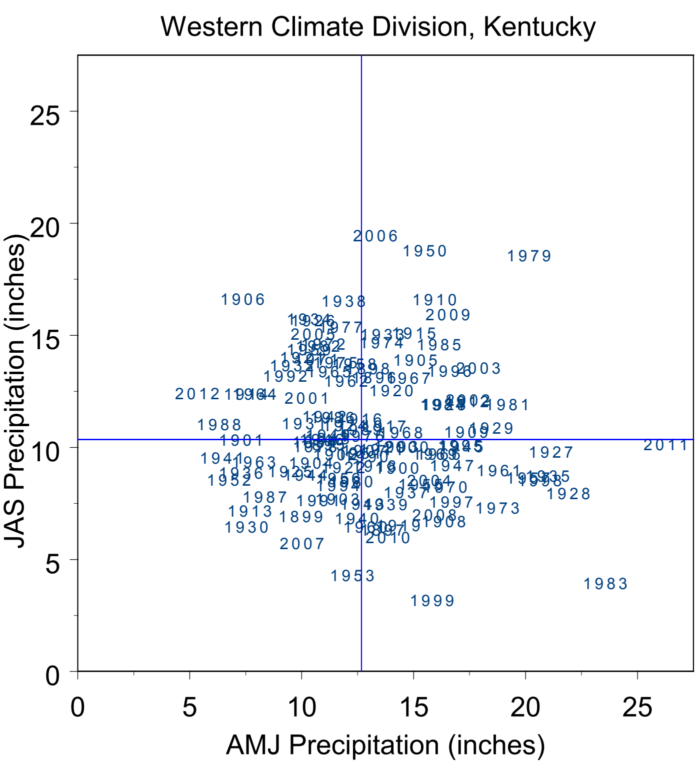

Figure 2. AMJ and JAS precipitation, 1895-2012

In summary, the drought of 2012 intensified rapidly through the spring and reached peak intensity in western Kentucky during the summer at a level comparable to some of Kentucky's worst droughts, but had a shorter duration compared with many of those droughts.

Drought Impacts: Irrigation and Groundwater

Kentucky normally receives abundant precipitation that helps to support a diversified agricultural economy. Average precipitation ranges from about 40 inches in the northeast to more than 50 inches across southern Kentucky. However, natural climatic variability and uncertainties regarding future weather and climatic conditions create risk for farmers. Over recent years, increases in prices received for agricultural commodities, particularly crops, have contributed to an increase in the value of agricultural land and provided farmers with an incentive to increase the productivity of that land. Though advances in agricultural technology continue to increase expected crop yields, weather and climate still pose a significant risk to realized yields in any given year. One means of managing risk is through investment in irrigation technology.

Center-pivot irrigation systems provide farmers with a means to mitigate risk of major crop loss in drought years, while offering incremental yield improvements in years when more normal weather prevails. Independent reports from the Jackson Purchase Region, which suffered from more extended and intense drought, and the Barren River Region, which was impacted by flash drought, both highlighted the impact of irrigation on corn yields in 2012. In these areas, where yields of near 150 bushels per acre are expected in an average year, irrigated corn yielded more than 200 bushels per acre, with some reports of yields exceeding 225 bushels per acre. In contrast, yields of 50-60 bushels per acre in the Jackson Purchase Region and 60-70 bushels per acre in the Barren River Region for corn were more representative of non-irrigated corn in these respective areas.

One factor entering the decision to invest in irrigation concerns the availability of a reliable source of water. Unless a source of surface water is available, farmers must be able to tap groundwater. Historically, irrigation was practiced on a very limited basis and confined to crop land in areas along the Ohio River and the Jackson Purchase Region. Aquifers in these areas are dominated by unconsolidated sediments consisting primarily of sand and gravel, with interspersed lenses of clay and silt. Wells drilled into these aquifers are typically productive and reliable.

Some of Kentucky's most productive cropland rests on the karst landscape of the Pennyroyal Region (Figure 3). Although little irrigation of cropland has traditionally occurred in this region, a growing number

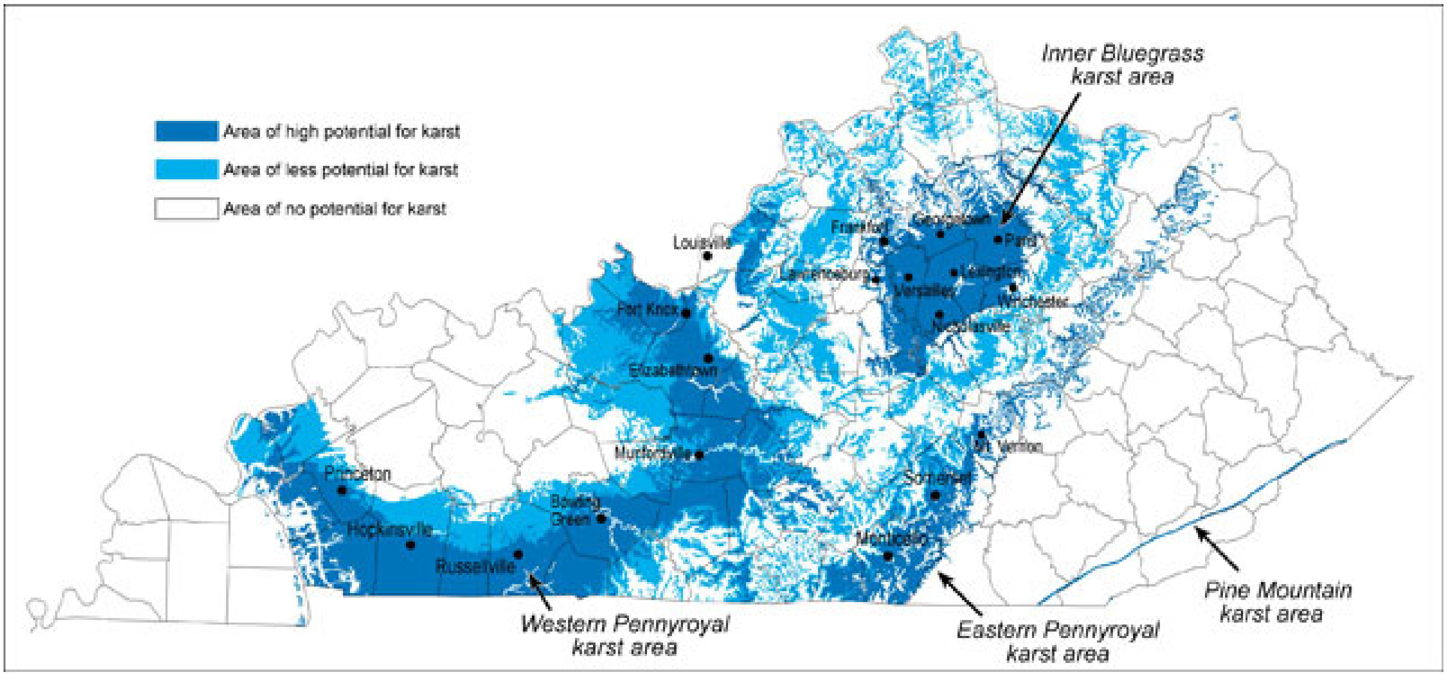

Figure 3. Areas of karst in Kentucky. (Source: Kentucky Geological Survey, University of Kentucky)

of wells are being drilled into the karst aquifer to access groundwater. Water enters the karst aquifer via surface runoff into sinking streams and sinkholes and by infiltration through unconsolidated material lying above bedrock. A karst aquifer includes narrow fractures, small conduits, and cave passages dissolved in bedrock through which groundwater moves (Figure 4). Unlike aquifers consisting of unconsolidated sediments in which the general pattern of groundwater flow can be readily predicted, the movement of water through a karst aquifer can be difficult to predict. Wells drilled into karst aquifers can be highly productive, but the nature of karst creates uncertainties concerning the availability and reliability of a water source at any given well site, and these uncertainties may be accentuated during periods of drought.

Photo by Natalie Grise

Low lake levels in Breckenridge County, Kentucky left many docks high and dry as seen during August, 2012.

Kentucky's agricultural landscape is changing. The 2007 Census of Agriculture for Kentucky indicated that although large-scale irrigation was becoming more common, only 0.3% of farms larger than 50 acres used irrigation. Based on field reports, irrigation has been adopted at an increasing rate in recent years, driven largely by high commodity prices, particularly corn. Observed differences in yields produced on irrigated versus non-irrigated land during the drought of 2012 are expected to continue to drive decisions by farmers to invest in irrigation systems, as systems are increasingly found in areas where large-scale irrigation has not traditionally been utilized. Figures 5a and 5b illustrate the changing agricultural landscape in Kentucky in the midst and aftermath of the drought of 2012.

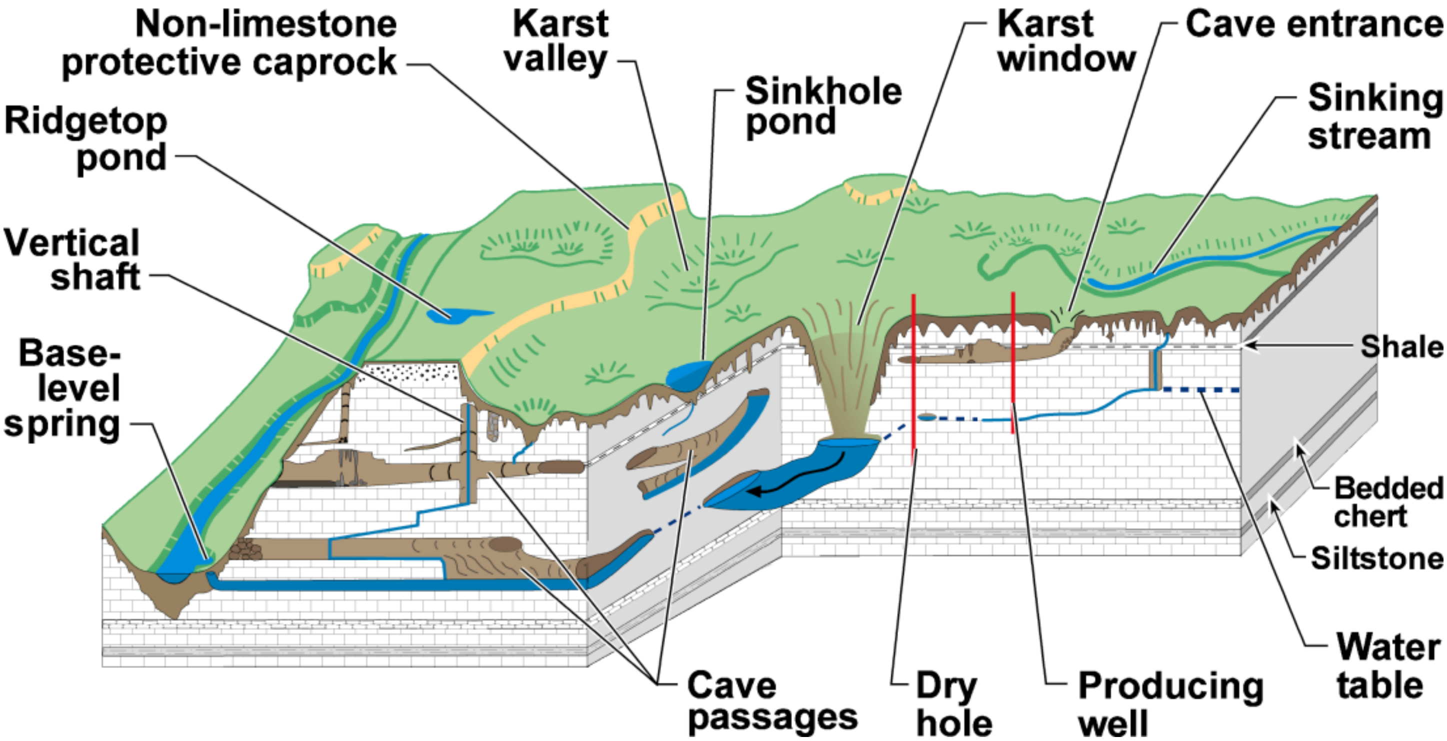

Figure 4. Idealized representation of karst features underlying cropland in portions of the Pennyroyal Region. (Source: Kentucky Geological Survey, University of Kentucky)

Photo by S. Foster

Figure 5a. Irrigation system being installed June 25, 2012 in aquifer of unconsolidated sediments in Carlisle County.

Photo by S. Foster

Figure 5b. Irrigation system being installed April 22, 2013 in karst aquifer in Warren County.

Lessons Learned: Drought Monitoring Using the Kentucky Mesonet

The Kentucky Mesonet, the official source of climatological observations for the Commonwealth of Kentucky, enables users to understand localized variability in drought intensity by tracking precipitation data at more than 60 sites across the state. Drought has traditionally been monitored using statistics calculated at the level of climate divisions. However, with only four climate divisions covering the entire state, important variations of drought intensity at the local level are often missed. The availability of in-situ observations from the Kentucky Mesonet, complemented by radar imagery, provides perspectives that enabled members of the Kentucky Drought Mitigation and Response Team to better understand the spatial structure and evolution of the drought of 2012. The map and graphs (Figure 6) below highlight variations in the intensity of the drought and timing of initial recovery. Recovery at locations in Clark, Adair, and Logan counties began

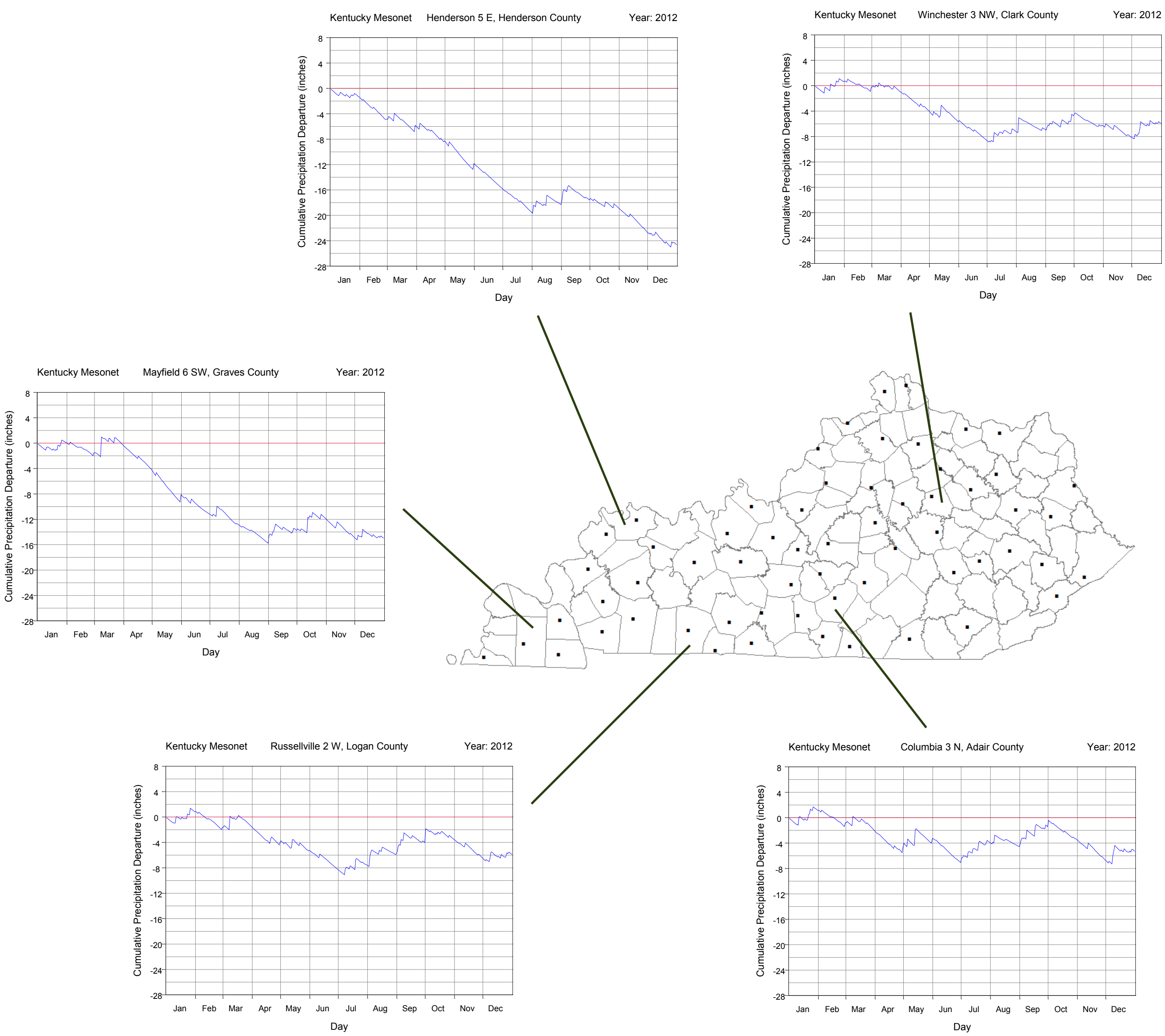

Figure 6. Cumulative precipitation anomalies from selected Kentucky Mesonet stations highlight important variations in the evolution and intensity of drought.

in early July, but rains did not return to Henderson County until early August, and they did not return to Graves County until early September.

The newest Kentucky Drought Mitigation and Response Plan, adopted in 2008, uses cumulative precipitation as a percentage of normal for time periods ranging from 60 to 180 days as triggers for determining drought intensity. To assist the drought monitoring effort, the Kentucky Climate Center used an inverse distance weighting algorithm to estimate daily precipitation normals for each Kentucky Mesonet station based on 1981-2010 climate normals produced by the National Climatic Data Center. These normals were then used to support development of a drought tracking tool as part of the Kentucky Mesonet website. The page enabled members of the Kentucky Drought Mitigation and Response Team, as well as the general public, to visually assess spatial variations in the intensity and evolution of drought. An example of the tool is shown below (Figure 7).

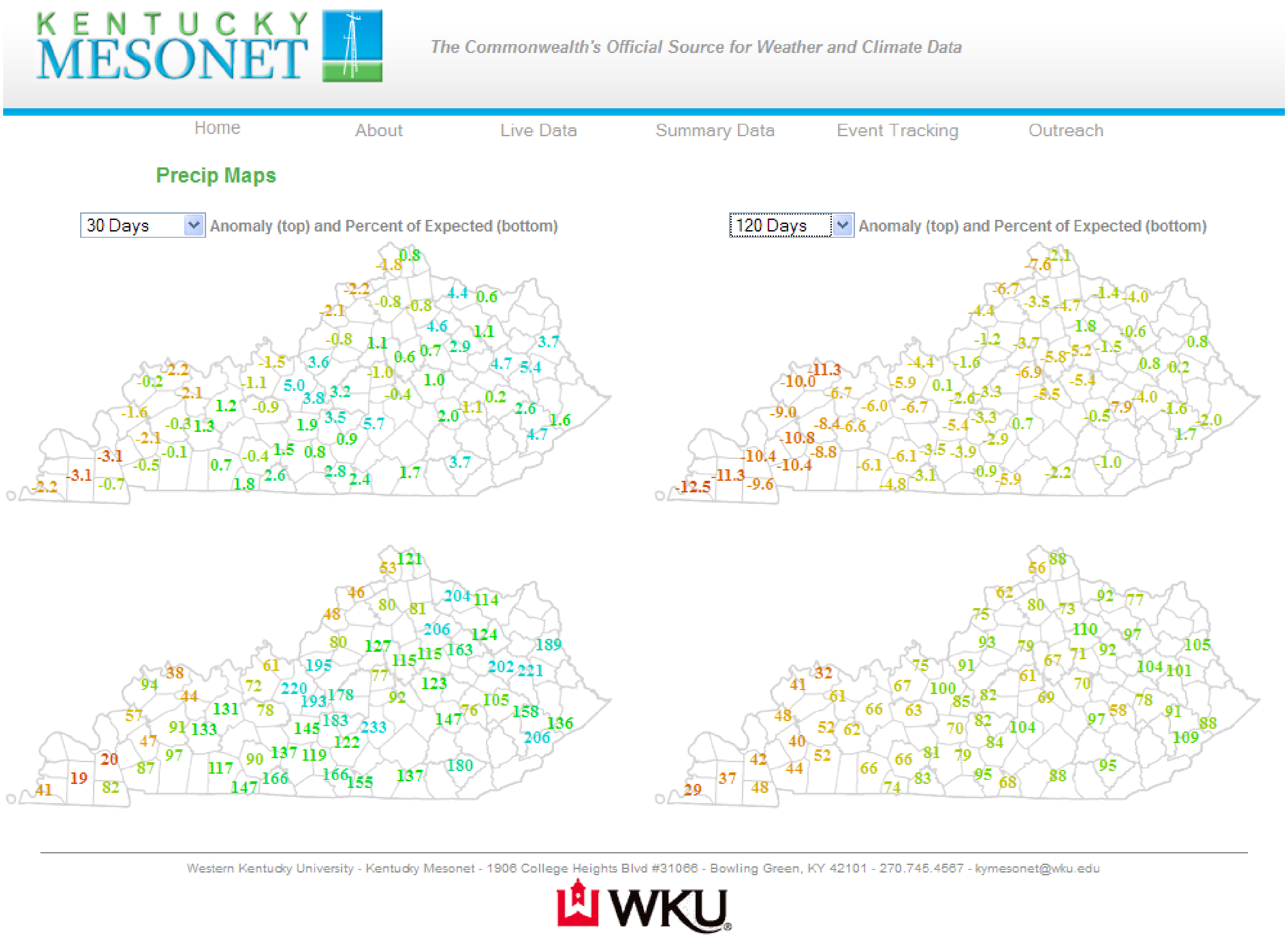

Figure 7. An example of the Kentucky Mesonet drought tracking tool reflecting conditions in early August 2012.

Section 3.7: MICHIGAN

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Weather conditions across Michigan and the Great Lakes region during 2012 included a series of extremes ranging from record warm early spring temperatures to severe drought conditions to flooding. The unusual weather presented serious challenges to many agricultural activities across the region. The 2012 growing season was preceded by an unusually mild winter across Michigan, with mean temperatures during the December through February period generally ranging 4-8°F above normal. The winter of 2011-2012 was marked by five consecutive months of above-normal temperatures back to October 2011, below-normal seasonal snowfall totals, and much above normal extreme coldest minimum temperatures. Although the relatively mild conditions resulted in relatively less winter/cold damage for overwintering crops, it also allowed a higher survival rate of some insect and disease pathogens that typically succumb to low temperatures during the season.

Perennial and overwintering annual crops in the region emerged from their protective dormant states much earlier than normal in 2012 because of an unprecedented heat wave during the middle of March. The March 2012 heat wave began in earnest on the 11th and continued through the 23rd of the month. At its peak during the third week of March, daily mean temperatures soared to 30-40°F above normal and observed minimum temperatures exceeded the normal maximum temperatures by more than 10°F. The heat wave resulted in many new climate records across the region. In Michigan, these included the warmest March ever for the state as a whole with a mean temperature of 44.4°F, which was 13.7˚F warmer than normal and 3.2˚F warmer than the previous record (1945). A new all-time state record was also set for warmest temperature ever in March, with 90˚F at Lapeer on the 21st. Growing degree day accumulations surged during the second and third weeks of March in response to the heat wave, quickly surpassing the levels of all other warm Marches, including the (previous) 1945 record. The heat wave led to rapid early growth and development of crops across the region. By late March, phenological development stages of most crops were at least four weeks ahead of normal, leaving them vulnerable to injury from freezing temperatures. On March 24-25, the upper air jet stream pattern that produced the heat wave broke down and was replaced by a troughing pattern across the north central United States, which led to the passage of a cold, dry Canadian air mass through the region and freezing temperatures over most areas on the mornings of March 26-27. Following the late March upper air pattern change, more than fifteen freeze events (including at least five with minimums below 28˚F) occurred across the region, including some of the advective variety in which subfreezing temperatures were accompanied by surface winds accentuating the magnitude of cold injury and causing fan-based frost protection equipment to be much less effective than is normally the case. Crop damage from the freezes in late March and April 2012 was severe across the region, especially to tree fruit, with losses of 90% or greater. The early warm-up also led to an abnormally early start of vegetative water use and the seasonal drawdown of soil moisture, which would turn out to be a critical factor later in the growing season.

Following relatively normal weather in late April and early May, a large upper air ridge of high pressure developed across the center of North America and persisted for much of June and July into early August (Figure 1). This feature led to persistent hot and dry weather across large portions of the Midwest and adjoining regions. Given the abnormally early start of the growing season, drought conditions developed rapidly across the central and southern Midwest and spread into Michigan during June. By mid-July, the percentage of the state experiencing drought conditions and/or abnormal dryness as defined by the U.S. Drought Monitor had grown to 82%. The area of severe or worse drought conditions expanded to 21%, and extreme drought conditions made their first appearance in a narrow area of southern Lower Michigan along the Indiana border. As of early August, three-month precipitation deficits ranged from 1 to 3 inches over central sections of the Great Lakes region to more than 6 inches across southern sections (Figure 2). Normal rainfall for this area is on the order of 8-11 inches and the time frame is usually among the wettest three-month periods of the year. Plant available soil moisture levels in the top 5 feet of the soil profile of affected areas during the same period fell to levels generally 1-5 inches below normal. The unusually dry conditions led to rapid use of soil moisture reserves and ultimately to water stress in many unirrigated crops. At that peak time of the drought, 81% of the Midwest region was classified as abnormally dry, with more than 69% experiencing some level of drought conditions. In more than 38% of the region, the drought conditions were characterized by the U.S. Drought Monitor as severe or exceptional. In southern sections of the state, the dryness was as intense as that recorded in 1988, the last major regionwide drought. Still, Michigan in general remained along the northern periphery of the most severe drought conditions, with much heavier and more frequent rainfall across northern sections of the state (some areas reporting more than 200% of normal values during the same time frame).

