State of Oklahoma
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WATER RESOURCES BOARD
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Oklahoma Comprehensive Water Plan
Supplemental Report

# Agricultural Issues & Recommendations

June 2011

This study was funded through an agreement with the Oklahoma Water Resources Board under its authority to update the Oklahoma Comprehensive Water Plan, the state's long-range water planning strategy. Results from this and other studies have been incorporated where appropriate in the OCWP's technical and policy considerations. The general goal of the 2012 OCWP Update is to ensure reliable water supplies for all Oklahomans through integrated and coordinated water resources planning and to provide information so that water providers, policy-makers, and water users can make informed decisions concerning the use and management of Oklahoma's water resources.

Oklahoma Comprehensive Water Plan
OCWP

**Agricultural Water Issues and Recommendations**

The following report was commissioned by the Oklahoma Water Resources Board and the Oklahoma Department of Agriculture Food and Forestry to study the current and future water issues associated with the agricultural industry in Oklahoma and to make recommendations regarding future actions necessary to assist in addressing those issues. This study was performed by the Division of Agriculture Sciences and Natural Resources (DASNR) at Oklahoma State University with input from various statewide agricultural commodity groups.

# AGRICULTURE'S ROLE IN THE COMPREHENSIVE STATE WATER PLAN FOR OKLAHOMA[1]

*Like good health, we ignore water when we have it.  But like health, when water is threatened, it's the only thing that matters*.[2]

## *Introduction*

Water–The Story of Oklahoma

The purpose of this chapter is to show the importance of agriculture to the Oklahoma economy, that access to water is vital for a robust agricultural sector, and that the management of agricultural land and water provides benefits far beyond the direct contribution to the economic well-being of Oklahoma residents.  Water access is pure potential—access translates into economic opportunity for agriculture and ecosystem services for all. Limits or restrictions will affect the dynamics of that potential.

Water in Oklahoma is intimately connected to the land, which captures rainfall, stores it, and determines the quality of our water.  Since nearly eight of every 10 acres in Oklahoma is used for agriculture, the management and condition of Oklahoma farmland affects the quality and availability of most of Oklahoma's water. Runoff and recharge from farmland is the major source of water added to aquifers, streams, rivers, and lakes across Oklahoma.

Land in farms includes a rich diversity of ecosystems, environments, and production systems such as rangeland, forests, woodlands, wetlands, prairie potholes, riparian zones tied to rivers, streams, creeks, lakes, and ponds.  The land and water support wildlife, farmsteads, feedlots, turf, and a wide variety of croplands–wheat, cotton, corn, soybeans, forage plants, sod, fruits, and vegetables, to name a few. This diversity is largely supported by ample and well-timed precipitation.

Water sources and water use in Oklahoma are diverse.

Water resources in the state may be seen as abundant or scarce or both, depending on the time, location, and intended use.  Statewide, average annual precipitation has ranged from less than 30 inches to more than 48 inches over the past 100 years and ranges spatially from more than 50 inches in the east to less than 15 inches in the Panhandle.  Over the past 100 years droughts brought scarcity, and floods brought abundance often at the same time, but in different regions.  Availability of water of suitable quality and quantity raises questions and concerns about specific uses. Planning and management can improve consistency of water availability for a variety of water uses.

Water “use” is a somewhat confusing and misleading concept if “used” water returns to the watershed or is never withdrawn from a body of water. **Consumptive use** of water from a body of water occurs when water withdrawals are not returned to a water source. Non-consumptive use relates to that portion of the withdrawal that is returned to the water course or when water is used but no actual withdrawal occurs. Fishing and boating are examples of non-consumptive uses for which no water need be withdrawn. Hydropower can constitute a non-consumptive use if flows are taken and returned immediately at the same location such as in an in-stream hydroelectric facility. Some permitted consumptive uses, such as irrigation, generally result in part, but not all of water withdrawn being returned to the aquifer and/or downstream users.

### *Background on the interaction between Oklahoma agriculture and water assets*

Challenges with respect to natural resource conflicts and pollution will continue. But history has shown that the stewardship ethic of most producers drives agriculture to protect and enhance the environment for future generations while contributing to the state’s economy. Numerous state and federal programs have harnessed this land stewardship ethic through combinations of public and private investment in conservation programs, research in new technologies, and public education.

Agriculture’s role has evolved from providing primarily food, fiber and feed to an industry expected to provide renewable fuels, pharmaceutical assets, recreational opportunities, wildlife habitat, carbon sequestration opportunities and renewable fuels, groundwater recharge and water supply, and other environmental services that have both market and nonmarket values. As the state’s population grows, there will be increasing competition for land, water and other natural resources and greater focus on the nontraditional products and nonmarket values. Competition for water could be devastating to many agricultural enterprises.

By 2008, the direct impact of the Oklahoma agriculture sector, including production and processing, was estimated to be about $20.1, and the total impact of the agriculture sector on the Oklahoma economy was estimated at $28 billion.[3] Today, irrigated cropland is about 27% more valuable than non-irrigated cropland, primarily because of increased productivity and reduced risk compared to rain-fed dryland agriculture.

Agricultural producers are doing more today with fewer resources than in 1960. Even as prime farmland has been converted to other uses, such as urban land and residential neighborhoods, the productivity of the remaining agricultural land has increased. The nominal value of agricultural production (cash receipts from marketing) has increased about 10-fold in nominal terms, or a 2-fold increase in real dollars. In other words, with less land, more technology and more water, the dollar value of agricultural production in Oklahoma has doubled.[4] The assumptions used in projecting the next 50 years are critical. Inflation, population growth, technological innovation, opportunity cost, climate change, and economic development, are just some of the key variables.