During the drought, Michigan had at least three major heat waves: the third week of June, the first week of July, and the third week of July, the second of which was the most severe and included many 100°F+ high temperature readings and a number of new records across the state (including some new all-time high temperatures). Another other critical factor during the 2012 growing season was an elevated rate of potential evapotranspiration (PET), the rate of combined plant transpiration and soil evaporation that potentially occurs under full sunshine when water is not limiting. A representative plot of accumulated

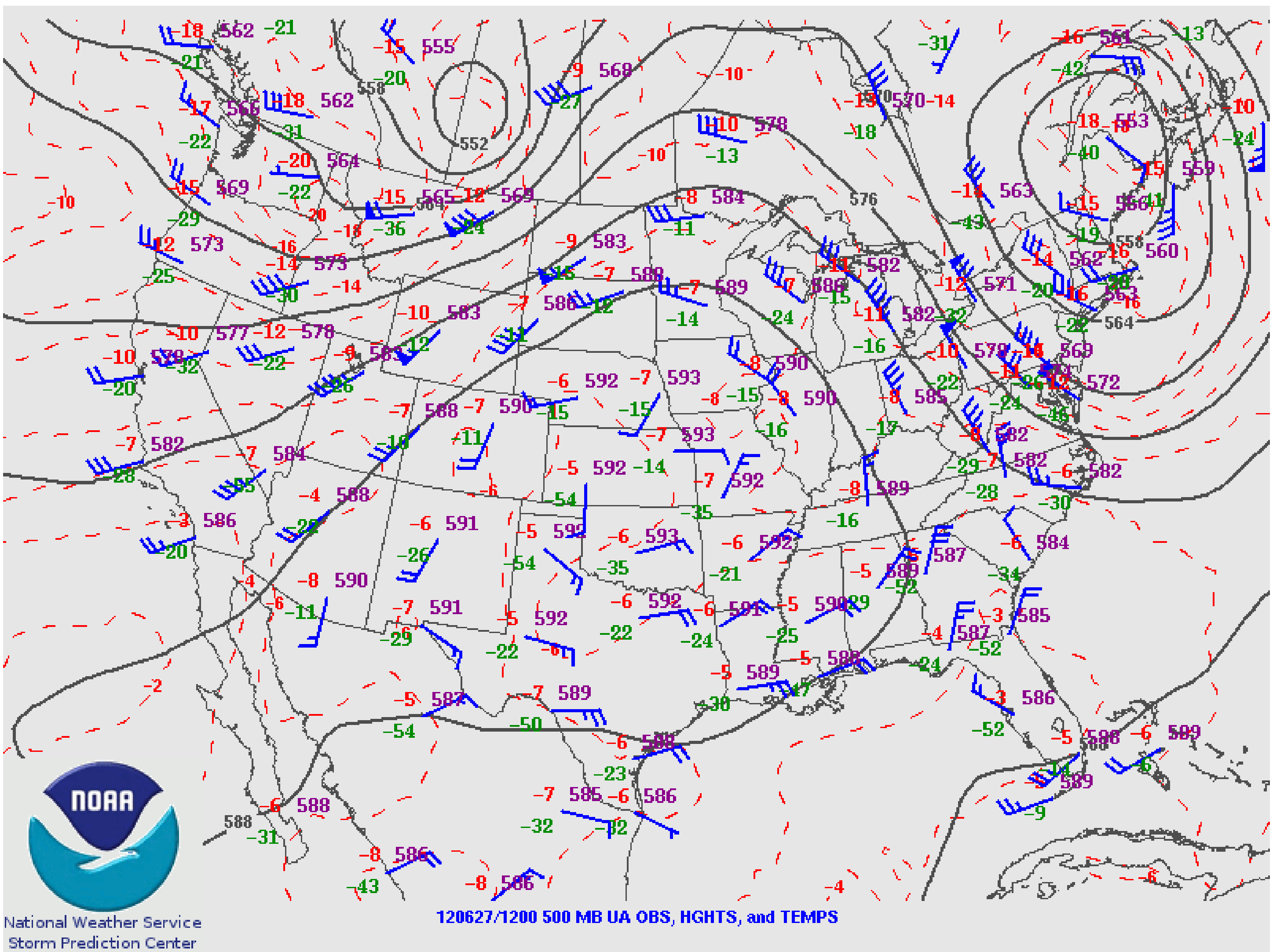


Figure 1. Air flow between 18,000 and 19,000 feet above sea level, June 27, 2012, at 8 AM EDT. Wind speed and direction are expressed in arrow/vector form at observing sites in blue (direction of arrow indicates direction, length of arrow depicts velocity). Solid black lines depict general pressure pattern and air flow (figure courtesy of National Weather Service Storm Prediction Center, http://www.spc.noaa.gov).

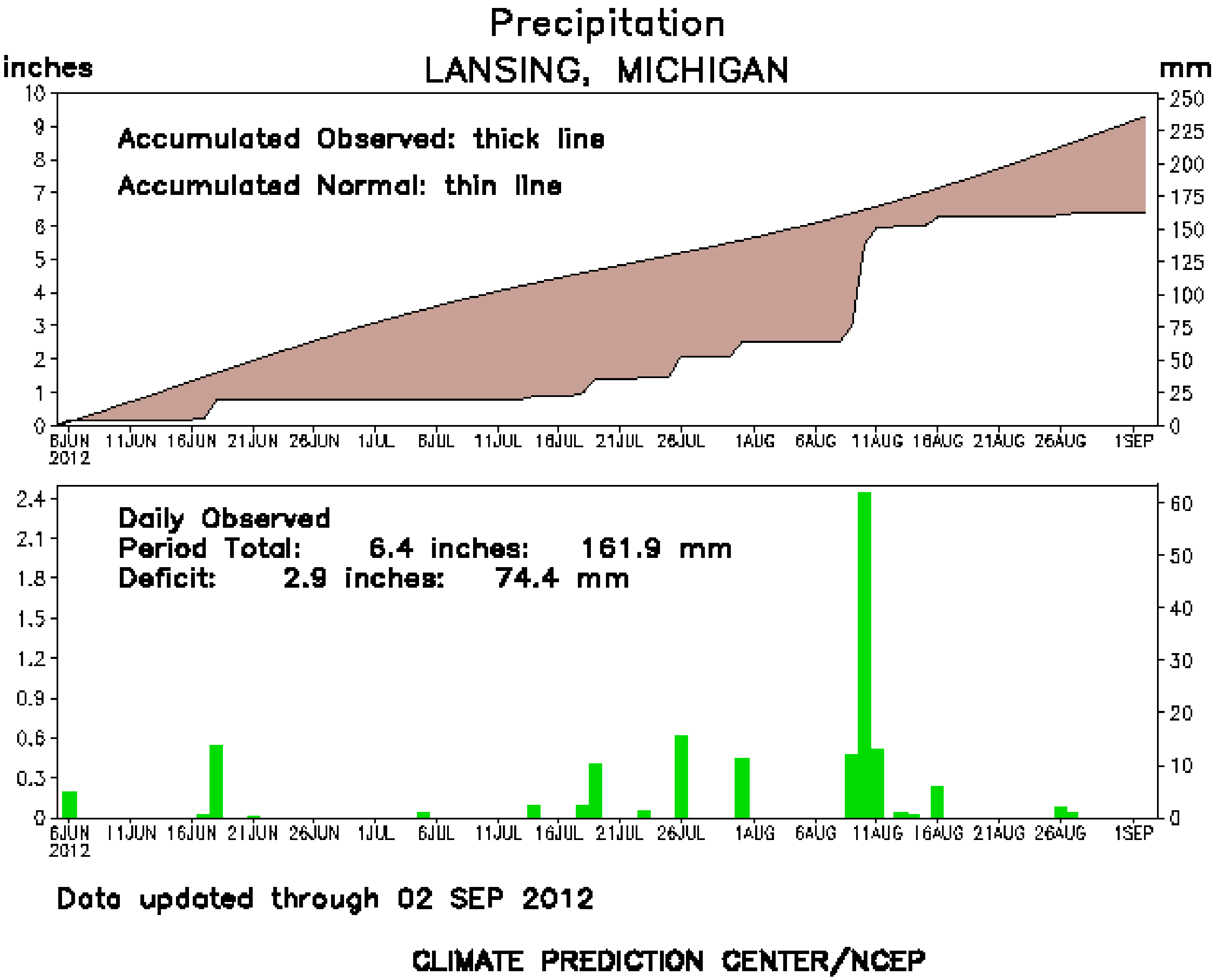


Figure 2. Daily precipitation totals (bottom) and accumulated precipitation totals (top) at Lansing, Michigan, June 5-September 4, 2012. In the top figure, accumulated precipitation surpluses are depicted in green and deficits in brown (figure courtesy of National Weather Service Hydrometeorological Prediction Center, http://www.cpc.ncep.noaa.gov/products/global_monitoring/precipitation/).

potential evapotranspiration for early May through early August for East Lansing relative to a long-term average is given in Figure 3. During the first half of the 2012 growing season, rates of PET far exceeded both actual evapotranspiration rates and normal PET rates. As can be seen in the figure, rates of PET were abnormally high beginning in the middle of May (the first half of that month was wetter and cloudier than normal), with a difference of 2.85 inches (21.6% above normal) by the last week of July. The difference during this period was due to several meteorological factors, including greater-than-normal solar radiation levels (8.5% greater than normal), higher air temperatures (3.1°F higher than normal), and lower humidity (10.6% lower than normal). Overall, in terms of crop water needs, this resulted in a "double whammy": Not only were soils generally not able to supply sufficient water to meet crop needs because of the extended dryness (topsoil moisture levels fell to or below wilting point levels [see Figure 4]), but rates of PET based on atmospheric conditions were significantly greater than normal this year, which exacerbated the impacts of the drought (Figure 5). To better understand geographic patterns of water availability and moisture stress over large areas, the USDA ARS's Hydrology and Remote Sensing Lab developed a new index

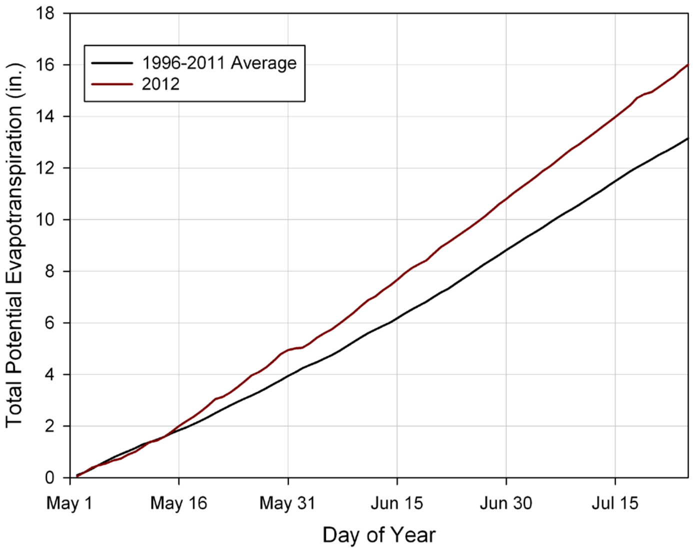


Figure 3. Observed potential evapotranspiration (PET) for May 1-July 24, 2012 (top line), versus the 1996-2011 average (bottom line) at East Lansing, Michigan. Data courtesy of the Enviroweather Project (http://www.enviro-weather.msu.edu).

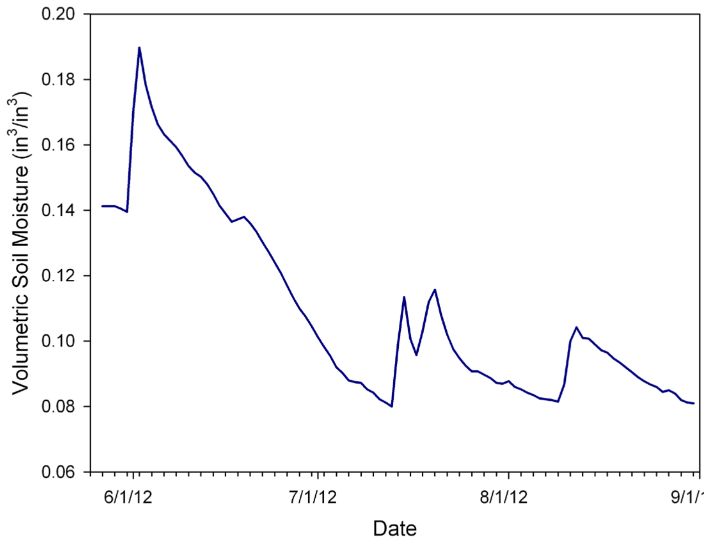


Figure 4. Average volumetric soil moisture (in3/in3) in the top 12 inches of the soil profile at East Lansing, Michigan, May 28-September 1, 2012. For reference, the soil at the site is Marlette fine sandy loam with a wilting point of approximately 0.10 in3/in3. Data courtesy of the Enviro-weather network (www.enviro-weather.msu.edu).

that depicts cumulative evaporative stress across the continental United States. An image of cumulative evaporative stress during July and early August is given in Figure 6. The index is based on the ratio of actual to potential evapotranspiration rates. If water available to plants on a given day is limited, the actual rate quickly falls below the potential rate, and the ratio for the day is relatively low. If water is freely available, the actual rate approaches or is close to the potential rate and the ratio is high. The index expresses this cumulative ratio in a standardized form, relative to a 10+ year historical data record. Thus, in the figure for the period July 8-August 7, 2012, brown-colored areas (low negative σ values) signify relatively higher levels of water stress while green denotes areas of relatively low water stress. The pattern of serious water stress across the central United States as a result of the drought (and relatively moist conditions across the Pacific Northwest) is striking. Interestingly, in Michigan, the major differences between relative abundance of moisture across northern areas and shortages in the south are also visible. For reference, major corn-producing areas of the country (as defined by USDA NASS) have been outlined in black. The standardized form of the index also allows some information about how often this level of stress would be expected to occur, which in this case suggests less than 5% of the time across much of the central Corn Belt. In terms of the growing season for corn, these unusually high levels of moisture stress generally occurred from late vegetative to pollination to early grainfill crop development stages.

In August, major changes in the upper air pattern across the region led to a general easing of drought conditions. During the second week of the month, the

Photo by Bruce MacKellar, MSU Extension

Figure 5. Cornfield at Decatur, Michigan, illustrating the effects of drought and heat stress on an unirrigated crop (foreground) in contrast to an irrigated crop (background), July 14, 2012.

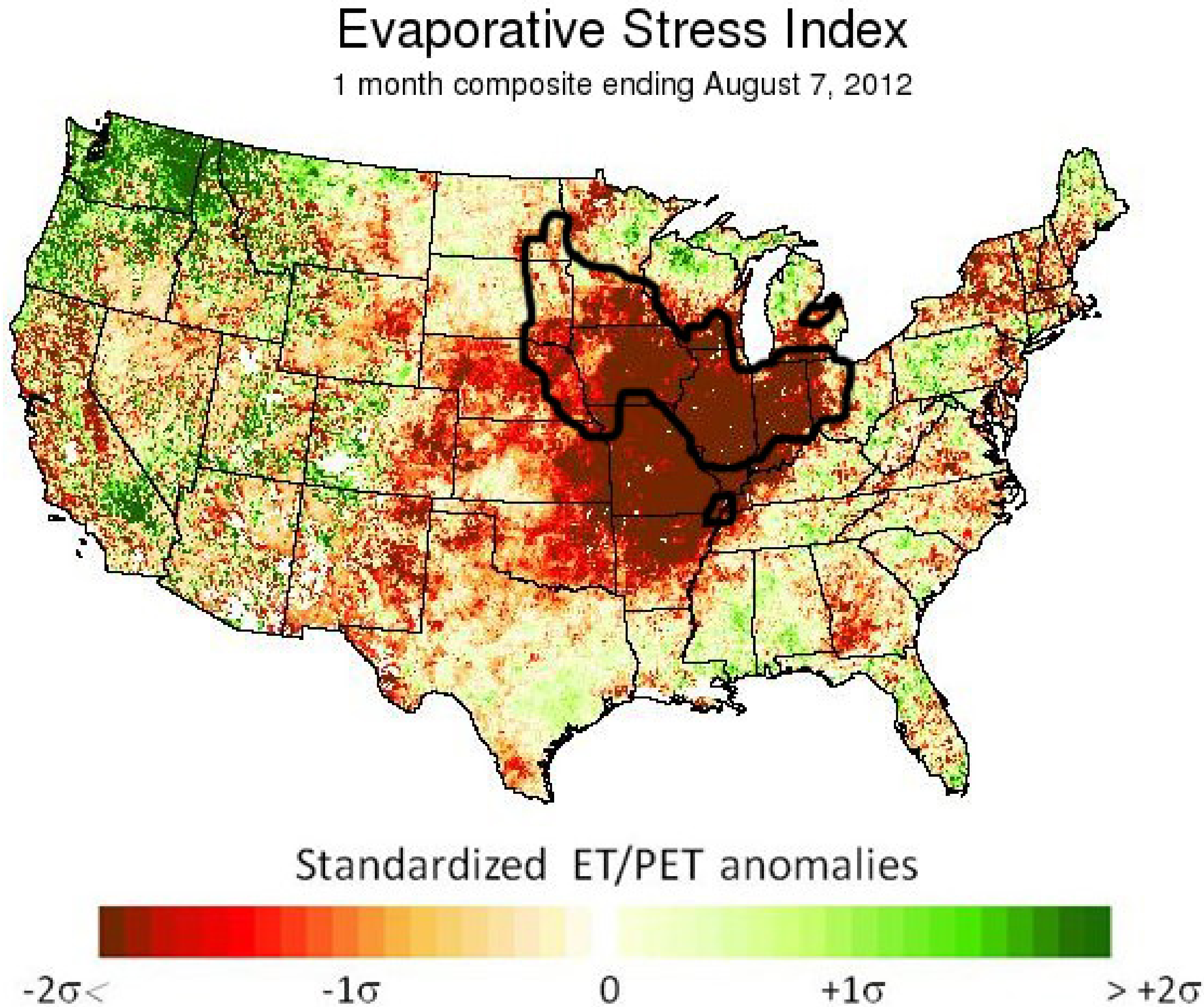


Figure 6. Evaporative stress index averaged over the period July 8-August 7, 2012. Brown-colored areas signify higher levels of water stress while green denotes areas of relatively low water stress. Major corn-producing areas (as defined by USDA NASS) are outlined in thick black line. Figure courtesy of the USDA ARS Hydrology and Remote Sensing Lab (http://hrsl.arsusda.gov/drought/index.php).

massive upper air ridge that had dominated weather conditions for much of the growing season flattened out, leaving Michigan under the temporary influence of southwesterly flow aloft and an active storm track through the region. This pattern change led to the passage of two major low pressure systems that brought significant rainfall (2-5 inches) to much of the region. In some cases (e.g., the Saginaw Valley region), heavy rains even led to localized flooding only hours after severe drought conditions had stressed crops. Subsequent rainfall in late August and early September (including the remnants of Hurricane Isaac) continued to help reduce the impacts of the drought, but long-term moisture deficits persisted into the fall season, especially across southern sections of the region.

Given a very mild winter season, the March heat wave, and a much warmer than normal summer, the first eight months of the year (January through August) were the warmest such period on record at most sites across the state. With slightly below normal average temperatures during September and October, 2012 ended up as the third warmest year on record (back to 1895) with a mean annual temperature of 48.2°F, just missing the all-time record of 48.4°F (in 1998) by 0.2° (the second warmest year on record was 1921 at 48.3°F).

Some Specific Impacts

Impacts of the 2012 drought varied greatly across Michigan. Agricultural impacts varied by both crop and soil type, with the most severe impacts on lighter, coarse-textured soils. Greatest overall agricultural losses due to the drought were observed across the southern three tiers of counties in the Lower Peninsula, especially along the Indiana border.

For some of the approximately 40% of Michigan residents who rely on well water for their households, the 2012 drought led to reduced-capacity or failed wells, leaving homeowners without drinking and bathing water or water for toilets. The groundwater level in some areas of the state dropped up to 40 feet by mid-summer. In areas where groundwater is relatively less abundant, links between well failure and nearby agricultural irrigation were observed, as irrigation wells are typically drilled much deeper than most home wells and have high pumping capacities, resulting in a potentially significant cone of depression in the local water table.

Economic losses associated with the drought were at least partially masked by relatively high commodity prices. The total value all crops sold in the state of Michigan for 2012 was $5.3 billion, which was an increase of $200 million over the 2011 value. For some individual crops, however, losses were significant. Corn production across the state dropped more than 17 million bushels relative to 2011, with a market value loss of more than $100 million. Forage crops were also severely impacted, with a 43.3% reduction in production relative to 2011. Low feed supplies led to much higher than normal prices, with mixed grass/alfalfa hays selling for $300-380 a ton by year's end. The reduced feed inventory and increased pressure for acres from commodity crops (corn, soybeans, and wheat) hindered producers' efforts to replenish hay stocks. Low feed stocks and high feed prices also caused many livestock feeders to eliminate breeding herds. In contrast, some crops benefitted from the abnormally hot, dry weather. Sugarbeet yields in the state averaged 29 tons per acre with total production of more than 4.4 million tons, increases of 5 tons per acre and 0.8 million tons over 2011. Average soybean yields of 43 bushels per acre were down slightly from 2011 levels of 44 bushels per acre, but production increased by 200,000 bushels owing to greater harvested area. Soybean production would have been much lower without the significant mid-August rain that fell across many of the state's major production areas.

On August 29, U.S. Secretary of Agriculture Tom Vilsack announced a natural disaster declaration for all of Michigan's 83 counties due to losses caused by drought and excessive heat that began on March 1, 2012. The declaration made farmers in Michigan eligible to be considered for assistance from the Farm Service Agency (FSA), including FSA emergency loans.

State Climate Office Response to the Drought

The State Climatology Program in Michigan is responsible for providing weather- and climate-related information and professional expertise to the general public. This outreach activity takes a wide variety of forms, including the dissemination of weather and climate data and information through print and internet media, public speaking engagements, professional consultation, continuing education activities, and interviews with the news media. During 2012, the office provided:

- 29 speaking engagements (a new record high)
- 69 interviews with media (a new record high)
- 10 Weather/Climate updates published in the MSU Extension News for Agriculture Update
- 1 article for an industry trade journal

Section 3.8: MINNESOTA

Greg Spoden
State Climatologist
Minnesota Department of Natural Resources

Overview

Minnesota was on the northern periphery of the devastating drought that impacted much of the Midwest and Great Plains during the 2012 growing season. An early planting season, heavy May 2012 precipitation, and well-timed summer rainfalls permitted Minnesota to avoid the worst of the drought impacts endured by its neighboring states. Nonetheless, excessive heat and significant precipitation deficits shaped a drought story in Minnesota in 2012, a story that lingered into early 2013.

Drought Chronology, Impacts, and Actions

Autumn 2011

Minnesota's 2012 drought was spawned during the autumn of 2011. Significant late-summer and autumn precipitation shortfalls in 2011 led to rapidly deteriorating hydrologic conditions. Precipitation totals from August through November were less than 3 inches in many areas, a negative departure from the long-term average of 5-9 inches. Autumn 2011 precipitation totals ranked among the driest autumns in the historical record. By late October 2011, nearly every Minnesota county was depicted by the U.S. Drought Monitor as undergoing some level of drought. Dry, hard soils made autumn tillage difficult and heightened concerns about the soil moisture profile for the 2012 growing season.

Winter 2011-2012

The 2011-2012 winter was mild and snow-sparse. The state-averaged temperature for the meteorological winter ranked among the warmest ever. The scarity of snow had negative connotations for the outdoor recreation industry, but eased municipal snow removal costs and allowed year-round outdoor construction activity. By February 2012, drought concerns for the upcoming growing season inspired the Minnesota Department of Natural Resources (MNDNR) to begin collecting contact information of those agencies, organizations, and industries interested in participating in a state drought task force. In February, the MNDNR required Minnesotans to obtain permits for open burning, a rare occurrence during the winter when snow cover typically eases wildfire threats. Also in February, the Minnesota Department of Agriculture issued a press release encouraging Minnesota farmers to consider purchasing all-hazard crop insurance ahead of the March 15 deadline.

Wildfire near Leech Lake, Minnesota, February 2012

Spring 2012

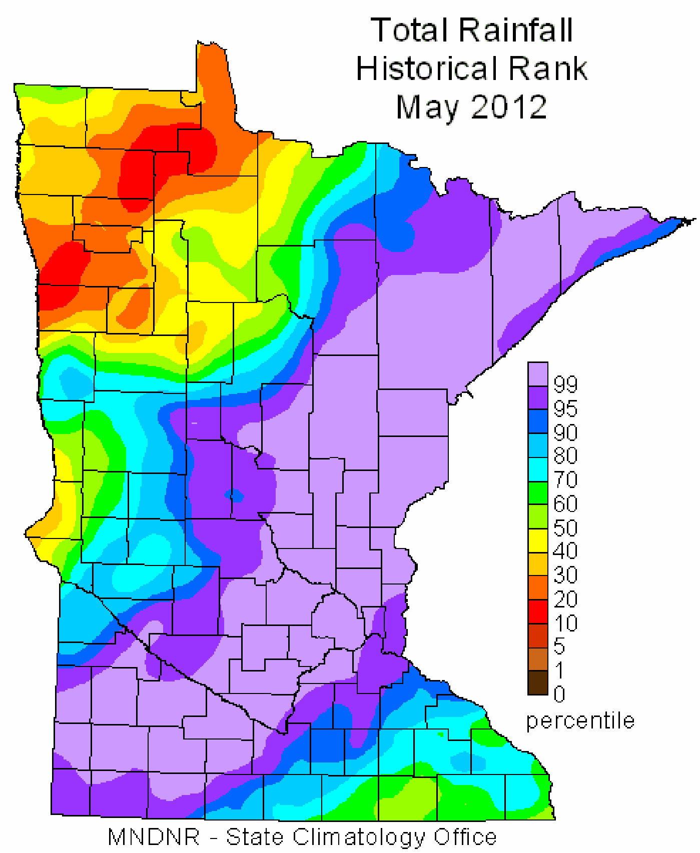
Minnesota's monthly mean temperatures for March 2012 were astoundingly warm, topping the historical average by 10-17 degrees across the state. It was Minnesota's, and the nation's, warmest March of the modern record. The extraordinarily warm weather led to rapid drying and advanced signs of spring, such as perennial plant development and lake ice out by three to four weeks earlier than average. By late March, lake, river, and wetland levels were notably low. Reports indicated short or very short topsoil and subsoil moisture for more than half the state. In late March, the MNDNR convened the State Drought Task Force via web conference. It was the first time the task force had met since 2007. Information was shared regarding hydrological and agricultural conditions and prospects for the coming growing season.

In early April 2012, the MNDNR activated its Mississippi River Low-Flow Management Plan. The plan recognizes that hydropower operations and adjustments to reservoir control structure gates have the potential to cause large percentage changes in river flow. Large flow fluctuations, especially during periods of low flow, can have significant negative impacts on instream fish and wildlife, and create water supply problems for downstream users. The purpose of the low-flow plan is to help ensure that "run-of-river" operations are maintained during periods of low flow to minimize artificial flow fluctuations and protect the aquatic resources and other values of this important river.

In most Minnesota spring seasons, a hard freeze during the second week of April is not noteworthy. However, on April 10, for the first time since mid-March, temperatures fell below freezing across central and southern Minnesota. The cold temperatures damaged early-blossoming apple orchards, eventually leading to yield reduction.

April 2012 precipitation totals were near, to above, normal across Minnesota. It was only the second month since July 2011 that monthly precipitation totals were near to above average. Adequate to abundant April precipitation totals somewhat improved Minnesota's drought situation. The topsoil laid first claim on the moisture, and spring prospects for agricultural and horticultural interests improved significantly. However, subsoil moisture content in some areas remained deficient because of multi-month precipitation deficits. Also, water levels on many lakes, rivers, and wetlands, as well as some aquifers, remained below average.

Very heavy rainfall in May 2012 differentiated Minnesota from its Corn Belt and Great Plains neighbors. The heavy rainfall eliminated drought conditions across much of the state and created a reservoir of soil moisture and surface water reserves that were to eventually mitigate the impact of a hot and dry summer. Unlike most of the central United States, Minnesota's state-average May precipitation total was well above average. On a statewide basis, May 2012 was the fourth wettest May of the modern record. While April-plus-May precipitation totals were abnormally large in most counties, the northwest corner of the state failed to receive the heaviest of the rains, and drought lingered in the northern Red River Valley.



Summer 2012

June 2012 monthly precipitation totals created a hodgepodge of very wet and very dry conditions across Minnesota. Two exceptionally heavy and destructive rainfall events in northeastern and southeastern Minnesota resulted in monthly rainfall totals that exceeded 10 inches, more than doubling the historical average. By contrast, rainfall totals across much of the rest of Minnesota, especially the southern two tiers of counties and some sections of northwestern and north central Minnesota, were short of the historical average by 1-4 inches. Late-month dry and hot weather led to an expansion of the areas deemed be undergoing drought conditions and topsoil moisture deficiencies. Stream discharge values for many basins in northwest Minnesota ranked below the 10th percentile by month's end. Nonetheless, late-month reports indicated that 70-80% of Minnesota's corn and soybean crop was said to be in good or excellent condition. This was a signficantly higher percentage of favorable conditions than those reported in other Corn Belt states at that point in the season.

July 2012 in Minnesota was dry and hot. Monthly precipitation totals were very low, especially in

Photo by Duluth News Tribune

Flood damage in Duluth, Minnesota, June 2012

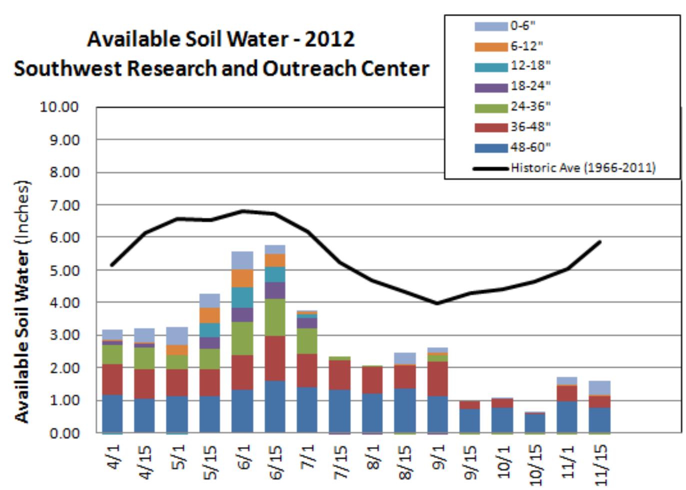
southwestern counties. July rainfall totals were well under an inch in the driest areas. In many Minnesota communities, monthly rainfall amounts fell short of the historical average by 1.5-3 inches. Monthly mean temperatures for July 2012 were 4-7° above average across the state. It was Minnesota's second warmest month in the modern climate record and the 10th consecutive month of above-normal temperatures.

Moisture deficits in southern Minnesota developed rapidly because of the hot, dry conditions in late June and throughout July. On July 31, the U.S. Drought Monitor placed many northwestern and southwestern Minnesota counties, and portions of southeastern Minnesota, in the severe drought category. Water levels on many Minnesota lakes fell in response to the dry, hot weather, and unusually warm lake water temperatures (near 90°F) were responsible for some fish kill. Late-July stream discharge values were very low across the state. In northwest Minnesota, stream flow measurements neared the lowest on record. In their July 29 report, the Minnesota Agricultural Statistics Service reported that topsoil moisture was 18% very short and 32% short. Nevertheless, 55-60% of Minnesota's corn and soybean crop was said to be in good or excellent condition in late July, presumably tapping soil moisture reserves established in May.

On July 24, the commissioner of the Minnesota Department of Agriculture convened a "drought roundtable". The gathering brought together representatives from a wide range of agricultural interests, including producer groups, state and federal agencies, state legislators, and the governor's office. The commissioner's goal was to hear from the producer groups about their immediate drought-related concerns and to offer assistance where possible. There was recognition of the high variability of drought impacts across the state. Much concern was expressed for livestock producers, specifically related to the availability and cost of feed.

In early August, it was announced that the U.S. Department of Agriculture had designated primary natural disaster areas that included Rock, Pipestone, Murray, and Nobles counties of Minnesota. These counties qualified for federal relief, including low-interest loans and the release of Conservation Reserve Program acres to more haying and grazing. In early August, landscapes with coarser textured soils were obviously stressed. Pasture conditions were degrading, some alfalfa fields had offered only one cutting, and some growers were making decisions on harvesting drought-stressed corn for forage. Yet, it remained apparent that on the whole, Minnesota farmers continued to escape the worst of the Midwestern drought impacts. Yield estimates for small grains in northwest Minnesota were surprisingly good, and projections for corn and soybean yields statewide remained cautiously optimistic.

With a few exceptions, August 2012 monthly precipitation totals were very low across Minnesota, especially in the eastern half of the state. Moisture deficits in southern Minnesota continued to develop because of very hot and very dry summer conditions. For the three summer months, rainfall totals in many Minnesota counties fell short of average by 4 or more inches, the climatological equivalent of missing an entire summer month's worth of precipitation. Stream



flow values at the end of August ranked below the 10th percentile in many watersheds. Topsoil moisture at month's end was reported to be 63% short or very short. Soil moisture measurements from University of Minnesota Research and Outreach Centers indicated extraordinarily dry conditions in the top 3 feet of the soil profile. In some Minnesota communities with high clay-content soils, shifting soils due to contraction led to the damage of home foundations. By late August, wildfire potential was rated by the MNDNR as high or very high in the northern half of Minnesota.

Intererestingly, the drought situation created advanteagous conditions for scientific investigations involving low stream flow. Low flow on the Minnesota River allowed the Minnesota Pollution Control Agency to more effectively monitor dissolved oxygen levels. The U.S. Geological Survey capitalized on minimal summer surface water runoff to study groundwater contributions to Mississippi River flow along a high population growth corridor north of the Twin Cities.

Autumn 2012

By early autumn, the geographic core of the 2012 drought was moving westward and northward. Heavy rains accompanying Hurricane Isaac led to drought relief in Missouri, Illinois, and Indiana. Meanwhile, drought conditions were worsening in Minnesota. September 2012 was the driest September on record in Minnesota. By the end of the month, all or parts of 45 of Minnesota's 87 counties were said to be undergoing severe or extreme drought. Soil moisture measurements made in late September at University of Minnesota Research and Outreach Centers indicated extraordinarily dry conditions in the soil profile. Soil moisture content in the top 5 feet of soil at these locations was less than 2 inches, near or below all-time record lows for mid-autumn. The potential for wildfires was explosively high and the very dry conditions, combined with a number of windy days, led to several wildfire outbreaks. In September, urban foresters expressed concern for drought-stressed trees, especially newly planted trees, and strongly encouraged watering.

The U.S. Geological Survey and MNDNR reported extremely low stream discharge values in late September, in some cases approaching the lowest on record. Water levels on many Minnesota lakes were very low as well. In an effort to safeguard water availability for instream uses and for downstream higher priority users, the MNDNR suspended 16 surface water appropriation permits across the state. The suspended permittees included a mining operation, golf courses, a sugar processing plant, and other public and private sector entities. At the request of the MNDNR, the National Weather Service North

Mississippi River near Clearwater, Minnesota, September 2012

Central River Forecast Center began providing low flow forecasts for points along the Upper Mississippi. These forecasts assisted hydropower dam operators and other stream flow-sensitive decision makers along this stretch of river.

Minnesota's drought situation continued to deteriorate in October 2012. The intensity and geographic distribution of the drought began to rival the extreme drought event of the late 1980s. Once again, monthly precipitation totals fell well short of average. All or parts of 55 counties were determined to be in severe or extreme drought at the end of October. By month's end, roughly 50 surface water appropriation permits had been suspended by the MNDNR. The MNDNR convened the State Drought Task Force in early October to exchange information among the public and private sector participants. In mid-October, the MNDNR contacted Minnesota's community public water suppliers to ask them to implement drought contingency measures and promote water conservation to their customers. In areas rated in the severe and extreme drought categories, public water suppliers were asked to implement water use reduction actions with a goal of reducing water use to 50% above January levels. Also in mid-October, the MNDNR initiated a statewide media campaign to encourage Minnesotans to conserve water, reminding citizens that water conservation is especially important during drought.

With little or no surface runoff, and suppressed base flow due to very little seasonal groundwater recharge, late October stream flow was historically low in some southern Minnesota watersheds. Lake levels were also very low and fisheries managers began to express concerns for potential fish winterkill in shallow lakes. A handful of well interference complaints were filed with the MNDNR when private wells went dry and neighboring production wells were suspected of amplifying the problems related to the drought.
Despite the persistently dry summer weather and worsening autumn 2012 drought conditions, row crop yield estimates released during the October harvest indicated a solid production year, nearly reaching trend expectation for corn and soybeans. Minnesota's farmers avoided the worst of the central U.S. growing season drought conditions and benefited from high grain prices.

November 2012 was yet another dry and warm month in Minnesota, and the drought situation deepened in intensity and spread in geographic extent. By late November, 83% of Minnesota's landscape was undergoing extreme or severe drought. This was double the Minnesota land area reported in the extreme or severe drought categories at the start of November. For large portions of Minnesota, July-November 2012 precipitation totals ranked at or below the lowest on record. Drought impacts are not readily apparent in Minnesota in the late autumn. However, concerns were already growing for the 2013 growing season. The Minnesota Agricultural Statistics Service reported that subsoil moisture was 88% short or very short. Typically, Minnesota's soils freeze during the winter and relatively little overwinter precipitation infiltrates into the soil moisture profile. Therefore, by late November it was becoming clear that Minnesota would be highly dependent on abundant 2013 spring rains to avoid major problems involving public water supply, agriculture, horticulture, and tourism.

Services Provided in Response to the Drought

During periods of drought, the Minnesota State Climatology Office (MNSCO) and Minnesota's National Weather Service Forecast Offices (NWSFOs) are frequently called upon as information resources. Drought-related inquiries from the media to the MNSCO alone numbered in the hundreds in 2012. The MNSCO and NWSFOs staff provided regular input to the authors of the weekly U.S. Drought Monitor (USDM). Using the USDM as a primary talking point, the MNSCO and the NWSFOs created web articles, newsletters, and weather wire releases describing drought conditions and their impacts. Working with partners such as the Midwestern Regional Climate Center, University of Minnesota Extension Service, Minnesota Department of Agriculture, and USDA NASS to prepare drought information, the MNSCO and NWSFOs reached a broad audience.

Lessons Learned

Minnesota is facing increased pressure on its water resources. This pressure is accentuated during drought. Minnesotans used a record amount of water in 2012. Even in a water-rich state such as Minnesota, conflicts over water emerge during dry periods. Examples of water issues or developments associated with the 2012 drought include the following.

- Some wells ran dry because of the combined impact of drought and adjacent high-capacity wells drawing from the same aquifer. Roughly one dozen "well interference" complaints were filed with the MNDNR.

- Homeowners along the shores of White Bear Lake, one of the Twin Cities' premier lakes, filed suit against state government, charging regulators with allowing an unsustainable amount of groundwater to be appropriated by nearby municipalities, which resulted in a shrinking lake surface.

- For the first time, Minnesota state regulators plan to experiment with stricter rules that will require some local communities to allocate water.

- Agricultural irrigation is now the second largest user of groundwater in Minnesota. Two hundred crop watering permits were issued in 2012, twice the number from the previous year and reflecting an upward trend in irrigated acreage.

- In autumn 2012, some southwest Minnesota communities imposed emergency water restrictions, banning outdoor watering for the first time in decades. Communities in these areas are reevaluating their water supply plans and water regulations.

- In 2013, the State Legislature, influenced by the 2012 drought, allocated an additional $7 million for groundwater monitoring and management programs.

Photo by John Flesher

Stranded boat on a drying up lake in Minnesota in November, 2012.

Section 3.9: MISSOURI

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State Climatologist
Commercial Agriculture Program

Missourians faced an extremely challenging year in 2012 when a dry spell emerged at the start of spring and evolved into a historic drought by the end of summer. More than two-thirds of the country was immersed in drought as summer progressed, a situation not experienced in nearly 60 years. Missouri and Kansas were the epicenter of the drought, with extreme to exceptional drought conditions extending from Utah to Indiana, and South Dakota to Texas, in July and August. Missouri's first form of widespread relief occurred on the last day of August when remnants of a tropical system brought significant rainfall to much of the state. Unfortunately, by then, significant drought damage had occurred.

Unusually dry conditions had evolved over the bootheel region and parts of west central Missouri in April, and spread across the rest of the state after the first week of May. May is typically Missouri's wettest month, but in 2012 conditions were unusually dry, warm, and cloud-free. Some locations in northeast, central, and east central Missouri went 24 consecutive days (May 8-31) with less than 0.10 inch of rain. Some of the lowest monthly totals were in southeastern Missouri, where Perryville and Poplar Bluff reported 0.40 and 0.30 inch, respectively.

Numerous sunny days in May and June, coupled with above-normal temperatures and below-normal relative humidity, led to unusually high moisture loss from soils, water surfaces, and vegetation. The high evaporative losses, in combination with lack of rainfall, resulted in a "flash drought" across the state, and impacts rapidly emerged. Reports of deteriorating pastures, declining soil moisture reserves, limited stock water supplies, and crop stress increased significantly as May progressed. Homeowners' lawns began turning brown and irrigation was going at a summerlike pace in many locations.

May 2012 ranked as the seventh driest May on record for Missouri (tied with 2005), with a statewide average total of 2.25 inches, or more than 2.5 inches below normal. It was also Missouri's fourth warmest May on record (+5.2°F), and warmest May since 1987. A seasonal temperature record for spring was also established with a March-May average temperature of 62.0°F (+7.8°F), smashing the previous record spring warmth, set in 1977, by an incredible 3°F. Unprecedented mild March weather (+14.2°F) contributed largely to the record-breaking spring.

By the end of June, one of the worst droughts in nearly 25 years was affecting Missouri, and many sectors were feeling the stress from lack of rain and sweltering temperatures. Precipitation data indicate June 2012 was the sixth driest June on record for Missouri and the driest June since 1988. Statewide average June rainfall was less than 2 inches, or nearly 3 inches below normal. The combined May-June average rainfall for the state was 4.18 inches, making it the sixth driest May-June period on record and the driest May-June period since 1988. Extreme heat during the last week of June exacerbated the stressful conditions, with many locations reporting triple-digit heat and record temperatures. The last time Missouri experienced triple-digit heat in June was 1988. On June 28, several communities reached all-time high temperature records for the month of June, including St. Louis, Columbia, Rolla, and West Plains, with 108, 107, 106 and 106°F, respectively.

Grass fires increased during June and burn bans were imposed across the state. Toward the end of the month, a forest fire in the Mark Twain National Forest burned 600 acres in Iron County. According to the Missouri Agricultural Statistics Service, by the end of June, 97% and 93% of the topsoil and subsoil moisture supplies, respectively, were in short to very short condition. And pasture conditions had declined to 76% poor to very poor.

Unrelenting dryness and extreme heat persisted through July. The average statewide temperature for the month was 84.0°F, or 6.5°F above normal. It was the hottest July for Missouri since 1936 and the fourth hottest July on record. July rainfall was paltry for the state, with a statewide average total of 1.58 inches, or 2.24 inches below normal for the month. It was the seventh driest July on record, and the driest July since 1970. Generally, west central and southwestern Missouri received the least amount of rain, with less than 0.50 inch reported in many locations. Several counties in far southwestern Missouri reported less than 0.25 inch for the month.

Drought impacts continued to mount in July. Hydrological issues such as dry wells and stream beds, low river levels, and rural and urban water restrictions were increasingly common. Even with burn bans in place, grassfires and forest fires were reported. The extreme conditions were adversely affecting gardens, lawns, trees, and shrubs, with numerous instances of vulnerable species succumbing to water and heat stress. Wildlife was affected by the lack of healthy vegetation and dwindling water resources. Numerous trees appeared stressed along river bluffs, or on hilltops, looking more autumnal than their typical summer green.

By the end of July, and according to the National Agricultural Statistics Service, Missouri had the distinction of having the worst corn, soybean, and pasture conditions in the United States. Soil moisture reserves were abysmal, with 99% of the topsoil and subsoil reported in short to very short condition. Water supplies were dwindling and river and stream flow levels were bottoming out.

The historic drought affecting Missouri intensified over portions of the Show Me state in August, as significant and widespread moisture relief was not realized until the remnants of Hurricane Isaac spiraled northward into southern Missouri on the last day of the month. The tropical system lingered in Missouri for much of Labor Day weekend and brought widespread drought relief in the form of a steady rain falling over multiple hours. Even with the remnants of Isaac, it was the third warmest and third driest May-August period on record for Missouri (Figures 1 and 2). Only May-August 1934 and 1936 were warmer (Figure 1) and May-August 1901 and 1936 were drier.

Cooler September temperatures in Missouri, in combination with rain events, mitigated the drought conditions affecting the state, but by no means eliminated it. Preliminary temperature data indicate a statewide average temperature of 67.2°F, or slightly more than 1°F below normal. The cooler-than-normal month broke a string of 11 consecutive months with above-normal temperatures for Missouri. The Labor Day weekend rains provided a small boost for soybean

Missouri May-Aug Average Temperature (1895-2012)

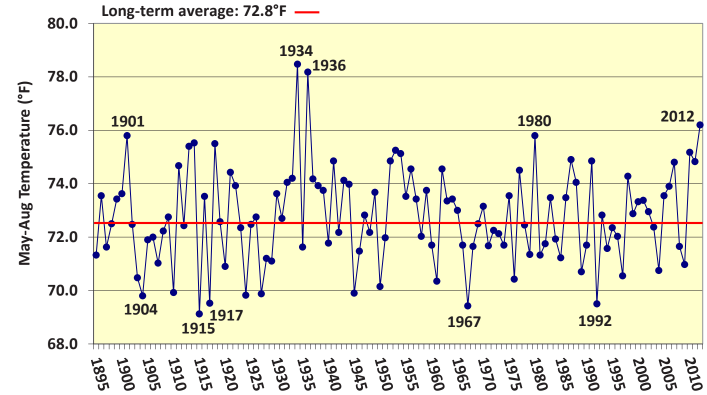

Figure 1.

Missouri May-Aug Average Precipitation (1895-2012)

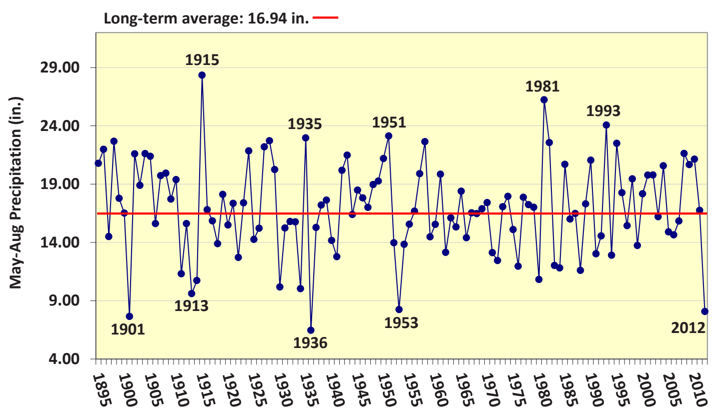

Figure 2.

Effects of 2012 Drought on Missouri Agriculture * (as of 10/31/12)

	Baseline (drought included)	Scenario (no drought assumed)	Absolute change from ????
2012/13 Crop Yields	**(Tons per harvested acre)**		
Corn	75.0	145.9	-70.9
Soybeans	30.0	41.3	-11.3
Hay (tons)	1.25	1.93	-0.68
2012/13 Crop Production	**(Million bushels or tons)**		
Corn	251.30	503.20	-251.9
Soybeans	157.50	219.90	-62.4
Hay (tons)	4.60	7.00	-2.5
2012/13 Crop Prices	**(Dollars per bushel or ton)**		
Corn	7.85	4.46	3.40
Soybeans	15.00	13.19	1.81
Hay (tons)	115.87	91.37	24.50
2013 Animal Inventory	**(Thousand head)**		
Cattle and calves	3,694	3,861	-168
Beef cows	1,808	1,872	-65
Dairy cows	87	87	0
Sows	352	359	-8
Cash Receipts	**(Billion dollars)**		
Crops, 2012	5.47	5.80	-0.33
Crops, 2013	5.47	5.52	-0.04
Livestock, 2012	4.39	4.06	0.33
Livestock, 2013	4.39	4.20	0.19
Farm Income	**(Billion dollars)**		
2012	2.70	3.77	-1.07
2013	3.70	2.99	0.71

* Information provided by Dr. Scott Brown, Agricultural Economist, University of Missouri.

Class A Pan Evaporation Apr-Sep HARC*, New Franklin MO 1956-2012

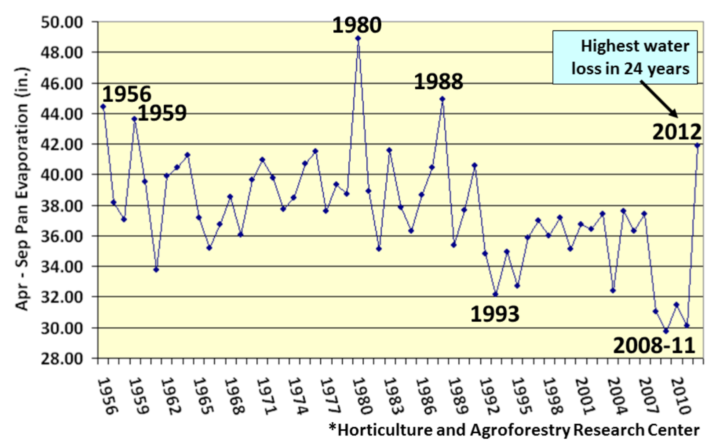

Figure 3.

yields, but, unfortunately, the agricultural damage had mostly been done. An income assessment of the effects of the 2012 drought on Missouri agriculture is given in Table 1, but does not cover all facets of the agriculture sector.

A combination of numerous sunny days, low humidity, and high temperatures during the growing season created the largest evaporative losses in a generation. Class A evaporation pan monitoring at University of Missouri research farms indicated the highest surface water evaporation totals since 1988 in central Missouri (Figure 3) and 1980 across southern sections of the state.

Varying periods of warm and cool weather, and the lack of any widespread killing freeze for most of October, allowed additional vegetative growth and green-up of lawns and pastures across the state. Topsoil moisture conditions improved across southwestern, south central, and northeastern sections where above-normal rainfall totals of 4-6 inches were common. Below-normal October rainfall occurred over northwestern and west central sections and a few

Photo by Pat Guinan

Columbia, Missouri

southeastern counties, where less than 2 inches were reported for the month. Long-term severe and extreme drought conditions were still affecting northwestern, central, and far southeastern Missouri toward the end of October, where year-to-date deficits were 8-12 inches.

Statewide temperatures averaged above normal in November and December, similar to the annual trend, making 2012 the warmest year on record (Figure 4). Below-normal precipitation fell during the last two months of the year, also not deviating from the annual trend, and ranking 2012 the seventh driest year on record and driest year since 1980 (Figure 5).

Missouri Annual Average Temperature (1895-2012)

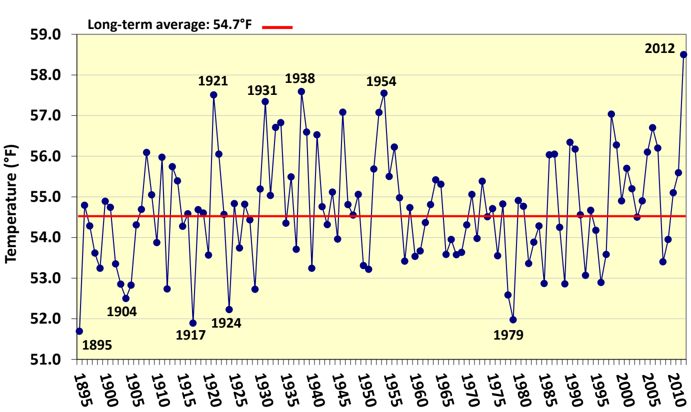

Figure 4.

Missouri Annual Average Precipitation (1895-2012)

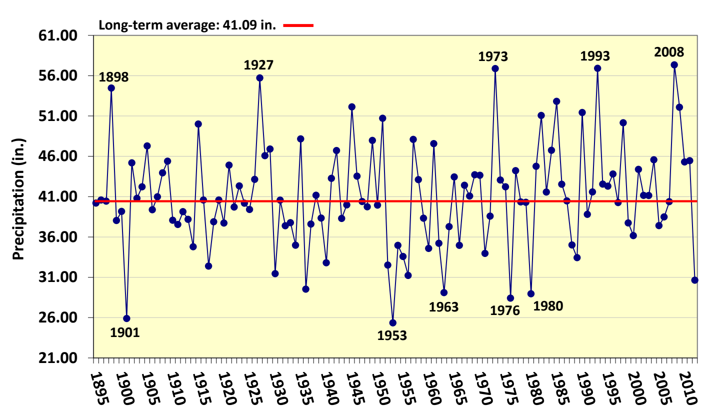

Figure 5.

NOTE: In Figures 1-5, departures from normal are based on the long-term average period, 1895-2012.

Section 3.10: NEBRASKA

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High Plains Regional Climate Center
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Drought Overview

At the beginning of the year, there was little indication that the drought of 2012 would develop and emerge as a significant natural disaster. By the end of 2012, Nebraska was being impacted significantly by drought, with 100% of the state in drought and a little more than 96% in extreme drought or worse according to the U.S. Drought Monitor. Dry conditions had allowed drought to develop in the eastern part of the state in the fall of 2011, which meant that as 2012 began, about 14% of the state was in drought, mainly the eastern third of the state. The majority of this area was in moderate drought (D1) and less than 1% was in the severe category (D2).

The warmth of the 2011-2012 winter season in Nebraska was influenced by many factors, including strong southerly winds, a lack of snowpack to the north, a jet stream pattern that kept the cold Arctic air to the north of the state, and a positive Arctic Oscillation (AO). When the AO is positive, areas to the east of the Rockies are typically warmer than normal, and this particular winter season was strongly influenced by the positive phase of the AO. Even with the mild winter, the drought status did not change much in Nebraska during the remainder of the winter months. Regionally, dryness and drought were developing around Nebraska, but for the most part, drought conditions were stable and improving slightly. By the end of February, a little more than 3% of the state was in drought, and that was confined to the extreme northeast corner of Nebraska.

The warmth continued into spring as a strong ridge built and subsequently brought record-breaking temperatures. In Nebraska's case, both March and the spring season were the warmest on record. The intense heat of March caused a quick and early green-up across the state. Although most people enjoyed the early onset of spring warmth and beauty, this unfortunately set the stage for a rapid decline in soil moisture conditions as plants started using the moisture earlier than usual. During spring, concern developed about the early use of soil moisture, which would need to be replenished or drought issues would develop. In early April, dryness was being monitored over the panhandle and eastern portions of the state, with moderate drought (D1) being designated in a handful of counties in extreme northeast Nebraska as well as the panhandle, encompassing a little more than 8% of the state. By the end of May, precipitation in the eastern half of the state eliminated much of the dryness and all of the drought. However, dryness in the panhandle worsened, and drought spread to almost all of the panhandle and into southwest Nebraska. By the end of May, 18.79% of Nebraska was in moderate drought (D1) and almost 44% of the state was identified as being abnormally dry (D0).

As the year progressed, summer brought no relief as a persistent ridging pattern caused hot and dry conditions into June. The extreme heat really took hold during late June as the ridge strengthened and caused an extreme heat wave to form over the Plains. Many locations set their all-time record highs during this time (see Table 1). With the continuation of heat into the summer and a lack of beneficial rains, drought conditions developed quickly. At the beginning of June, moderate drought (D1) covered about 32% of Nebraska, but by the beginning of July, more than 77% of the state was experiencing drought conditions. Around 40% of the state was in severe drought (D2) or worse, and extreme drought (D3) was introduced in the southwest portion of Nebraska. On July 2, Governor David Heineman declared a state of emergency due to the widespread drought. In August, the persistent ridge finally started to break down, allowing for temperatures to be closer to the historical average for that time. Unfortunately, rains were still severely lacking and the state had its driest August on record. Summer precipitation totals showed that the majority of the state received less than 50% of normal precipitation, with several counties picking up less than 25% of normal. In the end, the summer of 2012 went down as Nebraska's driest and third warmest summer on record. As the dryness and heat developed during the summer, the drought conditions took a turn for the worse as well. By the end of July, the entire state was in drought and 83% was in extreme or exceptional drought (D3-D4), with only southeast Nebraska in severe drought (D2). By the end of August, the drought conditions in Nebraska were rapidly deteriorating; 97% of the state was in extreme to exceptional drought (D3-D4) and almost a quarter of Nebraska (23.33%) was in exceptional drought (D4), which is considered a 1-in-50-year drought event.

While the fall brought drought relief to the state's eastern neighbors, as the remnants of Hurricane Isaac brought heavy rains to the central Midwest, drought conditions continued to worsen in Nebraska. As precipitation deficits climbed and impacts worsened, exceptional drought (D4) expanded from 23% to 71% in one week alone (August 28-September 4). The height of the drought came in October when the entire state was experiencing at least severe drought (D2) and a little more than 77% of the state was in exceptional drought (D4). From that point on to the end of the year, Nebraska was the epicenter of the drought. Even the lower-than-normal temperatures of October, which happened for the first time in several months, had no positive impact on the drought conditions. Nebraska had just had its second driest fall on record. As November came to a close, Nebraska was experiencing a historical drought in regard to intensity even though the duration had not been very long. At this time, around 77% of the state remained in exceptional drought (D4) and all but a handful of counties in extreme southeast Nebraska were in extreme or exceptional drought (D3-D4).

Nebraska entered the 2012-2013 winter season completely in drought—all locations were in at least severe drought (D2), with the majority of the state in exceptional drought (D4) (77%). Climatologically, these are the driest months of the year, so even above-normal precipitation would have had little effect on the drought. As such, these drought conditions generally held through the winter of 2013. Ultimately, Nebraska had its warmest and driest year on record, beating out all of the Dust Bowl years. As the winter progressed, the concerns were what the next year would bring, as the devastation from the drought of 2012 was far from being over.

Nebraska Drought Impacts

Impacts to the state of Nebraska were far-reaching and still being realized well into 2013. A wide variety of sectors were impacted, from agriculture to infrastructure to water supplies. The following section discusses the impacts. For a more detailed look, please see the National Drought Mitigation Center's Drought Impact Reporter (http://droughtreporter.unl.edu/).

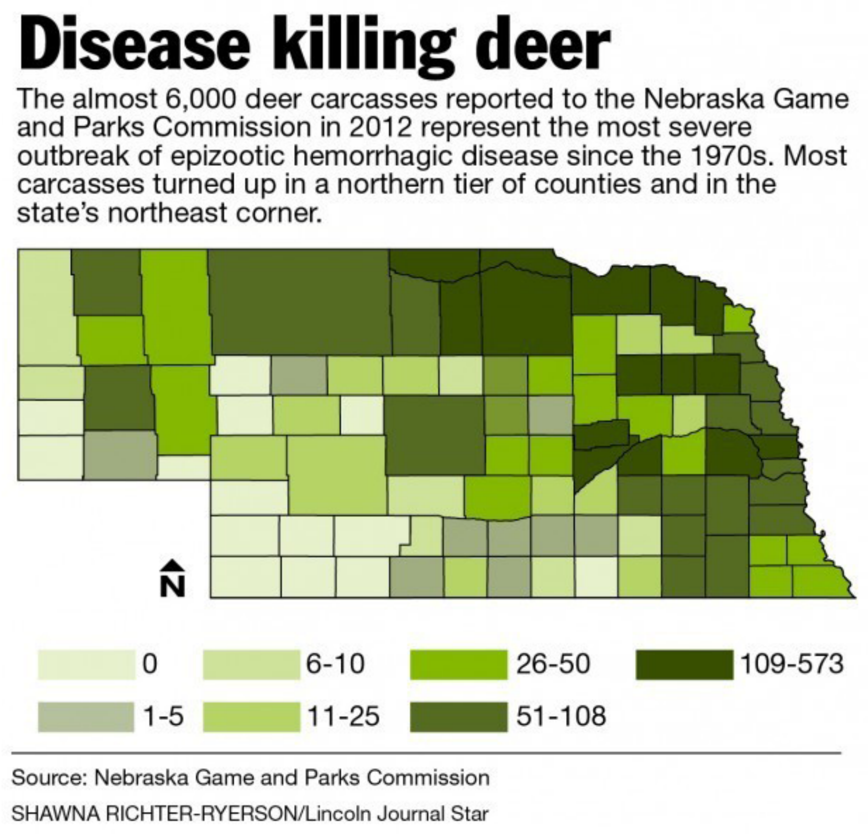
Agriculture

The heat and drought of 2012 had severe impacts on agriculture across the state. Impacts were felt on all scales, from

Photo by Duane Lienemann

August type pasture conditions in early June 2012 in south central Nebraska.

neighborhood plots and small organic farms to large-scale corn and soybean production and ranches. Hay production was down 28%, corn was down 16%, and soybean production dropped by 21%. Hay shortages from the previous year's drought in states to the south of Nebraska combined with low hay production in 2012 led to an increase in shortages and nearly a doubling in the price of hay, to record levels. Even though emergency grazing and haying of CRP acres was approved, scarce food and water supplies led many ranchers to relocate and/or cull their herds. Many irrigators also struggled during this time as surface water use was stopped because of low river levels. At least 1,100 irrigators were shut off from pumping from the Big Blue, Elkhorn, Loup, Niobrara, North Platte, and Republican Rivers. According to the National Agricultural Statistics Service, in some cases more water had been used by mid-July than what would normally be used in an entire season.



Drought conditions in Nebraska contributed to the widespread outbreak of epizootic hemorrhagic disease. Source: Nebraska Game and Parks Commission.

According to a March 2013 report for the Farm Credit Services of America, the total indemnity payments in Nebraska due to the 2012 drought totaled $1.49 billion. The crop losses and resulting indemnity payments in the state were actually lower than payments for other states because of the prevalence of irrigation. The economic impact of these payments was estimated to be $780 million, with more than 7,000 jobs preserved as well.

Cattle production was also impacted greatly by the drought conditions. Drought in the surrounding areas, especially the southern plains, forced many ranchers to ship cattle into Nebraska in 2011 and led to excess hay being shipped south. With the greatly reduced hay stocks already in place, the drought of 2012 did not bode well for ranchers. Ranchers were forced to cull herds by 25-60% in the state as forage production was only about 28-64% of normal during 2012 in western Nebraska. Those ranchers who were finishing out cattle on feedlots were experiencing increased costs because of the price of corn and forage. With those added expenses, ranchers were losing $200 a head (or more) based on taking cattle to market earlier than normal and also the added expenses of finishing them.

Ethanol production in Nebraska also was impacted by the drought. With the corn crop being damaged by the drought, commodity prices increased to the point that production of ethanol was not cost effective. Several ethanol plants in Nebraska reduced production or even closed during the drought.

Plants and wildlife

Drought conditions led to an increased fire danger during 2012. Drought combined with intense heat contributed to what was, according to CropWatch, Nebraska's worst fire season since 1919. More than $12 million in damage was reported, primarily in central and western areas of the state. By the end of the year, more than 400,000 acres had burned in more than 1,200 fire events, according to the fire program leader with the Nebraska Forest Service. The drought took a toll on the state's plant life not only through fire, but also from stress due to the high temperatures and lack of precipitation. According to the *Omaha*

World-Herald, one example of tree loss came from Pioneers Park, in Lincoln, where about 700 pine trees died and were removed. Many trees located in wind breaks died in western Nebraska as well. Evergreens were hit particularly hard, including white pines, arborvitae, spruces, red cedars, and junipers.

Wildlife also suffered during the drought of 2012. The *Norfolk Daily News* reported that the combination of drought and an outbreak of epizootic hemorrhagic disease (EHD) was estimated to have killed about a third of the whitetail deer population in Nebraska during the summer of 2012. In addition, according to the Lower Platte River Corridor Alliance, the Lower Platte River experienced record low flows over the summer, with many areas of the river running completely dry. Water temperatures were quite high, ranging from 92°F to 97°F. The low flows combined with high water temperatures led to considerable fish kills, including the endangered pallid sturgeon, catfish, carp, minnows, and others. In addition, most water-based recreation came to a halt.

Infrastructure

When thinking of weather-related infrastructure damage, most people would think of issues related to tornadoes or floods. But the 2012 drought caused quite a bit of damage to foundations, private and municipal wells, water mains, and even trails. The 2012 drought was particularly hard on home foundations. When the soils dry during a drought, they shift and sink, causing damage to the building's foundation. Damage to foundations was reported in at least 40 states, and this drought, in terms of foundation damage, was possibly one of the worst since the 1950s, according to the Basement Health Association of Dayton, Ohio. The *U.S. News & World Report* showed that one estimate indicated the drought damage to houses could reach $1 billion or more.

In May, June, and July alone, 178 water main breaks were reported in Omaha. Officials of the Metropolitan Utility District believe that a combination of extreme heat, drought, and increased water usage caused increased pressure on the city's water lines, causing some of them to crack. For comparison, only 56 water mains broke during those same months of 2011.

Water Supplies

As many as 81 municipal water systems in the state experienced drought-related water supply issues in 2012, according to the Department of Health and Human Services. The *Omaha World-Herald* also reported that the intense heat and drought caused Omaha and its surrounding areas to break a record for water use with 224 million gallons on July 23, 2012.

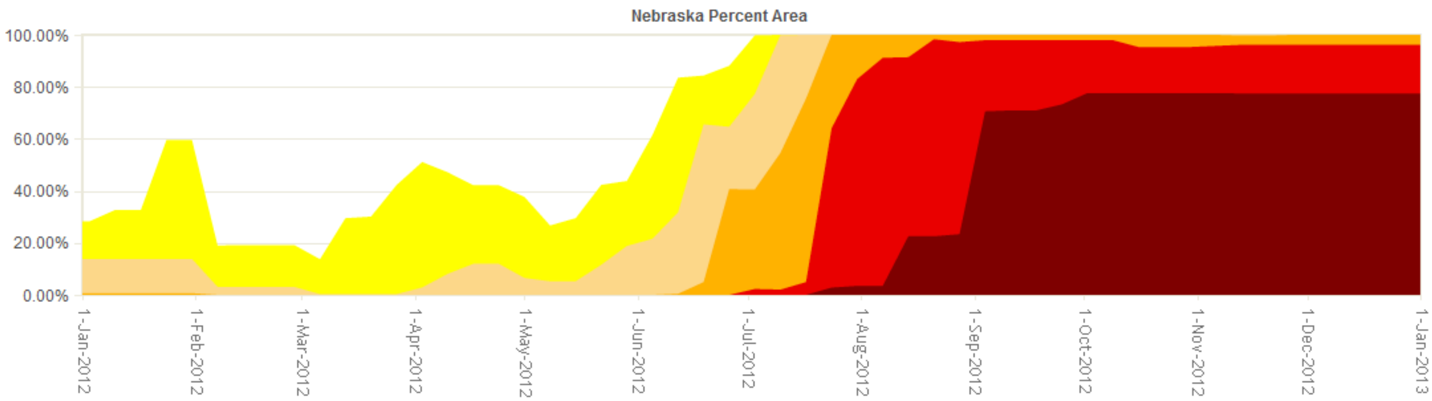
Transportation

The combination of high winds and ongoing drought conditions caused a large dust storm to form across the panhandle and surrounding areas of Colorado, Wyoming, and Kansas in mid-October. The dust storm reduced visibilities and many roads were forced to close, including I-80 in western Nebraska. Wildfires were also sparked during this time and spread rapidly because of the high winds. Buildings, machinery, and even crops were lost to the fires.

Photo by Jonathan Schelmann

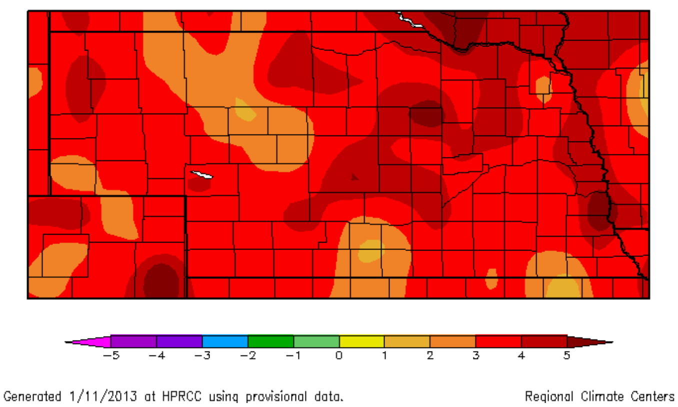
Panoramic view of the Platte River upstream from the confluence with the Elkhorn River, August 21, 2012.

Evolution of the Drought in Nebraska in 2012

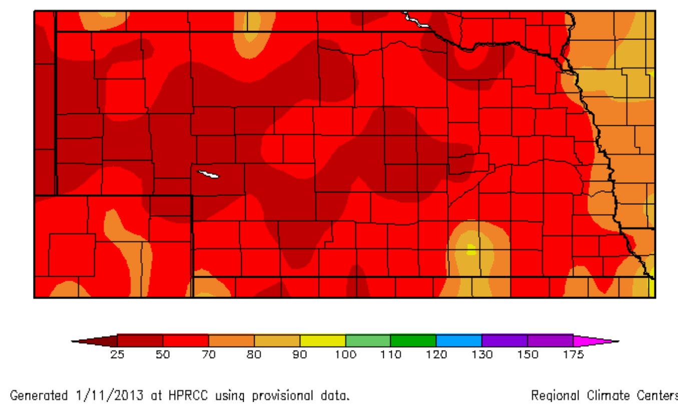


Courtesy National Drought Mitigation Center

Departure from Normal Temperature (F)
1/1/2012 - 12/31/2012



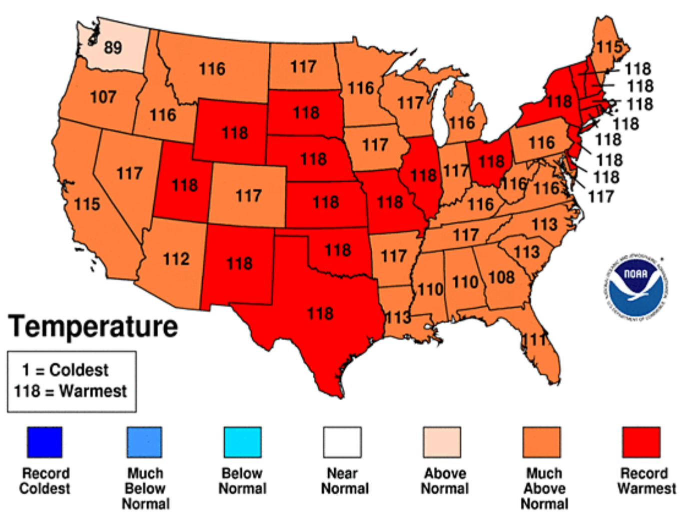
Percent of Normal Precipitation (%)
1/1/2012 - 12/31/2012

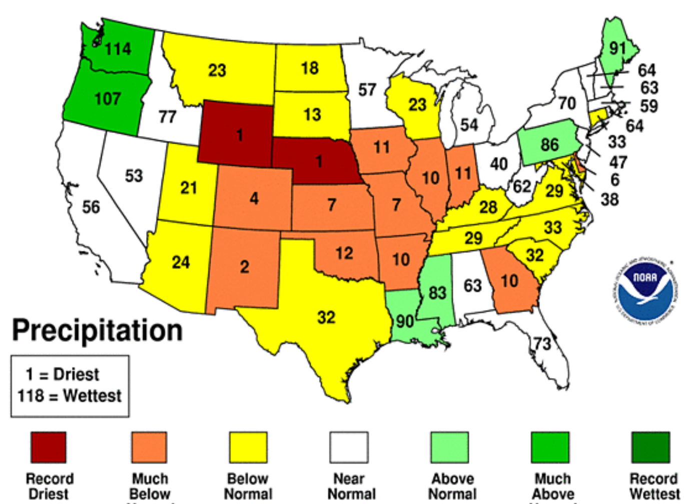


Courtesy High Plains Regional Climate Center

January-December 2012 Statewide Ranks

National Climatic Data Center/NESDIS /NOAA



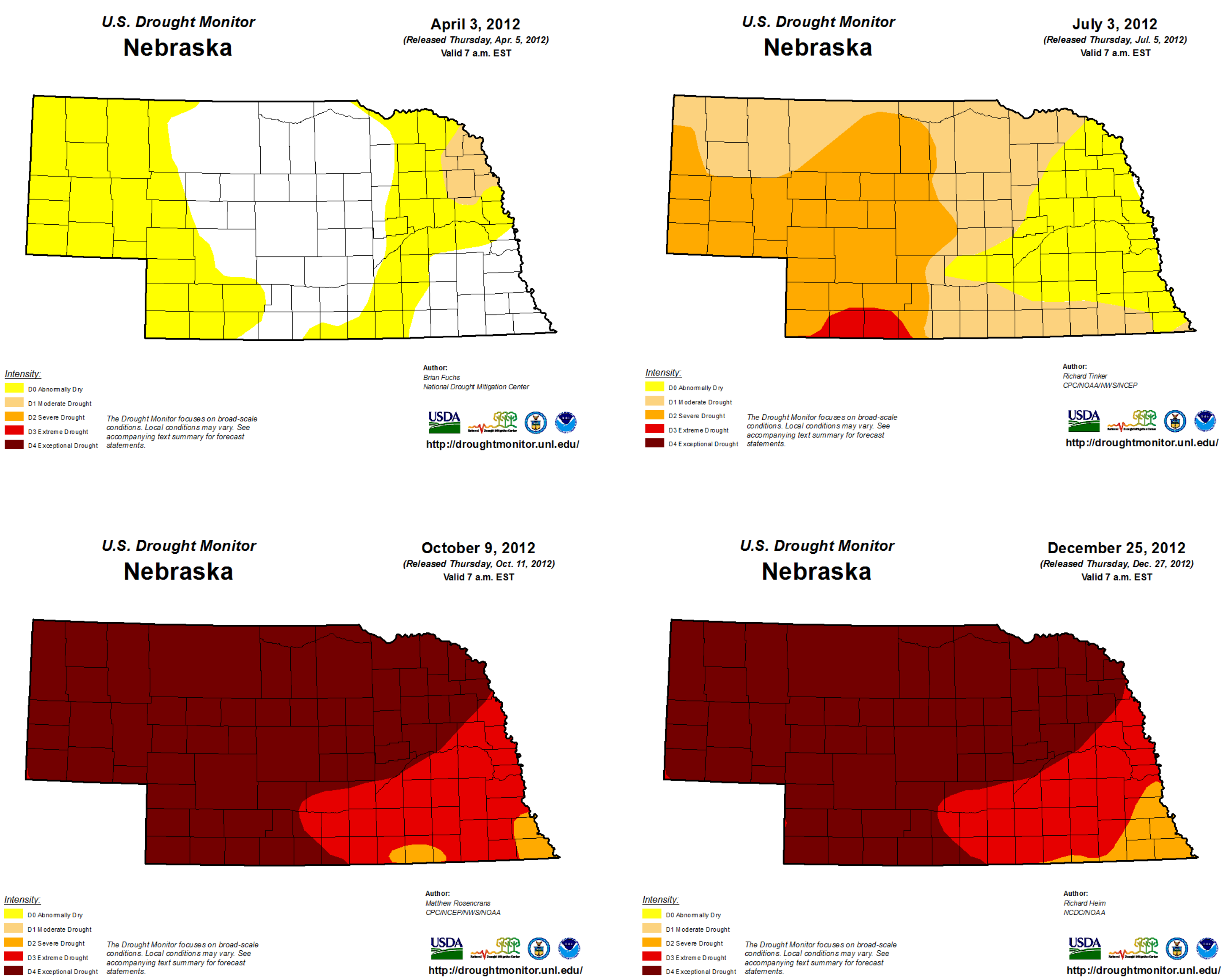


Courtesy National Climatic Data Center

All-time Record Highs Set in June 2012 Temperature in degrees F			
Location	Temperature – Date	Previous Record	Period of Record
Benkelman	114 – June 27	Tied – 07/11/1954	1906-2013
Harrisburg 12 WNW	105 – June 24, 27	Tied – 07/16/2006	1961-2013
McCook Muni AP	115 – June 26	111 – 07/19/2006	1967-2013
Sidney Muni AP	111 – June 26	109 – 06/25/2012	1948-2013
Table Rock 4 N	106 – July 26	105 – 07/20/2006	1931-2013
Trenton Dam	111 – June 27	Tied – 08/04/1954	1949-2013

Table 1. Selected all-time record high temperatures in Nebraska.

Drought Progression across Nebraska during 2012



Section 3.11: NORTH DAKOTA

Adnan Akyüz, Ph.D.
North Dakota State Climatologist

About 90% of North Dakota's land area is utilized for agriculture (the highest percentage for any state in the United States). The ground stays mostly frozen from late fall to early spring. Because of these characteristics, this section will discuss drought in North Dakota during the growing season. The 2012 growing season for North Dakota can simply be characterized as dry and warm when compared to the 30-year average from 1981 to 2010. The state average precipitation during the 2012 growing season was 10.69 inches (down 6.25 inches from last year), which made it the 13th driest growing season among the past 118 years (since 1895). Historical records indicate that the state average precipitation values ranged between a low of 5.62 inches and a high of 20.03 inches, which occurred in 1936 and 1941, respectively. On average, the state experienced an increase in precipitation of 0.03 inch per decade since 1895 (Figure 1). Even though the spring of 2012 appeared to be a wet season when compared to other years, only April was wetter than normal (17th wettest April). However, summer months were consistently drier than normal (19th driest summer).

Likewise, the state average temperature during the 2012 growing season was 60.7°F (up 2.4°F from last year), which was the 8th warmest growing season among the past 118 years (since 1895). Historical state average growing season temperature values in North Dakota ranged between 62.5°F (1988) and 52.7°F (1907).

Table 1 shows temperature and precipitation rankings for selected locations in North Dakota. Table 2 summarizes the length of growing season based on the number of consecutive days between the last and first day of frost and the ranking for those select locations. Figures 1 and 2 show statewide precipitation percent of normal and temperature departure from normal

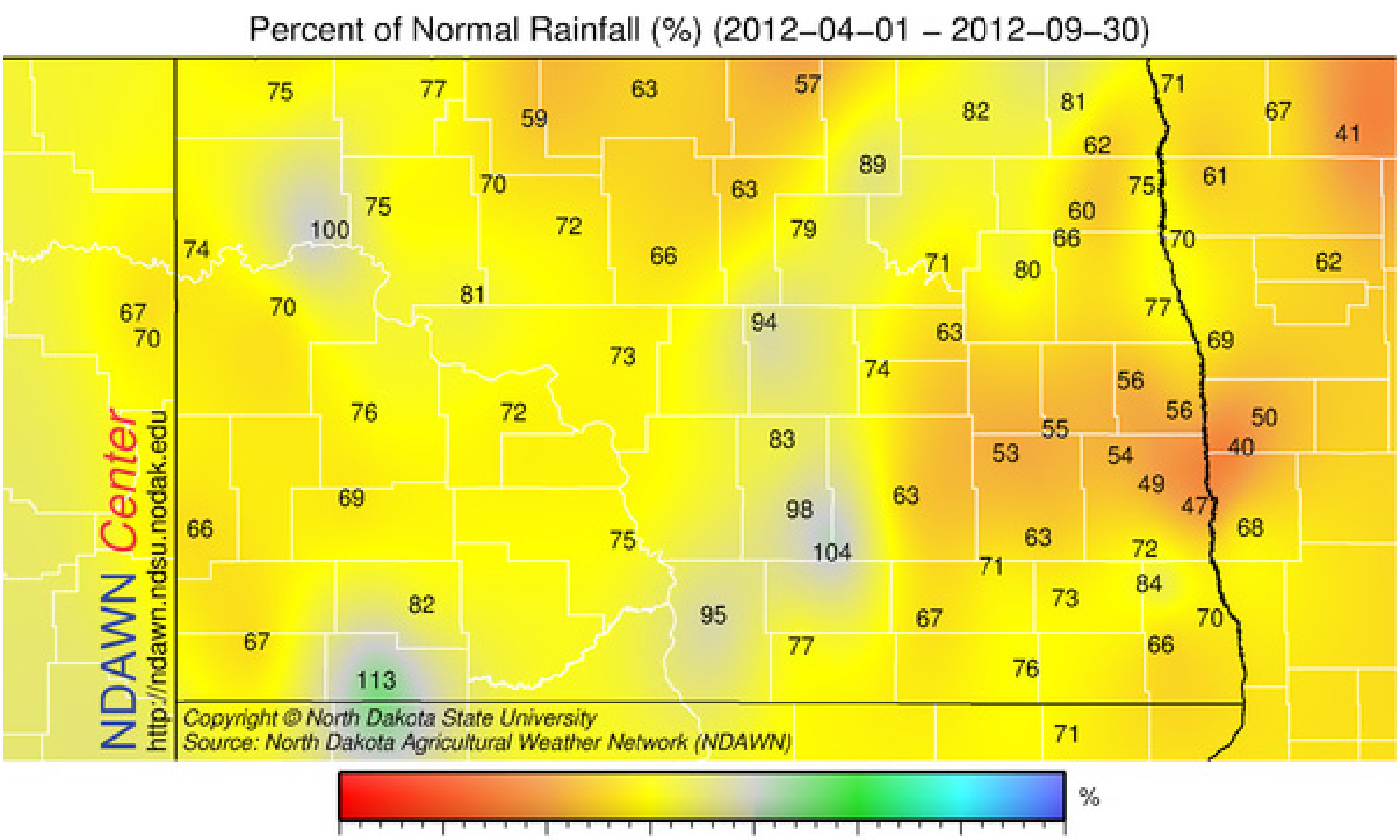


Figure 1. April through September 2012 Precipitation Percent of Normal (%) in North Dakota.

City	Temperature Ranking	Precipitation Ranking
Bowman	**The Warmest**	**21st Driest**
Bismarck	**23rd Warmest**	**52nd Driest**
Fargo	**2nd Warmest**	**10th Driest**
Minot	**5th Warmest**	**14th Driest**
Cavalier	**6th Warmest**	**28th Driest**
Williston Exp. Station	**21st Warmest**	**37th Driest**
North Dakota Average	**8th Warmest (118 years)**	**13th Driest (118 years)**

Table 1. April-September 2012 average temperature and precipitation rankings for select North Dakota locations.

City	Length of the 2012 Growing Season	Ranking of the 2012 Growing Season
Bowman	**131 Days (May 25- Oct 4)**	**44th Longest (Since 1915)**
Bismarck	**105 Days (May 31-Sep 14)**	**10th Shortest (Since 1875)**
Fargo	**144 Days (Apr 26-Sep 18)**	**35th Longest (Since 1881)**
Minot Exp. Station	**147 Days (Apr 27-Sep 22)**	**14th Longest (Since 1905)**
Cavalier	**139 Days (Apr 27-Sep 14)**	**24th Longest (Since 1934)**
Williston Exp. Station	**105 Days (May 31- Sep 14)**	**13th Shortest (Since 1894)**

Table 2. Length and ranking of the 2012 growing season based on number of consecutive days between the last and the first day of frost for select North Dakota locations.

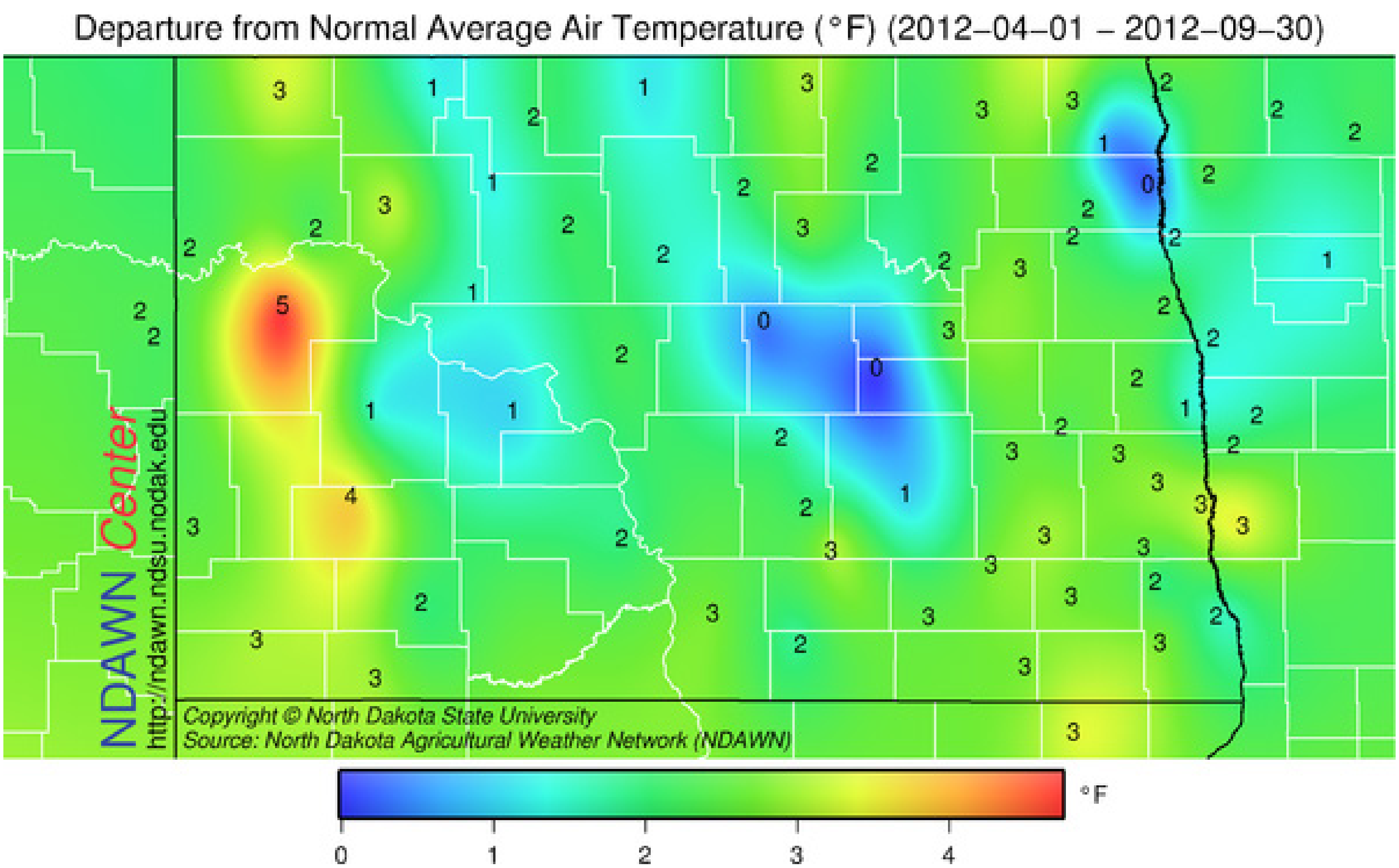


Figure 2. April through September 2012 Temperature Departure from Normal (°F) in North Dakota.

conditions, respectively, averaged over the period from April 1 through September 30. In Figure 1, numbers above 100 indicate wetter-than-normal conditions, and numbers less than 100 indicate drier-than-normal conditions. In Figure 2, negative numbers indicate cooler-than-normal conditions, and positive numbers indicate warmer-than-normal conditions (zero is no different from the normal). The values in the map represent the magnitude of daily average departures from normal.

Figure 3 shows the state's drought coverage and severity in 2012. The vertical axis is the accumulated coverage and the horizontal axis is the time. The intensity scale (Dx) is labeled from D0 through D3. D0, D1, D2, and D3 represent abnormally dry, moderate drought, severe drought, and extreme drought conditions, respectively. North Dakota experienced no severe drought in any parts of the state for 190 consecutive weeks from November 18, 2008, through July 10, 2012 (the longest stretch without severe drought in the state since 2000). At the beginning of the growing season, 18% of the state was experiencing at least a moderate drought. The drought conditions worsened throughout the season, with the entire state experiencing at least a moderate drought (Figure 4).

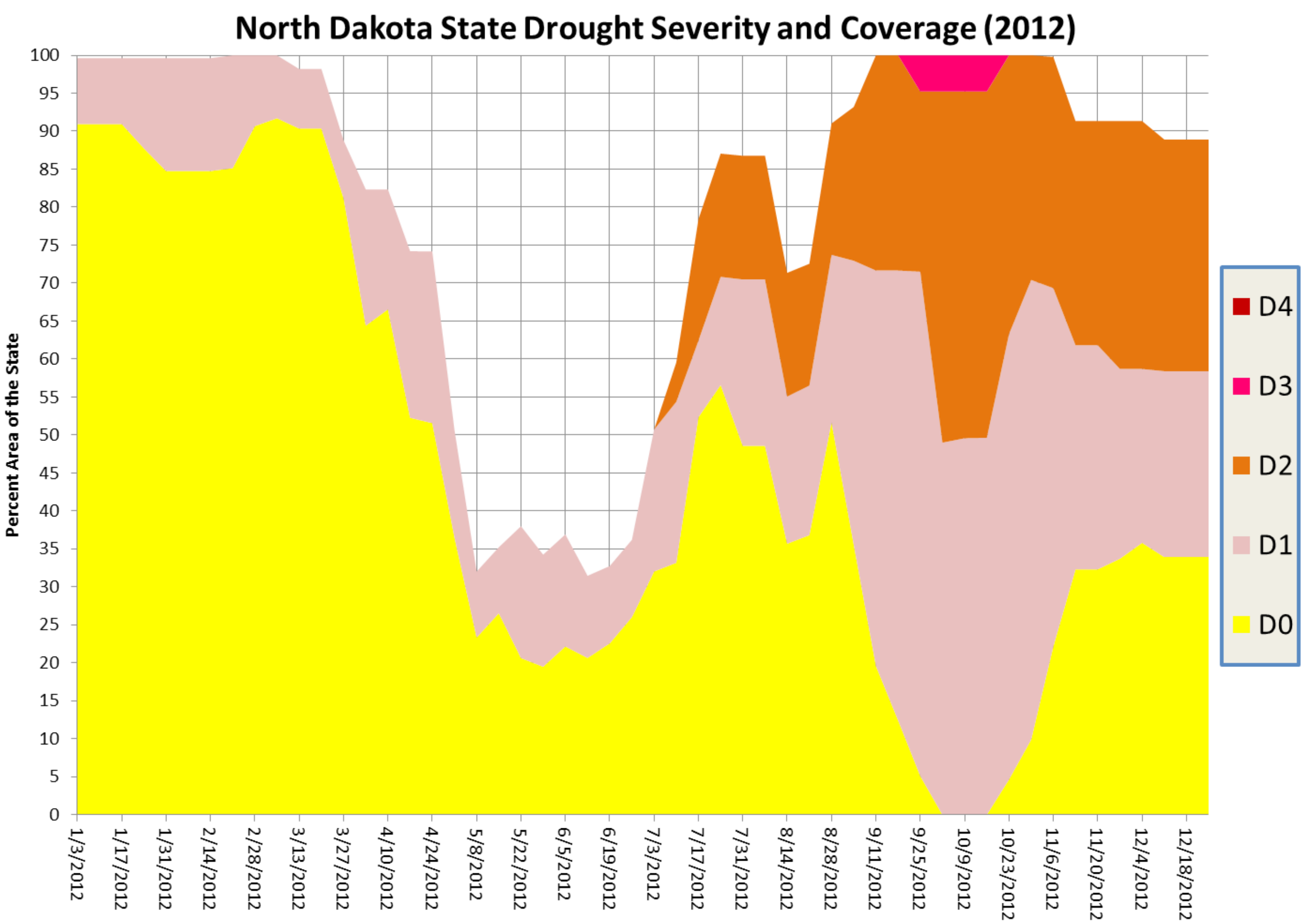
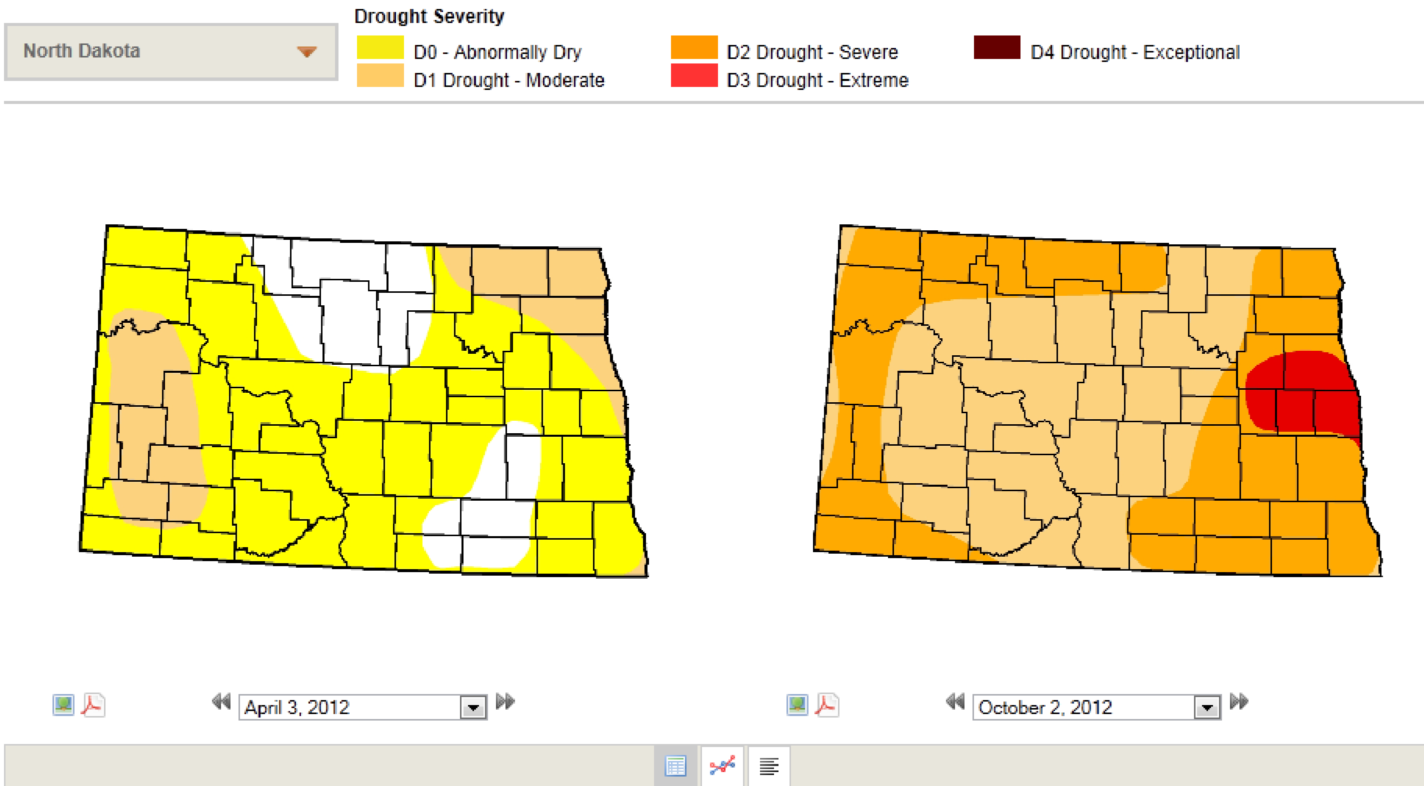


Figure 3. April through September 2012 North Dakota State Drought Severity and Coverage.



Week	Nothing	D0-D4	D1-D4	D2-D4	D3-D4	D4
April 3, 2012	17.66	82.34	17.94	0.00	0.00	0.00
October 2, 2012	0.00	100.00	100.00	51.00	4.78	0.00

Figure 4. Drought Coverage and Intensity Comparison between the beginning and the end of the 2012 Growing Season.

Worst Drought since 2008

The 2012 drought was the worst drought in North Dakota since 2008. Based on the state Drought Intensity and Coverage Index (DICI), the state reached its worst conditions in 2012 during the week of October 2, with an index value of 256 (Table 3). It was the worst statewide drought (based on intensity and statewide coverage) since 2008, when the state DICI was recorded as 264 during the week of June 3, 2008 (Figure 5).

The statewide DICI was developed by Adnan Akyüz, state climatologist for North Dakota, in order to quantify drought intensity and drought coverage by a given area (county, climate division, state, region, or nation). DICI assigns an intensity factor (fx) that intensifies with drought intensity (Dx). DICI is calculated by accumulating the products of intensity factors and associated areal coverage (Ax) of the state. The index can also be used to compare drought in different locations (regions/states/counties) for a given time period.

Conclusion

The state dodged what could have been the worst drought since 1988, mainly because of the soil moisture recharge from the previous wet period that started in 2009 and continued into 2011. The growing seasons of 2010 and 2011 were the 5th and 12th wettest growing seasons, respectively, in the state's recorded history. Even though fall 2011 was

Drought Intensity (D_x)	Intensity Factor (f_x)	State Areal Coverage (A_x) in %	f_xA_x
D0	1	0	0
D1	2	49	98
D2	3	46.22	138.66
D3	4	4.78	19.12
D4	5	0	0
State Drought Intensity and Coverage Index: Σf_xA_x			**256**

Table 3. North Dakota Drought Intensity and Coverage Index for the week of October 2, 2012.

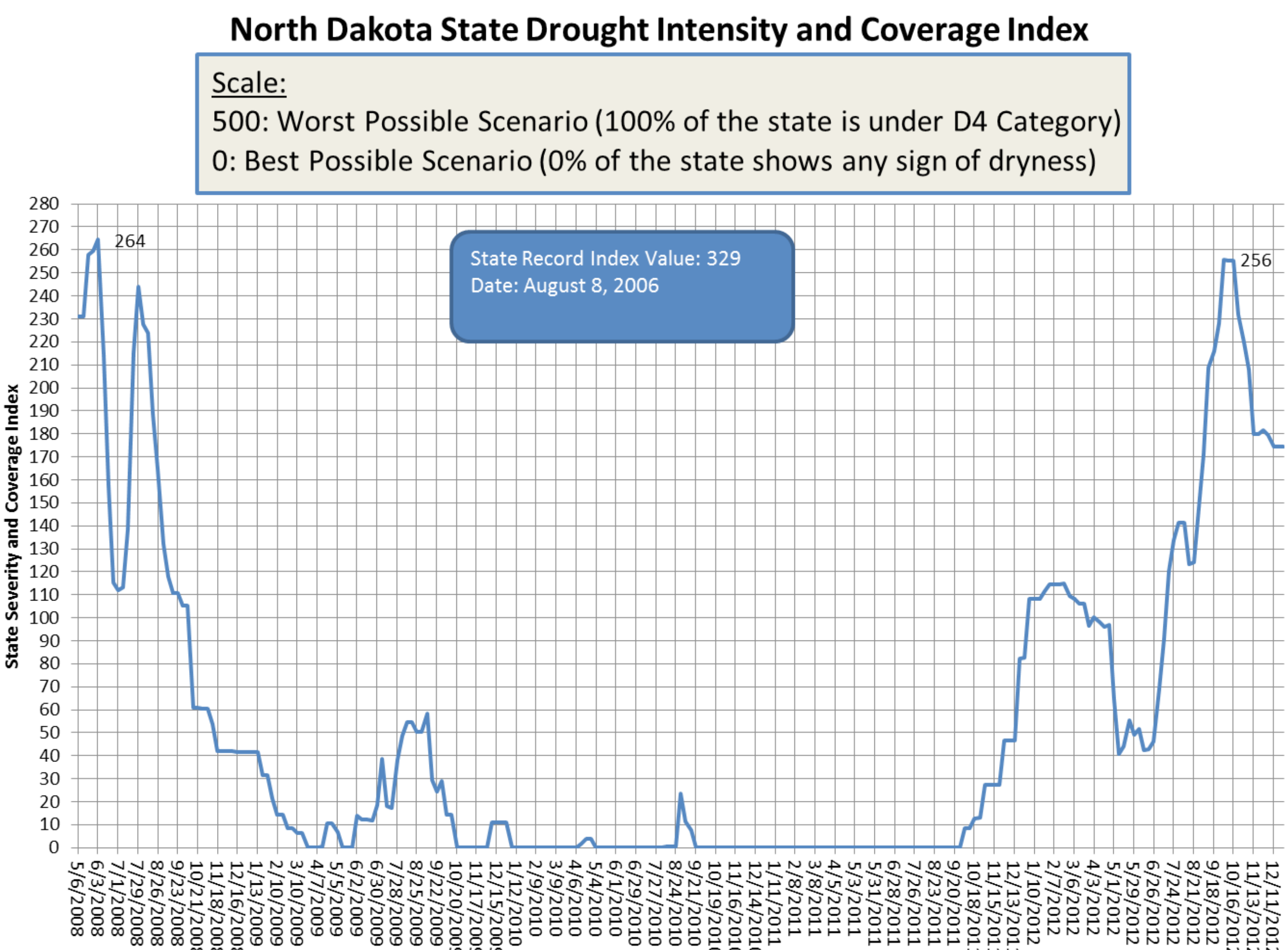


Figure 5. North Dakota State Drought Intensity and Coverage Index (DICI), 2008-2012

slightly drier than normal (40th driest fall) followed by the 25th driest winter in recorded history, the soil moisture profile at 5 feet was adequate. Much warmer than normal conditions in spring 2012 (2nd warmest spring in recorded history) helped get field work started early in the season. Crops took advantage of much above normal heat accumulation to develop good root systems that tapped into deep soil moisture.

At the end of the growing season, drought progressed. By the middle of October (October 16), 5% of the state was under extreme drought, 46% was under severe drought, and 49% was under moderate drought. If the state had not been able to take advantage of the soil moisture recharged from the previous years, the drought's agricultural impacts would have been similar to those in the other Midwestern states suffering from exceptional drought conditions.

However, if drought continues, the land in already-drought stricken areas will suffer from lack of moisture at the beginning of the growing season in 2013.

Photo by North Dakota State University

Dry creek bed in North Dakota.

Section 3.12: OHIO

Jeffrey C. Rogers, Ph.D.
State Climatologist
Department of Geography
The Ohio State University

Introduction

The drought of 2012 was the seventh statewide drought in Ohio since 1988. Some of these seven droughts were relatively localized to the eastern portion of the Midwest, but all had an impact on Ohio agriculture and water supplies. In terms of overall soil water dryness (as measured by the Palmer Drought Severity Index), the severity of the 2012 Ohio drought is second to that of 1988, particularly in western and southern Ohio, while the recent drought was more severe in northeastern Ohio. The 2012 drought had little impact on statewide water supplies as it followed the wettest year (2011) on record (to 1895; Figure 1a, left). In contrast, the 1988 drought caused numerous water supply shortages across the state and caused substantial reductions in both groundwater and water reservoir levels.

The state of Ohio was afflicted by four weather- and climate-related calamities in 2012, each of which is related to either prolonged heat, cold waves following heat waves, or unusual diurnal heating and atmospheric instability. The four events in relative order of severity of their economic consequences are as follows.

1. The summer drought from May to September 2012.

2. The derecho of June 29, 2012, which inflicted nearly $1 billion in damage in Ohio.

3. April freezes after an extraordinarily warm March 2012.

4. The hail storm of July 1, 2012, across northern Ohio.

Further discussion of the economic importance of these events is included later in this section.

Climatological Overview of Growing Season Events in Ohio

Heat and high temperatures were the primary cause of most 2012 crop-year disasters in Ohio. The month of March was the warmest on record (since 1895), with an average temperature of 52.2°F, breaking the old record of 49.5°F set in 1946. The spring season was the warmest (see Figure 1c, right) at 56.4°F, displacing the record set in 1991 (54.5°F) and additionally assisted by the third warmest May (66.6°F) since 1895. Despite the record warmth, a period of frosts and freezes occurred across the state on three occasions between March 27 and April 13. Many orchard trees had blossomed during the early March heat wave, and these buds were destroyed in the cold weather. Damage to crops such as apples, peaches, and strawberries was especially notable and is described later in this section. Many stations in Ohio reported multiple days with daytime maximum air temperatures of ≥ 100°F during the subsequent summer, although there were not as many of these days as in 1988. The longest and one of the most severe heat waves in state history occurred from June 28 to July 8 with temperatures in excess of 90°F

Photo by Farmer/Rancher in McClure, Ohio

Cracks in an alfalfa field on June 8, 2012 in Henry County, Ohio.

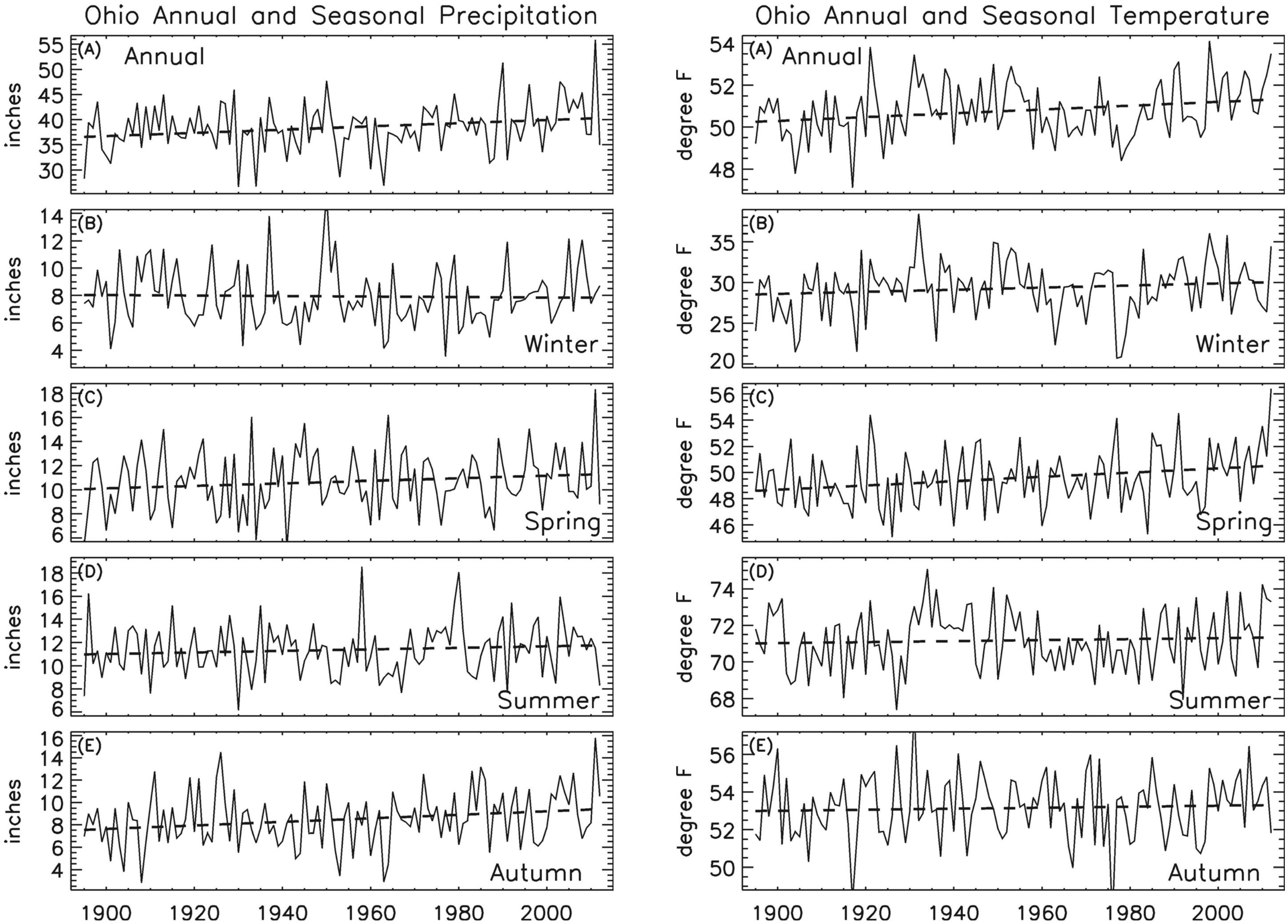


Figure 1. Ohio annual and seasonal precipitation (left side) and air temperatures (right), 1895-2012, based on statewide averages computed from climate division data. Precipitation is in inches and temperature in °F. Trend lines (dashed) covering the entire 118-year time span are also provided.

and sometimes above 100°F daily. The summer of 2012 was only eleventh warmest (73.3°F; Figure 1d, right), exceeded by the warmest summer (75.1°F in 1934) and several other recent hotter summers (2010, 2002, 2005, 2011, and 1995). Ohio's three recent summers are all in the top 10% warmest. July was the second warmest on record (77.8°F), just behind 1934 (78.3°F).

After the wettest year on record in 2011 (see Figure 1, left) a precipitation deficit beginning in April 2012 led to general soil water deficits by late May that were especially noticeable in the northern half of the state. The lack of precipitation was widespread over the entire state in June, ultimately leading to severe and extreme drought conditions. This continued through August, and drought severity in that month matched the conditions of July. The prevailing summer weather pattern changed in mid-August, however, and precipitating storm systems were once again returning to Ohio. Substantial improvement in rainfall in September led to a clear reduction in the overall severity of the drought, and these rains are regarded as largely helping save the state's soybean crop from even greater yield reductions. Drought conditions steadily improved through the remaining months of the year until much of the state returned to either normal or moist conditions. Ohio monthly precipitation statistics were unremarkable; June was the 12th driest and July and August were 32nd and 38th driest, respectively. The consistent monthly dryness, however, led to a full summer season ranking of 8th driest, compared to 1988, which was 13th driest (the 1988 drought ended in mid-July in Ohio). In contrast, the spring was 27th driest while the 1988 spring was 6th driest.

Table 1 shows a relative comparison of Ohio precipitation and evaporation during a 6-week period at the height of the drought. Data are from Ohio's fledgling CoCoRaHS evapotranspiration station network of four locations as of 2012. Data for the first period (June 28-July 18) encompass a 3-week period of excessive heat that started with the heat wave of June 28-July 8. In that period, evaporation is generally more than 4 inches (in 21 days) while precipitation is less than 2 inches. The second period

Evaporation and Precipitation at Ohio **CoCoRaHS** ET Sites

	June 28 to July 18, 2012		July 20 to August 9, 2012	
City	Evaporation	Precipitation	Evaporation	Precipitation
Avon	3.86 "	2.06 "	3.19 "	1.83 "
Eaton	4.67 "	0.90 "	3.34 "	1.51 "
Bradford	4.59 "	1.35 "	3.15 "	3.78 "
Alexandria	4.49 "	1.72 "	3.43 "	2.08 "
Mean Max Temperature:		93.9°F	Mean Max:	89.8°F

Table 1. Three-week averaged evapotranspiration and precipitation (in inches) at four Ohio CoCoRaHS (Community Collaborative Rain, Hail, and Snow) volunteer evapotranspiration-reporting weather stations during summer 2012. The bottom line also gives the three-week average maximum daytime high temperature at Columbus, Ohio.

from July 20-August 8 was not quite as hot, and evaporation, although reduced from the first period, exceeded rainfall by 1-2 inches at three stations while the fourth station had an excess of precipitation. Over the 6-week period, evaporation was between 7-8 inches and precipitation was highly variable between 2.5 and 5 inches.

The derecho of June 29, 2012, originated as a cluster of thunderstorms in northwestern Illinois on the afternoon of that day. The weather was characterized by near 100°F temperatures and extremely high environmental instability. The squall line began organizing near Chicago and in northern Indiana. It was well organized with new powerful leading-edge thunderstorms along a large multi-storm bow echo as it rapidly moved across eastern Indiana into Ohio with forward velocity of more than 70 mph and storm winds in excess of 85 mph. Figure 2 is a composite, compiled by the Storm Prediction Center, of the radar leading-edge echoes as the storm progressed from Indiana, across central and southern Ohio, and into West Virginia. As Figure 2 shows, the derecho traversed Ohio in about 3.5 hours. Its high forward speed was its saving grace, as one insurance analyst said in an interview in the Columbus Dispatch (Williams, 2013), since winds approaching 90 mph would have caused much greater damage had the storm been moving less rapidly. Ohio residents had most recently been affected by an even more severe and more costly slow-moving storm, the remnants of hurricane Ike, in September 2008. The derecho occurred on the second day of the extraordinary heat wave and unfortunately many Ohio businesses and residences were without power for much of the subsequent period of the hot spell because of the derecho winds. The economic consequences of the derecho are discussed below.

Environmental and Economic Impacts: Ohio Agricultural and Crop Impacts

Corn: Ohio's average corn yield for 2012 is estimated at 123 bushels per acre, down 22% from 158 bushels per acre in 2011. This reduction comes despite a 13.4% increase in harvested acreage in 2012 from 2011. According to one newspaper account (Vanac, 2012a), the corn in Ohio suffered its greatest damage when it went through its pollination stage right around July 4, at the height of the June 28-July 8 heat wave, when air temperatures were as high as 104°F in parts of the state and little rain had fallen in the preceding two to three weeks. Because of the characteristics of the seasonal cycle of corn growth, the sporadic rainfall increase starting in late August did little to improve the overall corn crop yield. In the 1988 drought, the corn crop was reduced by 25% from the average crop yield of the time. The 1988 drought in Ohio ended in mid-July and subsequent normal rainfall through August prevented early forecasts of corn yield reductions of up to 50%.

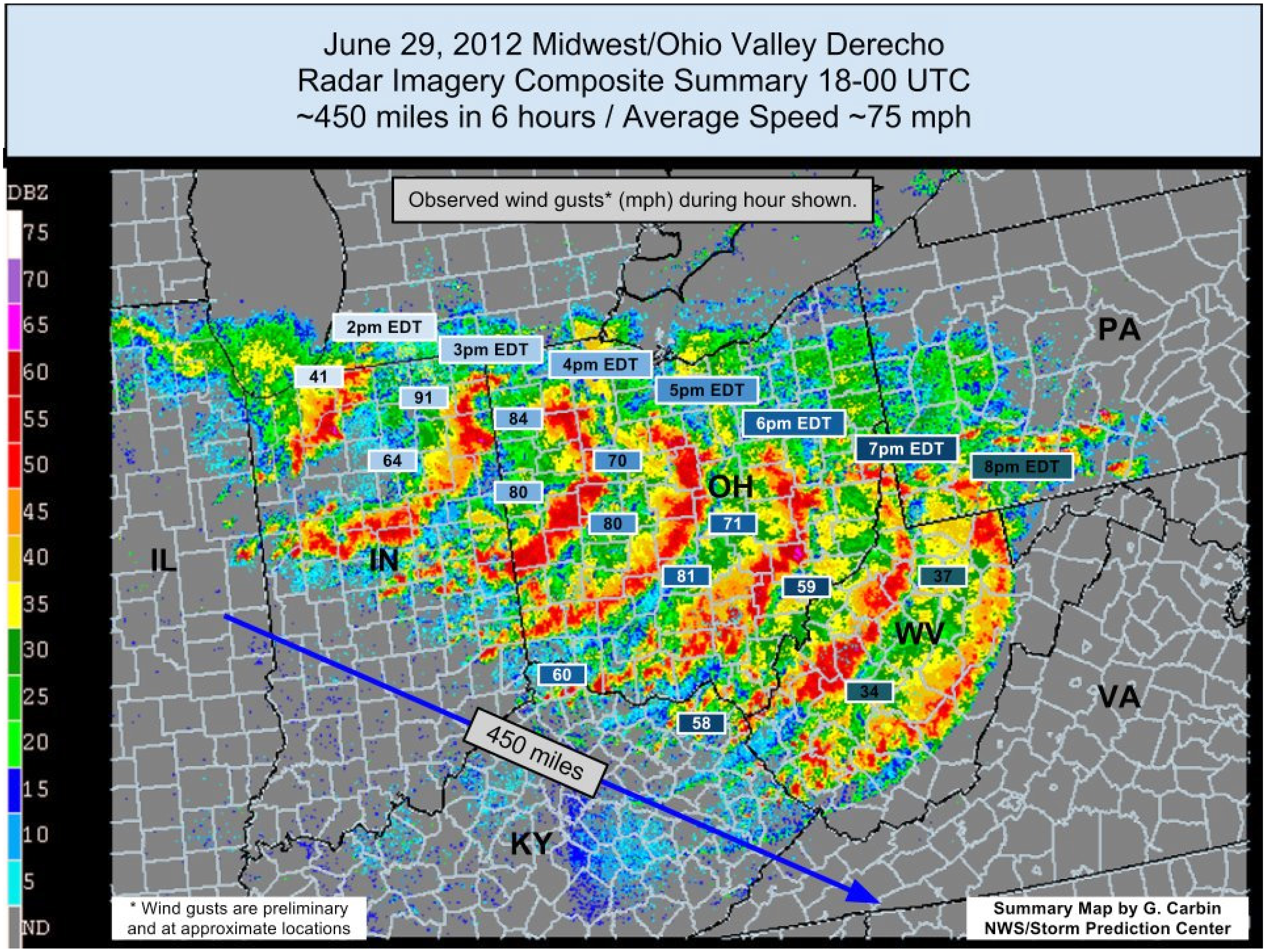


Figure 2. Time composite of the leading edge of radar image bow echoes as the June 29, 2012, derecho crossed Indiana, Ohio, and West Virginia. The map is provided by Greg Carbin of the Storm Prediction Center.

Soybeans: Ohio's 2012 soybean yield estimate is 206.1 million bushels, down 5.7% from 217.9 million bushels in 2011. The increased rainfall in August and September is thought to have played a key role in trimming the losses in soybean yields.

Alfalfa and hay: Alfalfa hay yields averaged 2.80 tons per acre in 2012 compared to 3.4 acres in 2011, a reduction of 18%. Other hay decreased about 10% to 1.8 tons per acre. The reduction in hay yields was compensated by an increase in price for hay sold to livestock owners. The final reductions in hay yields were much smaller than estimates from July 2012 had suggested.

Winter wheat: Winter wheat yields increased by 19% in 2012 compared to the previous year even though there was a 47% reduction in acres harvested in Ohio.

Apples: Ohio is typically one of the top dozen apple-producing states in the United States. However, the 2012 apple crop was only 39.6 million pounds compared to 66.6 million pounds in 2011, a 41% reduction according to the National Agricultural Statistical Service. This is in line with the expected 40% reduction in national apple production east of the Mississippi. The negative impacts on the 2012 crop include the March 27-April 13 frosts, which killed apple buds that had emerged three to four weeks ahead of schedule because of the record heat wave in March 2012. This is the same pattern of weather events (unusual March heat followed by an April cold wave) that destroyed much of the Ohio apple crop in spring 2007. Apples that survived were regarded as high quality in terms of sweetness and flavor (Vanac 2012b). Prices of apples sold in the state were generally 33% to 80% higher than in previous years, especially at pick-it-yourself orchards. Grafted apple trees and newly planted apple trees experienced the greatest amount of damage and death from the frosts and subsequent summer heat, according to Diane Miller of the Ohio State University Extension.

Peaches: The Ohio peach crop was also damaged by southern Ohio frosts in late March and early April, following early blossoming of peach trees in the March 2012 heat wave. Nearly 500 peach trees and the entire crop of peaches were also lost on one farm on Catawba Island, Ohio, after a July 1 hailstorm and 75 mph winds, while other orchards sustained lesser degrees of damage.

Photo by Eric Albrecht

Yield damage to corn in Ohio due to drought in June, 2012.

Environmental and Economic Impacts: The Derecho

The estimated Ohio insurance costs for the June 29, 2012, derecho and subsequent severe thunderstorms of July 1 are now estimated at $845 million according to the Ohio Insurance Institute estimates (Williams, 2013). This estimate of statewide losses, just short of $1 billion, assures that the derecho alone was a sizeable contributor to overall Ohio losses linked to the crop year 2012. The derecho and subsequent violent thunderstorms of July 1 are now considered the third costliest insurance disaster in state history. The derecho winds of up to 85 mph produced electrical power outages in businesses and homes for a week over parts of the state. The total insured losses for this event trailed only those of the remnants of Hurricane Ike (2008) and the 1974 Xenia tornado. Events such as these have increased homeowner insurances costs in Ohio by 29% since 2006, and the events are part of an increasing tendency for major weather disasters in the midwestern United States (Williams 2013).

Ohio Climate Services Provided

The Ohio state climatologist serves on the Governor's Drought Assessment Committee, which was activated in 2012. The committee, led by the Ohio Emergency Management Agency, met on a regular basis during the summer. On July 12, however, a special media-oriented meeting was attended by two of the governor's staff members. I gave a presentation, as state climatologist, describing the 2012 drought severity conditions and placing them in a historical context. The governor's staff was particularly attentive to this latter issue, trying to establish a decision-making context based on any past historical events and precedents. On July 30, Ohio governor John Kasich sent a letter to the U.S. Secretary of Agriculture, Thomas Vilsack, requesting natural disaster designations for all eligible Ohio counties because of losses by drought and additional disasters that occurred during the 2012 crop year. In early September, Secretary Vilsack designated 85 (of 88) Ohio counties as primary natural disaster areas. His letter to Governor Kasich listed the reasons for the designations and the number of counties affected by the various disasters:

1. The summer drought (83 counties designated)

2. Spring season frosts and freezes (7 northern counties, some that are part of the drought designation)

3. Excessive rains, flooding, and flash flooding from May 2 through May 4 (9 southern counties)

4. The hail storms of July 1, 2012 (5 counties, mostly along Lake Erie)

Farm operators in all declared counties became eligible for Farm Service Agency (FSA) emergency loans.

Lessons Learned

At the height of the 2012 drought, it was apparent that the Drought Monitor maps were underestimating the severity of the drought in Ohio relative to Palmer Drought Severity Index (PDSI) maps and media reports of agricultural damage across the state. The best example of the discrepancy is shown in Figure 3. The Drought Monitor map for Ohio on August 21 (Figure 3, left) shows areas of near-normal conditions in Ohio while the PDSI values for August 18 (Figure 3, right) keep the state in severe or extreme drought. Given the sizeable losses to the corn crop (described above), and the comparative event severity of the 1988 drought, it appears that the PDSI estimates better reflect the conditions in Ohio. This matter has been discussed among the state climatologist, the National Weather Service, and the Ohio Emergency Management Agency. They concluded the agencies need to establish a network among county and agricultural extension agents to better gather accurate and timely reports of agricultural and water supply conditions around the state during droughts. This information can then be passed on to the Drought Monitor to help assure that the Ohio conditions on maps better reflect conditions on the ground.

Newspaper sources:
Vanac 2012a: "It's cooler, but drought worsening, some say" Columbus Dispatch, August 24, 2012

Vanac 2012b: "Apple crop sliced" by Mary Vanac, Columbus Dispatch, September 16, 2012.

Williams 2013: "Insurance: Derecho's dollar cost doubled" by Mark Williams, April 13, 2013 Columbus Dispatch

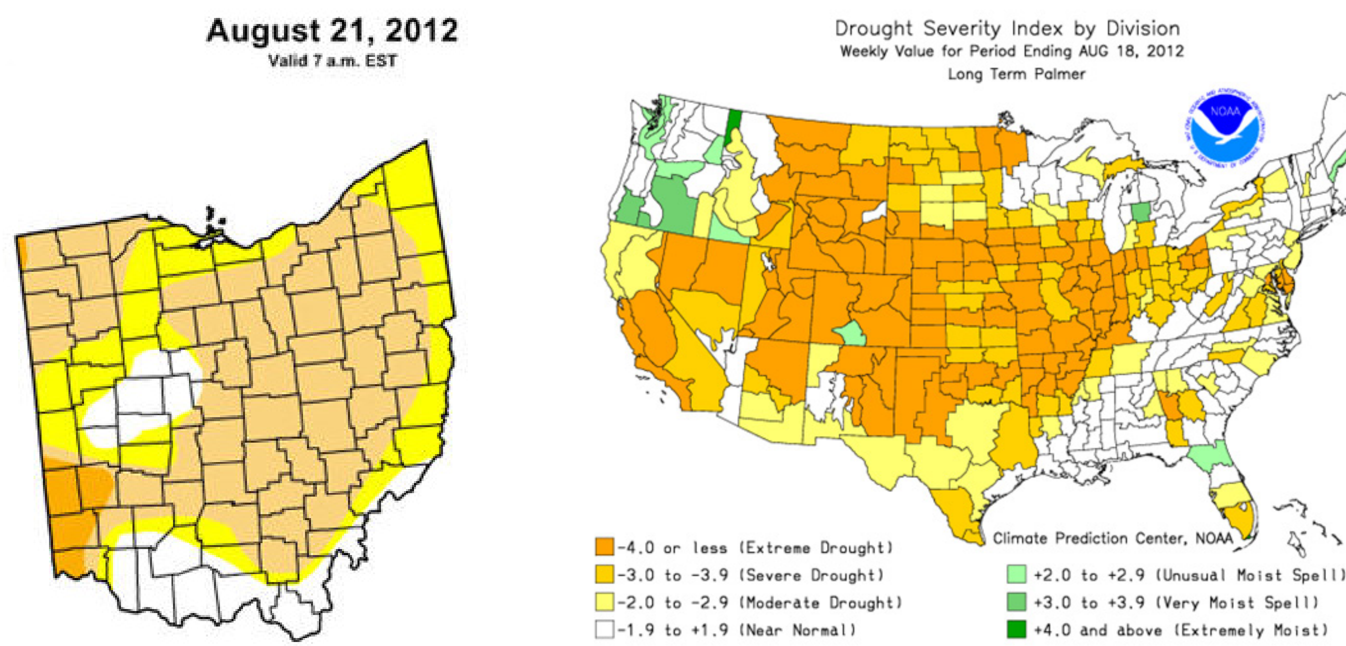


Figure 3. Drought Monitor map of Ohio drought conditions for August 21, 2012 (left), and the Climate Prediction Center Drought Severity Index map for August 18, 2012 (right).

Section 3.13: SOUTH DAKOTA

Laura M. Edwards,
Extension Climate Field Specialist
Dennis Todey,
State Climatologist
South Dakota State University

The 2012 drought in South Dakota was one of the state's most significant single-year historical droughts, causing major crop damage, fire problems on range and crop land, and economic losses across the state. There were also some positives, as some of the wetter areas of the state dried out, removing some excessive water. The year was comparable to any of the individual years in the Dust Bowl, while also being the worst Corn Belt drought since 1988.

The onset of the drought came in the latter part of the summer of 2011. A several-year wet period culminated in a major flood event on the Missouri River in 2011. Areas of the state not adjacent to the Missouri also had experienced flooding and widespread inundation. Thus, the dry latter part of the summer of 2011 was welcomed in helping dry out land and drain higher water in many areas. The dry summer continued into the fall of 2011, leaving soils dry heading in to the following spring.

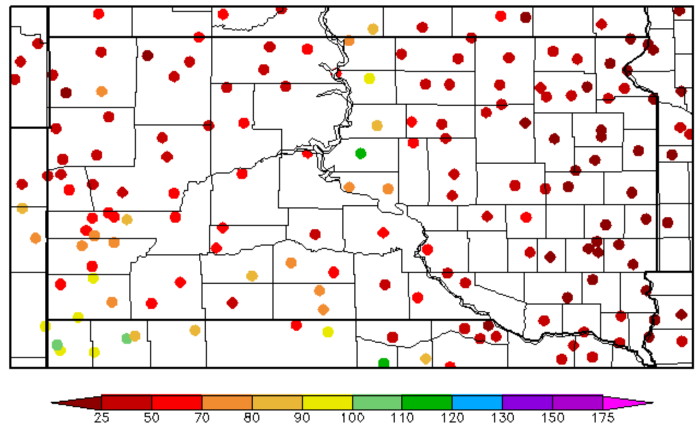
Spring conditions set in early in 2012 with much warmer than average conditions in March. At 16.7°F above average, it was the 11th driest March on record for South Dakota. The very warm spring carried over into the summer, with above-average temperatures and below-average precipitation throughout the warm season, carrying into the fall.

Precipitation was reduced to 25-50% of average or less during the summer over the southeast part of the state, heavily impacting row crops in the area. The northeast part of the state was dry, but not as seriously as the southeast. The additional heat helped crop development in the northeast. June-August was the fifth driest on record, comparing well with the worst years of the Dust Bowl. Summer temperatures were also the fifth warmest in the state's history.

Drought conditions according to the U.S. Drought Monitor (USDM) are shown in Figures 1 and 2. Some drought conditions were already apparent in the spring from the carryover fall dryness. But the most serious drought conditions developed as the summer continued, extending even into the fall.

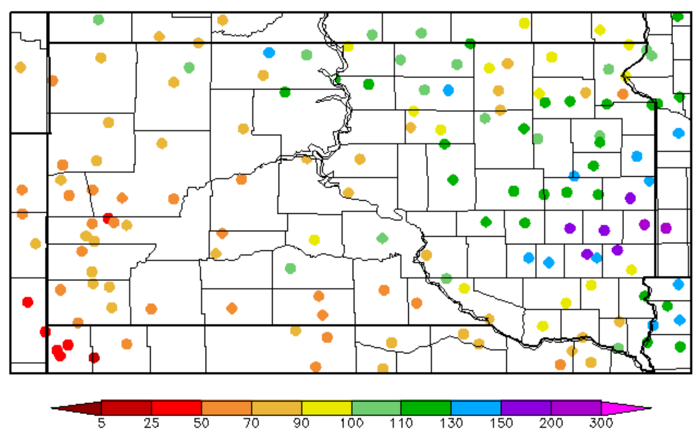
Percent of Normal Precipitation (%)

9/1/2011 - 11/30/2011



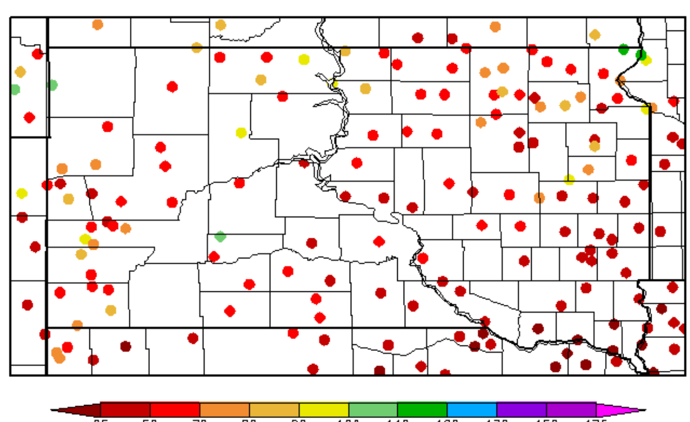
Generated 6/15/2012 at HPRCC using provisional data

3/1/2012 - 5/31/2012



Generated 6/11/2012 at HPRCC using provisional data

6/1/2012 - 8/31/2012



Generated 9/18/2012 at HPRCC using provisional data

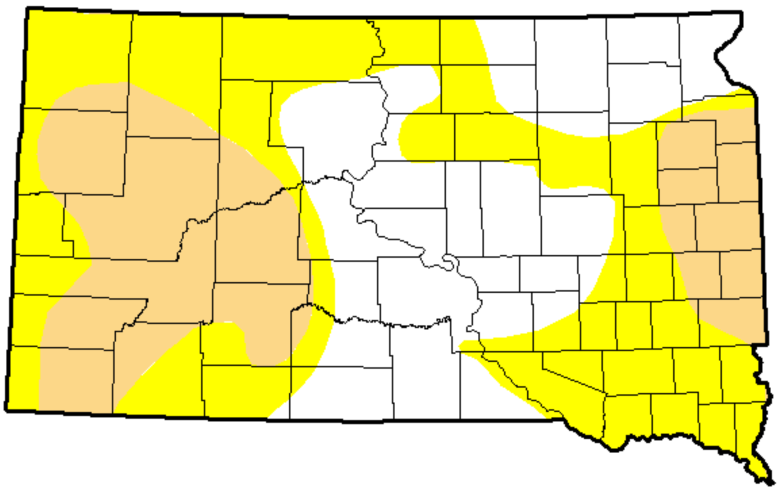
Regional Climate Centers

U.S. Drought Monitor
South Dakota

April 17, 2012
(Released Thursday, Apr. 19, 2012)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	32.56	67.44	27.22	0.00	0.00	0.00
Last Week 4/10/2012	12.33	87.67	41.14	2.45	0.00	0.00
3 Months Ago 1/17/2012	36.21	63.79	16.46	2.11	0.00	0.00
Start of Calendar Year 1/3/2012	48.14	51.86	13.86	2.11	0.00	0.00
Start of Water Year 9/27/2011	71.37	28.63	7.36	0.00	0.00	0.00
One Year Ago 4/19/2011	100.00	0.00	0.00	0.00	0.00	0.00



Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

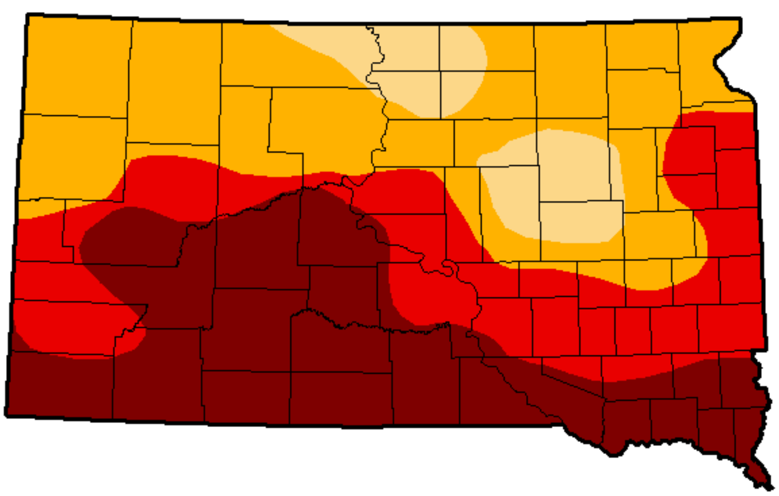
Author:
Anthony Artusa
NOAA/NWS/NCEP/CPC

http://droughtmonitor.unl.edu/

October 16, 2012
(Released Thursday, Oct. 18, 2012)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	100.00	91.45	57.21	32.57
Last Week 10/9/2012	0.00	100.00	100.00	91.39	52.65	32.57
3 Months Ago 7/17/2012	0.00	100.00	90.37	44.93	0.00	0.00
Start of Calendar Year 1/3/2012	48.14	51.86	13.86	2.11	0.00	0.00
Start of Water Year 9/25/2012	0.00	100.00	100.00	74.69	50.53	6.72
One Year Ago 10/18/2011	73.44	26.56	7.43	0.00	0.00	0.00



Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Matthew Rosencrans
CPC/NCEP/NWS/NOAA

The U.S. Drought Monitor map of South Dakota at the peak of the drought in October 2012, as defined by the largest area designated in D4 (exceptional drought).

USDM Map Archive: http://droughtmonitor.unl.edu/DataArchive/MapArchive.aspx

Agriculture

Wheat

Before the onset of the drought, fall 2011 was dry, but soil moisture was fair to good for the time of year. Planting and emergence occurred very close to the average time. Soil moisture was sufficient to germinate winter wheat, which set the stage for a record or near-record yield in 2012. The "open" winter, with little to no snow cover, was cause for some concern early on, as there was no protection from extreme cold temperatures. The winter season of December through February ended up being more than 4°F above average, with few, if any, extreme cold events to cause damage to the crop.

The spring season was exceptionally warm, as has been noted previously. This allowed the winter wheat crop to grow well, without significant winter damage. Phenomenal yields resulted because of the warm weather and sufficient soil moisture over the winter season, averaging 45-50 bushels per acre in South Dakota's wheat-growing region. Harvest was about three to four weeks ahead of the five-year average, with completion by mid-July.

Corn

Nationally, corn yields in the United States averaged 123.4 bushels per acre, well below the long-term trend line. In South Dakota, statewide average yield in 2012 was 101.0 bushels per acre, below the national average and about 30 bushels per acre less than the average yield in both 2011 and 2010. Total production of corn for grain was 535,300,000 bushels, which was more than 118,000,000 bushels less than the previous year, despite the increase in acres harvested. More than 300,000 more acres were planted to corn in 2012 than in 2011.

There was also a three-fold increase in acres harvested for corn silage in 2012, compared to 2011. About 600,000 acres were planted for corn silage in 2012, but averaged only 8 tons per acre, about half of the 2011 average ton per acre. Despite the three-fold increase in corn silage acres, total production for the state increased by only 64%, because of the low tonnage per acre. The increase in silage was largely due to taking corn for silage that was not going to create sufficient yield or was already drying out.

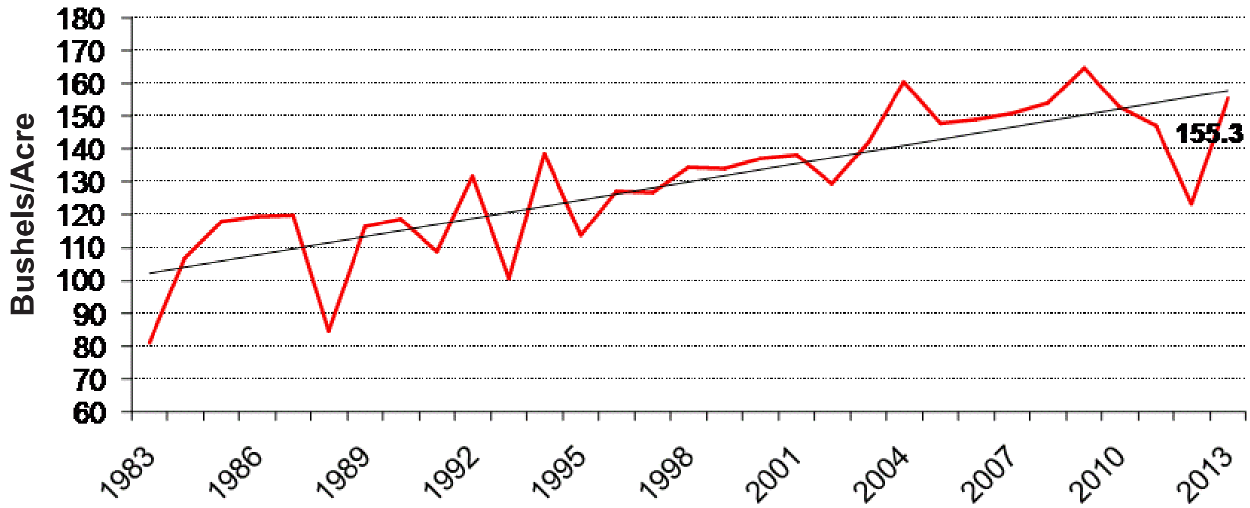
In the southeastern and south central counties of South Dakota, yield per acre ranged from 0 to 50 bushels per acre in the worst-hit areas that did not have irrigation available. See the map below for yields reported by county. Farmer reports noted 0-10 bushel-per-acre yields in the corners of fields that were outside of center-pivot irrigation systems. The highest yields were from the northeast, where some timely rains produced yields of 125 to more than 175 bushels per acre in limited areas.

In northeast Day County, an SDSU field research program estimated the water deficit at nearly 8 inches at the completion of the corn growing season, using evapotranspiration estimates from daily weather data in the field. This means that the corn crop needed nearly 8 inches more moisture to produce that crop than it received from rainfall. This moisture deficit was made up by soil moisture stores that the roots were able to take up into the plant. In that field, the corn yield was about 120-140 bushels per acre.

Corn crop condition in 2012 began well, as NASS data show. May and early June indicated the best crop condition in five years. The warm dry spring allowed for one of the quickest plantings in history. Corn crop condition steadily fell in the latter half of June, then quickly tumbled through July and early August, with a maximum of more than 50% of the crop rated poor or very poor by late August. This rapid decline in crop condition corresponded with the silking period, which occurred about two weeks ahead of the five-year average, and also dough and dent stages. The corn harvest was very fast, with most of the corn acres harvested in about a two-week period in September. Harvest was completed by mid- to late October, about three to four weeks ahead of 2011 and at least a month ahead of the five-year average. Dry conditions enabled rapid harvest of both corn and soybeans, which often occur at about the same time of year.

There are a number of reasons for the increase in corn acres in 2012. First, there was no spring flooding, which had been a chronic concern in the past few years in the corn-growing region of the state. Second, the price of corn was rising, and ended up more than $7 per bushel as the drought affected production across the Corn Belt states. The price increase was due to many factors, including low production nationwide, ethanol demand, and livestock feed demand.

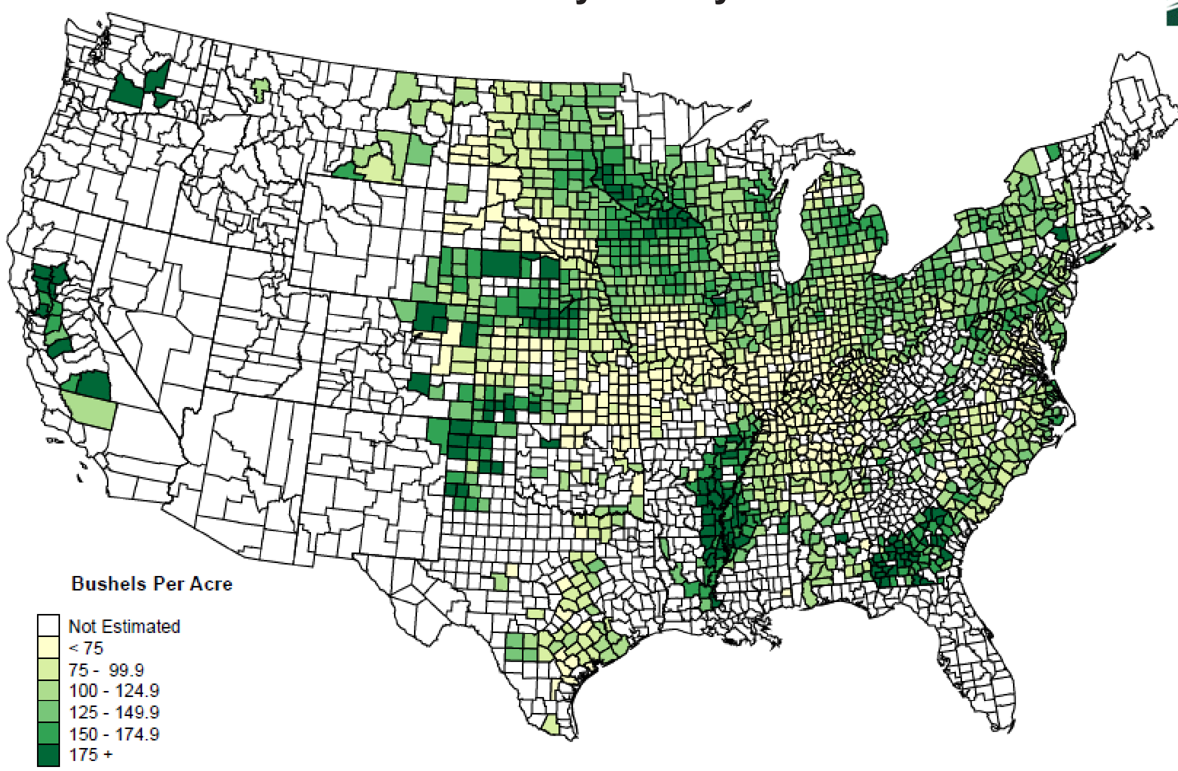
U.S. Corn Yield



Yields from USDA-NASS:
http://www.nass.usda.gov/Charts_and_Maps/Field_Crops/cornyld.asp

Yield per harvested acre:
http://www.nass.usda.gov/Charts_and_Maps/Crops_County/pdf/CR-YI12-RGBChor.pdf

Corn for Grain 2012
Yield Per Harvested Acre by County for Selected States



Wildfire at Hansen-Larsen Memorial Park near Rapid City, South Dakota on March 9, 2012.

Soybeans

Nationally, soybean yields were below the long-term trend in 2012. The national average yield was 39.6 bushels per acre. In South Dakota, the state average yield was 30.0 bushels per acre. By way of comparison, the statewide average in 2010 was 38.0 bushels per acre, and in 2011 the average was 37.0 bushels per acre.

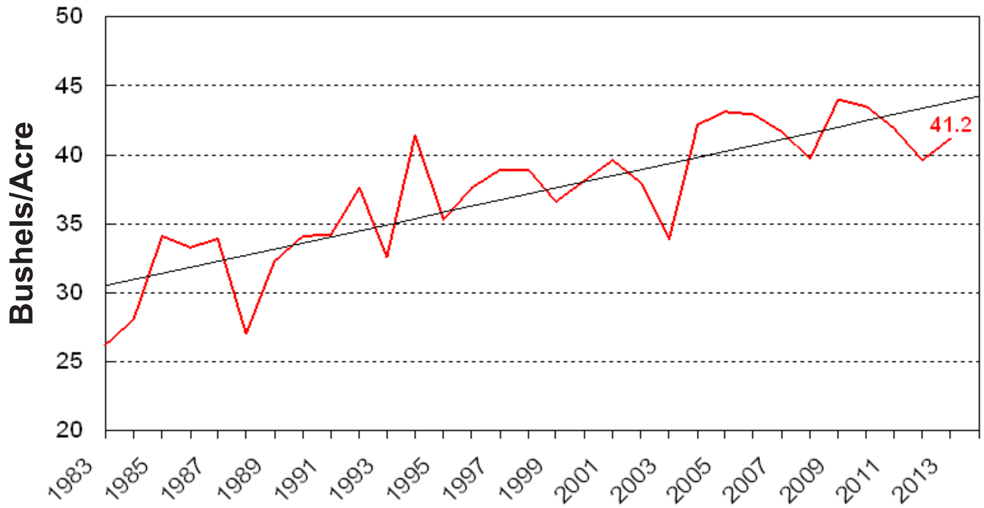
In South Dakota, soybeans are usually planted in May or June, after the corn crop has been planted, and 2012 was no exception. Spring planting went relatively quickly, given moderate rainfall and warm temperatures. As of early to mid-June, NASS reports showed the best soybean crop condition in the five-year period. There was sufficient soil moisture carryover from the previous year to germinate and start the plants.

By mid-summer, the heat and low rainfall began to take a toll and plants suffered. Crop condition was declining in late June and continued to do so at a rapid rate through most of July. Leaf "flipping" to conserve water usage was evident in late July. Plants were small in size and had fewer than average blooms during the flowering period in July and August. There was a brief improvement in mid-August due to a rainfall event during the period when soybeans were setting pods. In general, crop progress was about two weeks ahead of the five-year average throughout the growing season. Some central counties near Pierre had no more than a trace of rain in a six-week period in August and September, which caused severe drought stress to those crops.

Many plants died in the field because of the extreme water stress, especially in the southeast and south central counties. As shown in the county yield map below, those counties averaged 0-15 bushels per acre, and northern counties in the state averaged 30-40 bushels per acre. Some farmers in the north central and northeastern counties had their best soybean yields ever in 2012, with some land yielding more than 40 or 45 bushels per acre. This area is where the drought was less of a factor, both in duration and severity, reaching only D1 or D2 on the USDM map at the peak drought period. These counties benefited from some especially timely small to moderate rainfall events, even though total rainfall was below normal for the season.

Harvest season in 2012 was completed by mid-October, about a month or more ahead of the five-year average. Harvest progressed quickly given the dry and warm conditions, with 80% of harvest completed in a three-week period.

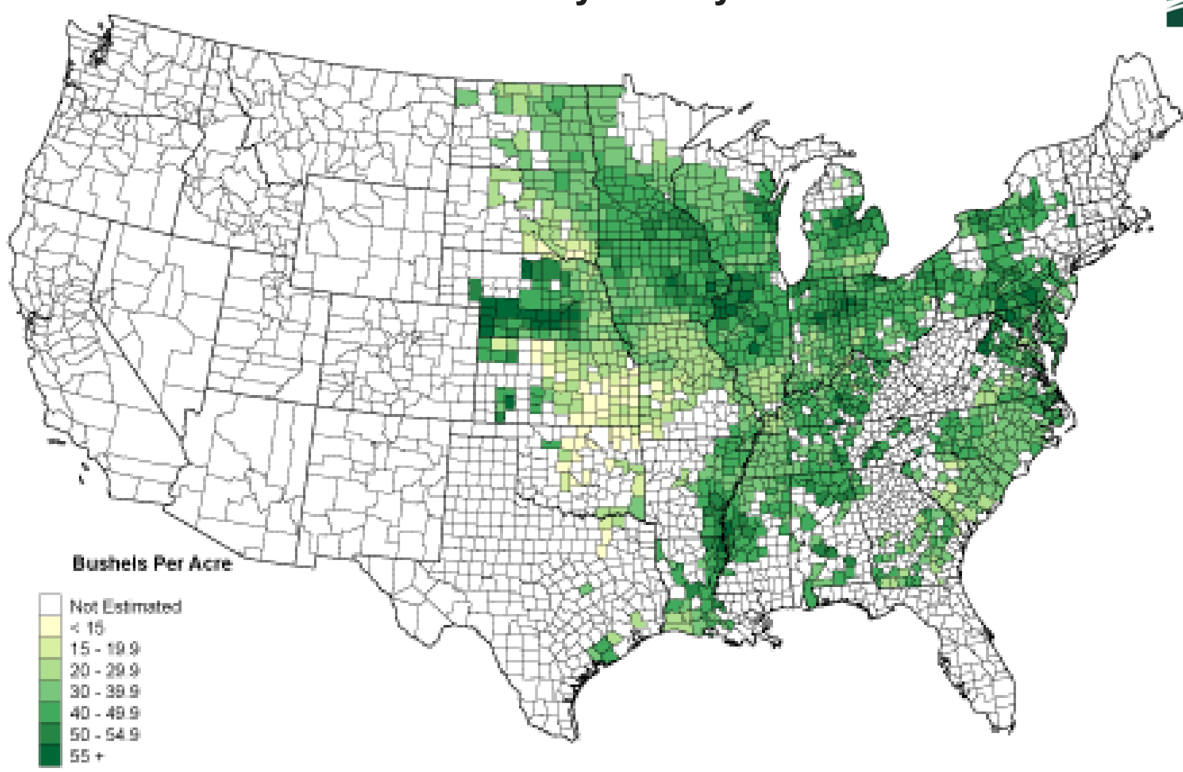
U.S. Soybean Yield



National yields from USDA-NASS:
http://www.nass.usda.gov/Charts_and_Maps/Field_Crops/soyyld.asp

Harvested acreage by county:
http://www.nass.usda.gov/Charts_and_Maps/Crops_County/sb-yi.asp

Soybeans 2012
Yield Per Harvested Acre by County for Selected States

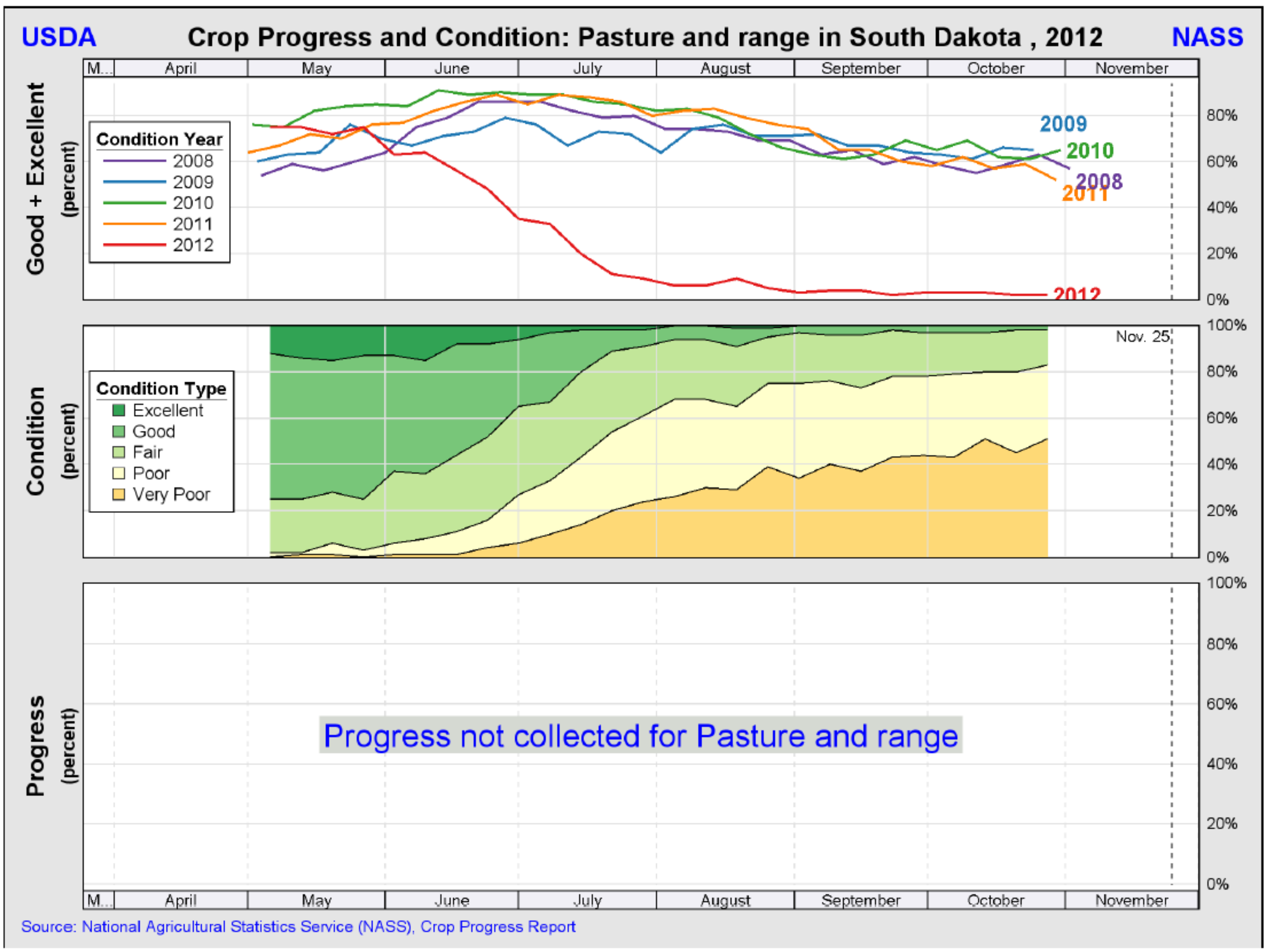


Pasture and Range

Pasture and range conditions were rated well within the five-year average to start the season in May, when reporting begins for NASS. As with field crops, the heat and dry conditions began to impact crop conditions in June, as seen in the graphic below. A steady decline in pasture and range conditions was evident throughout June and July. In most areas, there was just one cutting of alfalfa hay in 2012, which caused hay shortages for producers who did not have additional hay storage on hand. A secondary impact of poor hay and alfalfa production was an increase in feedlot costs, as corn silage was also in short supply regionally because of the drought. Moving cattle to feedlots is a common drought coping strategy when other feed or pasture and forage is not available, and that option became more costly with low hay and corn silage supplies.

By the end of the 2012 growing season, pasture and range condition had plummeted to more than 80% being rated as poor or very poor statewide. The percent of area rated good to excellent was much lower than in any of the previous four years, by a margin of more than 40%.

See the graphics on this site for crop progress and condition in the 2012 growing season: http://www.nass.usda.gov/Charts_and_Maps/Crop_Progress_&_Condition/2012/index.asp



Wildfires

Wildfires became a huge problem during the year because of the dryness across the rangeland problems and limited green-up during the spring and early summer. A few ranchers specifically noted almost no green-up because of the lack of spring precipitation and additional spring water demand from the warm temperatures.

The dry conditions in the fall led to numerous fires during harvest season. Fires started by heat and sparks from combines resulted in burned crops and the loss of several combines.

On February 28, 2012, the governor of South Dakota signed an executive order expanding the South Dakota Division of Wildland Fire Suppression's authority to augment its firefighting response efforts throughout the state (http://sdsos.gov/content/html/adminservices/adminpdfs/Executive%20Orders/EO2012_03.pdf).

A major loss from the fires was a military aircraft and crew fighting a fire in southwest South Dakota. A C-130 aircraft with a crew of six crashed while fighting a fire near Edgemont on July 2, 2012. Two crew members died.

Hunting and Wildlife

White-tailed Deer

The 2012 drought affected wildlife, fishing, and hunting, which make up a significant portion of the state's economy, both in license fees and sales tax from related equipment and gear sales. Tourism dollars related to these and other outdoor sports are also very important to the state. The economic impact of the drought on outdoor sports is unclear at this time. White-tailed deer are a major game species in eastern South Dakota (mule deer are more common than white-tailed deer in western South Dakota). In early October 2012, about six weeks before rifle season for white-tailed deer, the South Dakota Game, Fish and Parks put a stop to sales of white-tailed deer hunting tags. They implemented this policy in six counties in southeastern and south central South Dakota, where the drought was the worst. A large number of tags had already been sold through the state's lottery system. The reason for the decision was the large number of white-tailed deer that had died from epizootic hemorrhagic disease (EHD, or "bluetongue"). This disease is carried by a midge that bites the deer and then infects them. Death can occur within 24 hours of the initial exposure. Although this not an uncommon disease, the drought brought deer closer together near watering locations, and midges were able to infect many more deer within small areas. By the time the decision to stop new license sales was made, several hundred to more than a thousand deer had already died from EHD. The six counties ceased sales of deer tags, and in addition allowed full refunds on tags that had already been issued.

Pheasants

Pheasant hunting is a strong anchor of the state's economy. The pheasant season in South Dakota starts in mid-October and runs for 79 days. In 2012, there were about 1,000 fewer hunters than in 2011, the lowest number of registered hunters since 2003. The number of pheasant roosters harvested was 1,428,873, the lowest since 2002, another drought year in the state. The number of birds shot per hunter was also the lowest since 2002. As a result, the 2012 pheasant hunting season could be described as the most difficult season in a decade.

Climate-related reasons for the reduction in pheasant population and hunter success have included an extremely warm spring brooding season with a hard freeze that could have killed young birds, and lack of snow cover in the previous winter for protection from predators and weather extremes. One usual drought impact was the reduction in vegetation and also insects that the pheasants use for nesting and to feed chicks, but the drought did not greatly impact the spring chick season in 2012.

The drought conditions in the fall season also greatly affected broods, with 50% mortality in the state's radio-collared birds in the south central area, much higher than average for that time of year. The exact cause of this die-off is unknown, but it may be due to the great loss of habitat in combination with the shortage of invertebrates to feed on.

Other non-climate factors of note have included the large reduction in habitat in recent years due to the increase in cropping acres, and in 2012 there may have been a reduction in safe cover from predators because of the early harvest of corn and soybeans completed in September, weeks before opening day.

The 2012 drought had a carryover impact and affected pheasant numbers in 2013 as well. The South Dakota Game, Fish and Parks brood survey report cites poor winter wheat establishment in fall/winter 2012-13 as one factor in the reduction of birds. Winter wheat provides cover during the snow cover season.

Fishing

One activity that was affected more by the 2011 flood than by the 2012 drought was fishing in the Missouri River reservoirs in South Dakota. Walleye is one of the most sought-after species of fish in the river. Data from Lake Oahe, Lake Sharpe, and Lake Francis Case indicate that walleye fishing was good in 2012.

In Lake Oahe, which reaches from North Dakota to Pierre, South Dakota, hourly catch rates of walleye were very high in each month of the primary fishing season, April through October. Walleye size averaged almost 16 inches, as the minimum size allowable to keep is 15 inches. Fish in the lake are plentiful, and so food sources are competitive and fish sizes are smaller during those conditions. In essence, there was high success in catching fish, but they tended to be small-sized. Walleye abundance in Lake Oahe was above the long-term average, with 2012 surveys reporting slightly more than 20 fish per net, because of production of many young fish in the 2005-2011 period, particularly in 2009. It takes walleye about four years to grow to 15 inches in length.

Lake Sharpe, the next reservoir downstream from Lake Oahe, terminates at Big Bend Dam at Fort Thompson. Here, the walleye population index was just at the long-term average of 23 fish per net. The number of fish of harvestable size (15 inches or longer) was below the long-term average in 2012. Again, there is a delayed period with fish production due to the four-year period it takes for the walleye to grow to harvestable size. As in Lake Oahe, production was high in 2009. This generation made up about half of the net catch in 2012 walleye surveys. Lakewide catches were above average, with an hourly average of about 1.6 walleye, the highest since recordkeeping began in 1994.

The next reservoir on the Missouri River is Lake Francis Case, which stretches from the Chamberlain area to Fort Randall Dam at Pickstown, South Dakota, just north of the Nebraska border. Runoff from area flooding in 2011 replenished nutrients, and it was an excellent production year. For walleye, 2012 was a moderate production year, possibly because of the drought, at least in part, as runoff into the basin was a little less than a third of the 2011 amount. The fish per net in the South Dakota Game, Fish and Park surveys declined to 2009 levels in this lake, but it is uncertain if this is directly attributable to the drought.

South Dakota has more than 570 lakes, reservoirs, and ponds. This is just a sampling of data that has been made available. Overall, it appears that the wet years that preceded the 2012 drought were beneficial for fishing, as nutrients were able to flow into water bodies and provide sufficient food and sources of cover in times of higher water levels. Area lakes did not drop low enough to become anoxic and cause large fish kills.

Risk Management
Crop insurance (RMA, FSA)

The dry conditions leading into the 2012 drought ended a period of many years of large prevent plant losses in the northern plains. This was welcomed as many acres were potentially going to lose their prevent plant insurance. The Risk Management Agency (RMA) granted a one-year extension to its rule of a field needing to be planted once every three years to maintain prevent plant status. The very dry early season allowed planting of many acres that had not been planted in several years.

Crop insurance indemnities still mounted during the year because of the large losses incurred with the drought (Fig. xx). The largest losses in South Dakota were in the James River Valley and the southeast. These areas were the most heavily impacted by drought conditions during the year. All counties experienced losses that were reported to RMA.

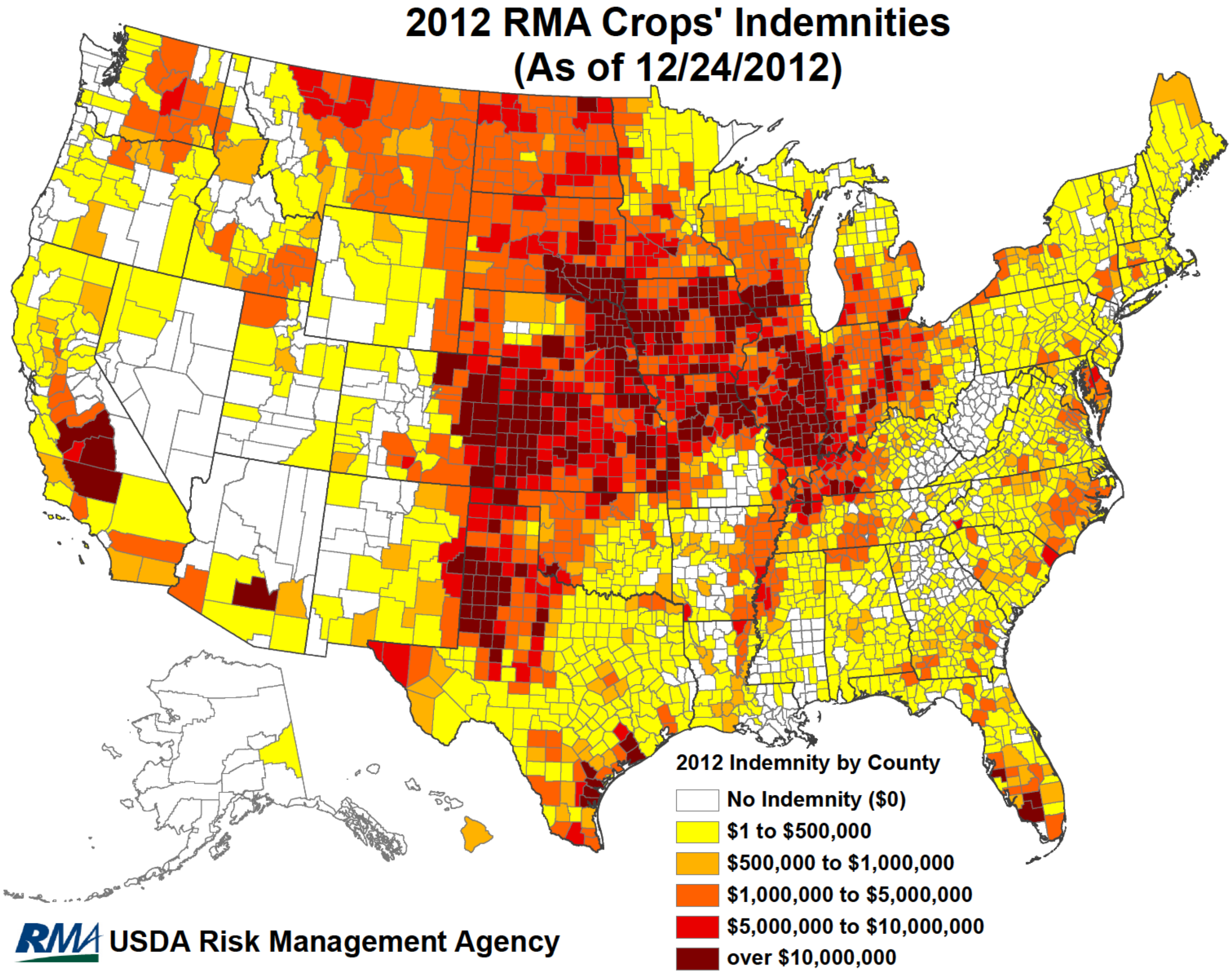
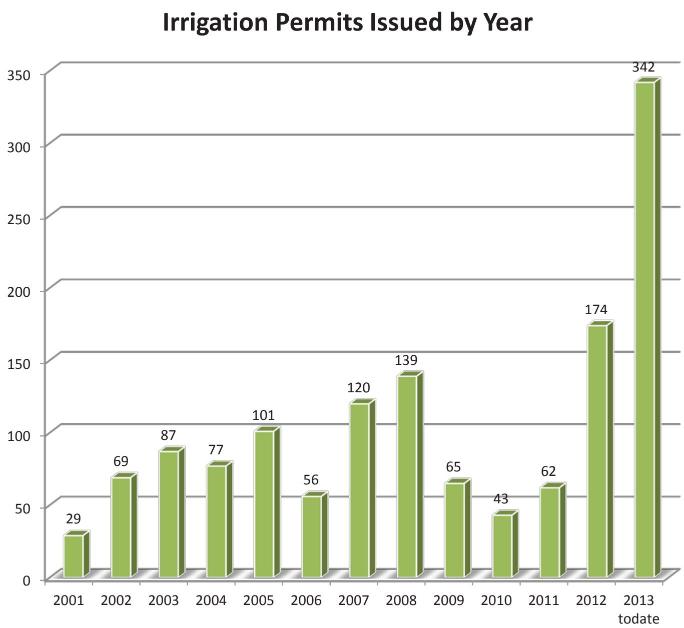


Photo by Kelly Hertz

Drought stressed corn tasseling ahead of schedule in Yankton County, South Dakota on July 13, 2012.

Irrigation

With the increase in corn prices coupled with the drought of 2012, interest in irrigation reached an all-time high in South Dakota, and the subsequent requests for well permits created a several-month backlog and a large increase in the number of permits issued (Figure 5). Permitting of wells for irrigation is granted through the South Dakota Department of Environment and Natural Resources (SD-DENR).



Regional Climate Services Provided in Response to the Drought

The increased need for climate services became very apparent during the summer of 2012 in South Dakota. Information and services were provided across several platforms and through various delivery methods.

Dennis Todey and Laura Edwards began issuing weekly updates of current conditions and outlooks to South Dakota media using the SDSU Extension iGrow platform (http://www.igrow.org) and weekly radio segments. Additional TV, newspaper, and radio interviews ensued, with Todey and Edwards giving a total of more than 100 individual interviews. This included two full episodes of South Dakota Focus, a weekly hour-long current affairs program produced by South Dakota Public Broadcasting.

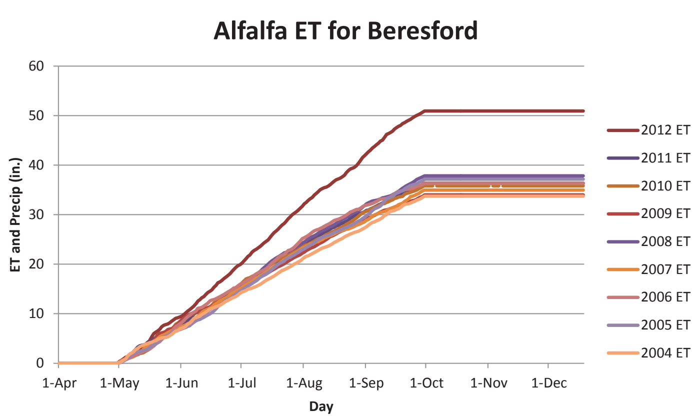
SDSU Extension delivered two drought webinars and numerous additional webinars and articles on the iGrow site dealing with the impacts of drought in South Dakota.

Dennis Todey and Doug Kluck (NOAA) adapted webinars to provide bi-weekly drought updates starting in early July 2012. These webinars were originally created to deliver outlook information as a follow-up to the 2011 Missouri River Flood supporting the US Army Corps of Engineers. As the drought rapidly worsened, the webinars were quickly reworked to present current drought conditions, impacts, and outlooks. An evaluation of these and subsequent webinars is currently in process.

Lessons Learned, Best Practices, and Next Steps

Evapotranspiration Data

The combination of lack of precipitation and heat both drove issues with drought in 2012. Increased evapotranspiration (ET) caused by early warm temperatures and more rapid growth in the spring along with warm temperatures throughout the season seemed to exacerbate the 2012 drought. Precipitation was lacking. Impacts were made worse by very high crop water demands quickly eliminating existing soil moisture profiles. ET data is available, but not regularly included in drought mapping. Since 2012, several products have started to fill this void. Alfalfa reference ET indicates how large the atmospheric demand was during 2012, dwarfing any year in the previous eight.



Penman calculated reference ET for Beresford, South Dakota, from the automated station at the Southeast Regional Research Farm.

Soil moisture

Soil moisture monitoring is also needed. Spring precipitation in parts of eastern South Dakota seemed to reduce some drought issues, making the overall impact of drought difficult to determine because of the lack of widespread soil moisture monitoring.

Additional Data Collection

The USDM's depiction of drought across the western part of the state was hampered by a lack of impact reports and mixed messages from measured data. Precipitation totals and remotely sensed data such as radar precipitation estimates and rangeland stress data presented mixed messages in the latter part of the spring, despite the aforementioned lack of spring green-up.

After some on-ground communication from a local NRCS office, the severity of South Dakota's drought was reflected by the USDM. But it became very clear that additional on-ground reports were needed regularly. The change in SDSU Extension from county offices to regional offices in 2010 meant the loss of many potential local reports, which added to the problem.

Outlook limitations

NOAA outlooks (or any other outlooks) still are not able to show the potential for extreme climate conditions. Although outlooks likely will never be able to indicate such extreme issues as those that occurred in 2012, the NOAA CPC outlooks gave no indications of pending drought issues, even in the May outlooks. The June outlooks did seize on warm and dry conditions continuing in the Corn Belt. Ongoing improvement of outlook products is a must.

Policy

- Activated state drought task force.
- Forced South Dakota (specifically the Department of Emergency Management) to go into revision of state drought plan.
- Brought soil moisture monitoring to the forefront as a need for improving the climate and drought monitoring system in the state.

Section 3.14: WYOMING

Tony Bergantino,
Service Climatologist
Wyoming State Climate Office

Introduction

Statewide, 2012 was the driest and warmest year in Wyoming since 1895. The previous year was above average for precipitation and almost right at average for temperature, and this sequence of years proved both beneficial and detrimental. Figure 1 shows Wyoming annual precipitation for 1895-2012; note that the final data point (2012) is also the lowest at 8.07 inches.

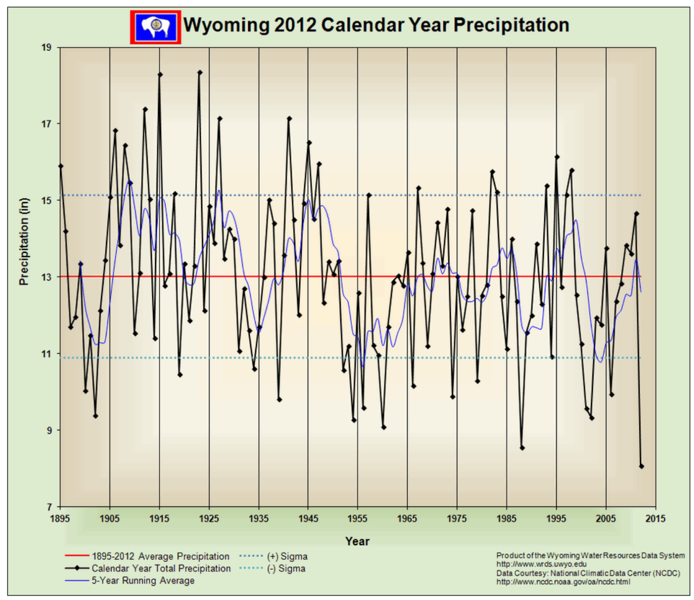


Figure 1. Wyoming Calendar Year Precipitation (1895-2012)

In one sense, following a good year for precipitation was beneficial in that some reservoirs were near full, which provided a store of water to be used later in the season in 2012 when a record dry June would have otherwise made irrigation much more difficult.

The other side of the coin, though, was that the conditions in 2011 helped create a potential situation for fires. This potential was realized when low spring precipitation in 2012 coincided with near-record June and July temperatures and Wyoming suffered one of its worst fire seasons in several years. June average temperature statewide in 2012 was tied for fourth highest while July was the second highest since 1895. Figure 2 shows the annual mean temperature in

Wyoming for each year since 1895, and 2012 is more than one standard deviation higher than any year since 1981.

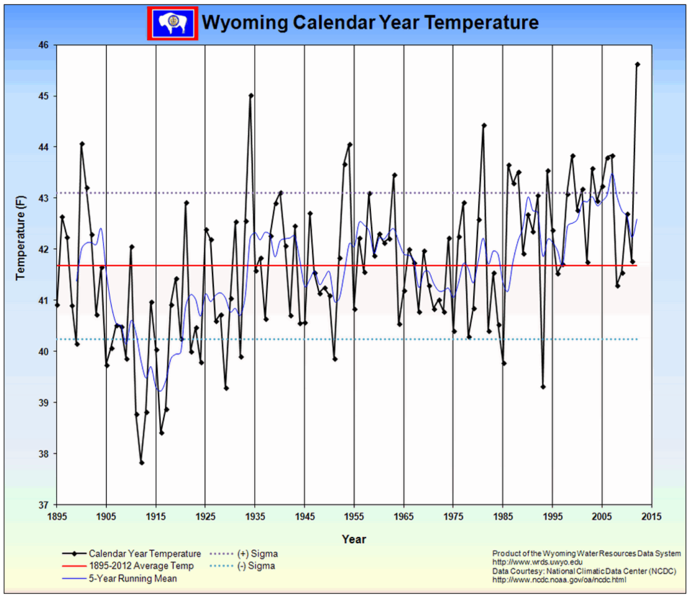


Figure 2. Wyoming Calendar Year Average Temperature (1895-2012)

Drought

Although 2011 was a relatively good year for moisture, it did not take long for conditions to deteriorate. Figure 3 shows the percentage of each level of drought in Wyoming on a weekly basis from the start of 2000 thru the 2013 Water Year. At a glance, it can be seen that the drought of 2012 followed hard upon one of the few periods of relatively good conditions that have been seen in this century. Most of 2011 saw Wyoming free of drought and with good precipitation, but 2012 started with abnormally dry conditions creeping into the state and soon followed by worsening conditions that quickly surpassed levels last seen in 2007.

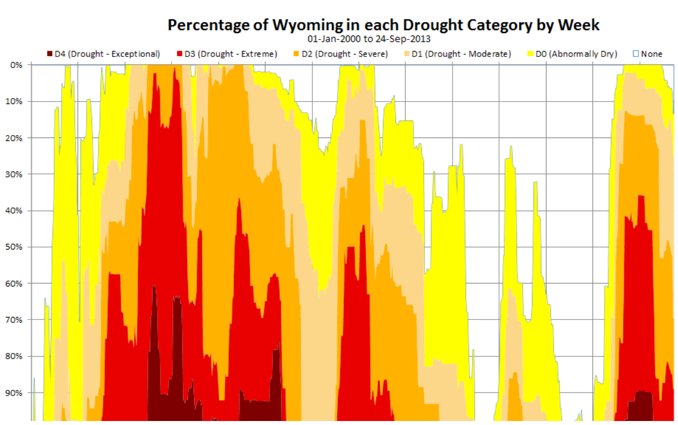


Figure 3. Percent of Wyoming in each drought category shown by week (01-Jan-2000 to 24-Sep-2013)

Wildfires

Fire management practices have changed over the years, making the number of fires or the amount of land burned a questionable metric for determining the severity of a particular year. For example, a 1934 policy decreed that all fires were to be extinguished by 10:00 AM of the next day following detection. Although this was obviously not always feasible, the policy led to low numbers of annual burned acreage, not to mention a buildup of fuels.

As a result, the policy shifted toward allowing fires to burn while they could be contained to Management Units. Policies were again reviewed following the Yellowstone fires of 1988. All of these changes make it difficult to use acreage as a reliable indicator of relative conditions. The acres burned and the costs associated with suppression are certainly measureable impacts, however. Different data sources disagree on both the number of fires and the acres burned, but 2012 stood out as being high in both sets of numbers.

Using data from the National Interagency Fire Center, Figure 4 shows 2012 as having the most acreage affected out of the last 11 years (2002-2012). The acreage given for 2012 (357,117) is certainly low, with estimates made toward the end of the fire season putting the number at more than 500,000 acres burned.

With an average annual total of only 8.07 inches, the statewide precipitation for Wyoming in 2012 was the lowest on record going back to at least 1895. This followed 2011, which not only had the highest precipitation statewide since 1998 but also was the third year in a row with above-normal precipitation. This sequence of events led to an abundance of fuels. Hot temperatures and the dry conditions made these fuels ripe for ignition, and fires like the Arapaho and Fontenelle quickly consumed acres and resources. Roads and recreation areas were closed, curtailing much summer activity. The timing of the fires saw several bans and the cancellation of some public Fourth of July celebrations. The total cost of fighting the fires in Wyoming in 2012 was estimated to be about $108.5 million, with $42 million of that being Wyoming's share.

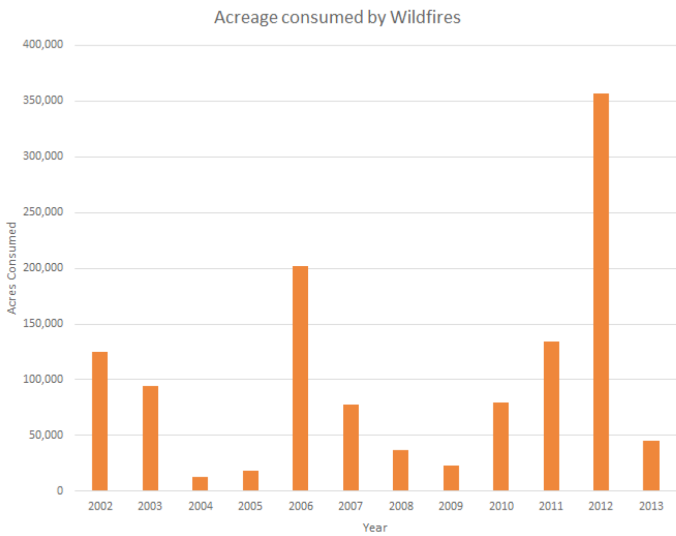


Figure 4. Acres burned in Wyoming by year (National Interagency Fire Center)

Water Rights and Irrigation

The drought of 2012 had varying impacts on water rights, depending on the part of the state. Occasionally, as in State Engineer's Office Division 1, District 1, the severity of the drought made the job of water rights administration quite easy: "The 2012 water year was one of the easiest years I have had on this job. The lack of water in the streams made for a short irrigation season for some appropriators. The hot dry persistent winds and unusual high temperatures were detrimental to the growing season. All of the stream flows in my district diminished to trickles by late May and some just dried up completely. Because there was no water to regulate I only had two calls for regulation this year." –Scott Ross, Division 1, District 1.

As bad as it was in some places, it could have been a lot worse: "Water Commissioners from the Lower Green River Basin all stated that this was an extremely difficult year due to the drought conditions. They also stated that due to full reservoirs a difficult year of regulation was made easier." Easier, however, does not equate to easy: "Over all the down side is that some users never had the opportunity to irrigate at all with complete to significant losses in hay crops. Those users that were able to divert and those that had storage water had fair to mediocre hay crops, with reports coming in at 50-80%. Having 2 exceptional water years in a row to compare to really showed this year as a horrible year to try to raise hay." –John Yarbrough, Water Division 4, Districts 1, 3, 9, 14, 15.

In central west Wyoming, although dry, conditions allowed for irrigation all around. "What a WATER year. It was the driest winter we have had for some time. Winter came late and not very much of that. Spring came early and most folks got their crops in the earliest in history. The amazing part was that we had water for everyone all summer long." –James Wilson, Division 4, District 13.

Helping the situation in the Bear River Basin was the fact that Woodruff Narrows Reservoir ended the 2011 water year with a carryover of 90.2%. In contrast, and as a testament to the conditions, the carryover reported at the end of the 2012 water year was only 9.7%. This was lower than the carryovers seen in 2003 and 2004.

Although some streams and rivers did not go into regulation at all, the depth of regulation in some areas was the lowest or near the bottom of the last 10 years and was sometimes equal to that experienced in 2007 or even 2003-2004. In Division 1, District 4A (the Laramie River) water year 2012 started with no regulation, but by April 26, 2012, regulation was

Notable Fires in Wyoming in 2012

Fire	Acres	Date of Origin	Containment Date	Cause
Arapaho	98,115	27-Jun-12	23-Aug-12	Lightning
Fontenelle	64,220	24-Jun-12	25-Oct-12	Under Investigation
Oil Creek	62,318	29-Jun-12	9-Jul-12	Human
Alpine Lake	46,184	7-Aug-12	15-Nov-12	Lightning
North Buffalo	28,000	24-Aug-12	~16-Oct-2012	Human
Sheep Herder Hill	15,556	9-Sep-12	16-Sep-12	Under Investigation
Sawmill	14,185	14-Jul-12	~Aug-2012	Human
Squirrel Creek	10,921	30-Jun-12	9-Jul-12	Human

called for at the October 1, 1884, priority. A month and a half later, the regulation date was dropped to the April 19, 1879, rights. By the end of August, the priority was dropped to the very first right on the river, and regulation was carried at the 1868 priority date through the end of the water year.

Services Provided

The Wyoming State Climate Office (WYSCO) provided drought information via its website and via media interviews. Information was also provided to support drought declarations and the WYSCO also served as focal point for updates to the U.S. Drought Monitor and provided input to its authors.

Lessons Learned

Communication. There can never be too much communication between the various entities in the state that are affected by drought. Data availability in terms of geographical extent and parameter type can always be and should be improved whenever and wherever possible. The capability to monitor conditions needs to be improved through the installation of more sensors; especially those measuring more non-traditional parameters such as soil moisture and evapotranspiration, for example.

The Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) has been an invaluable source of precipitation data. This has long been recognized and, after 2012, efforts have been increased to get even more stations established. This has resulted in more than a 20% increase in the number of observations being reported per day in 2013 compared to 2012. The importance of reporting when there has been no precipitation (as opposed to reports of only measurable precipitation) is well understood by Wyoming observers. That is not to say, however, that there is no room for improvement, and every opportunity has been taken to let observers know the value of a zero report.

Section 4: Conclusions

Brian Fuchs, National Drought Mitigation Center

At the end of 2012, more than 74% of the region was still in drought and more than a third (34%) was still experiencing extreme or exceptional drought, mainly over the western portions of the region. With many natural disasters, the questions arise as to why an event happened and what were the driving forces behind it. The 2012 event was unique as the precipitation spectrum shifted dramatically from the flooding in 2011 to the significant drought in 2012. With an early spring and close to normal precipitation through the first half of the year, there were few indications of what would develop in the summer and how quickly the drought would intensify. Sometimes there are no clear answers to all of our questions about natural disasters like drought. What we can do is learn from the past and assess what worked and did not work in responding to drought. Proper planning, monitoring, and impact assessment can contribute a great deal to lessening the societal impact of drought. The National Drought Mitigation Center has long promoted the idea that societies will deal with drought events better through preparedness and risk management rather than a crisis management approach.

The multi-billion-dollar drought that impacted the central United States in 2012 has been outlined in this report by state and regional experts who were actively involved in monitoring its effects. Each state in the region took a unique approach to identifying and dealing with the drought's impacts. Regionwide, many of the agricultural impacts were similar, but impacts in other sectors varied by state. The drought's effects varied throughout the region—not too surprising considering the differences in the climatic regimes from east to west and north to south in this part of the United States. Planning, preparedness, monitoring, and impact collection all play an important role in lessening the devastation during a drought event. It is hoped that the lessons learned from the 2012 drought event, as outlined in this report, will increase our knowledge of how to address the next drought event. Many remembered the drought of 1988 during the drought of 2012 and the similarities and differences between the two. It is hoped that this report will help decision makers understand exactly what happened during the 2012 drought and use this information to prepare for the next drought.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