Nonmarket values and ecosystem services

The opportunity cost of water from society's perspective should also include nonmarket values like recreation, aesthetics, biodiversity and quality of life. These nonmarket values include ecosystem services directly related to agriculture and agricultural land management.[5] These are benefits that people and other species gain from environmental assets and natural capital stocks associated with land in farms. Many of these services benefit from agricultural land stewardship practices that help maintain, restore, or preserve natural areas on which they also depend. Examples that serve to provide soil retention and carbon sequestration include minimum tillage on cropland and improved forest management practices. These activities require water.

Also dependent on a healthy agricultural sector are programs to restore native biodiversity in prairie systems. Conversely, the quantity and quality of water can deteriorate when good stewardship practices are not employed. For example, water quality is improved and protected and fisheries often improve through installation and maintenance of **best management practices**, or BMPs, including riparian management and restoration of wetlands. Land stewardship, water management, and BMPs have an impact on the economic value and nonmarket values of the state. Maintained and restored wetlands, for example, provide better fishing and wildlife watching, and reduce flood damages. Recreational streams and rivers flow through land in farms, with much of their health dependent upon the management of that land.

Some ecosystem services may have market value such as payments for hunting rights, but for most of these, no markets exist. Landowners and agricultural producers provide these values either without external payment or through participation in U.S. Farm Bill programs such as the Conservation Reserve Program (CRP), Environmental Quality Incentive Program (EQIP), and Wetlands Protection Program (WRP).

Landowners and managers typically need financial resources to effectively manage the land. Agricultural production provides the economic base and focused attention that can only occur with private management of the natural resources. Participation in public programs such as those identified above provides additional funds for some producers and landowners to see a net benefit in maintaining, enhancing or restoring ecosystem services. The result is overall improved provision of ecosystem services for the state. A primary beneficiary of these services is water quality and recreational benefits that accrue to urban areas and all residents of the state, most of whom are located in urban and suburban areas. This helps avoid degradation of ecosystems, reduced recreational opportunities, and increased water system maintenance, water treatment costs and healthcare costs.

In addition to ecosystem services, there may also be important intrinsic emotional value associated with lakes and streams of cultural, historical and symbolic significance that is difficult to quantify and is often ignored. The private versus public view of opportunity cost is an important source of conflict over water rights and allocation decisions.

### ***Summary of Oklahoma water law as it affects agriculture***

Changing Oklahoma's water laws implies significant economic impacts as well as affecting the property rights of its citizens. At issue with Oklahoma water law is the private property rights of landowners and the public value of the water resource. Oklahoma law recognizes that landowners may have vested property rights in stream and/or groundwater, and a change to the state's water laws that affect these rights may be a constructive "taking" of those rights that would require compensating landowners.

Another factor to consider is that Oklahoma's current laws defining rights to access and use water are based on a presumption that stream water and ground water are not connected. This presumption does not match with the true nature of water in the environment, though. It is likely that Oklahoma will eventually need to adopt a "conjunctive use" system that treats stream water and groundwater as linked together. While this may make sense from a scientific perspective, it may also require existing water allocations to be recalculated, and this could lead to some water users receiving less water, or none at all.

While these issues address changes to allocations for traditional uses of water (such as irrigation, watering livestock, etc.), new uses have also gained prominence in recent years. Increasingly, the importance of water for "in-stream" uses such as wildlife habitat, recreation, and scenic value is being recognized. Again, though, reserving quantities of water for these uses means those quantities are not available for other purposes and could conflict with existing water rights.

A final important issue is the matter of tribal water rights. Water rights associated with federal "reserved lands" and "public domain lands" (e.g., Indian reservations, national parks, forests, monuments, etc.) have limited but superior water rights compared to other vested rights.[6] Although these federal reserved rights are very narrowly defined, courts have consistently held that the federal rights trump state-based appropriative rights. Current court cases are evaluating whether these rights should have been construed much more broadly in Oklahoma. If the definition of federal reserved rights (e.g., for tribal lands) were to greatly expand, much less water would potentially be available to current and future users outside of the federal lands. This has serious implications for agriculture in the state. However grave this sounds for agriculture, there are indications that federally reserved water rights do not include un-appropriated groundwater, which is most often used for irrigation and other agricultural purposes.[7]

***Agricultural production and water use: Crop production***.

Water from farmland

Precipitation is a renewable water resource. Farmland management directly controls the partitioning of this resource between runoff, recharge, and evapotranspiration. For example, when land is converted from perennial vegetation to annual crops, runoff and recharge can increase.[8, 9] Therefore, the current quantities of streamflow and groundwater recharge in the State are likely higher on average than they would be if annual crop production ceased. The future of surface and groundwater resources in Oklahoma is inextricably linked to agricultural land management. Water resource planning should therefore consider trends in land management.

At least three trends are worth considering in regards to Oklahoma farmland: 1) no-till adoption, 2) bioenergy development, and 3) loss of farmland to urban expansion. Each of these may influence quantity of groundwater and streamflow in the future. Further research on hydrologic impacts of these trends in Oklahoma is needed. Nevertheless, Oklahoma farmland will continue to play a major role in provisioning water for downstream users.

Water for farmland

Many Oklahoma farmers rely on irrigation from groundwater or surface water for crop production. According to a federal survey, 3,026 farms in the state were irrigated in 2007, many of them using improved water conservation practices. This accounted for 534,768 irrigated acres, predominantly in western Oklahoma. About 481,000 irrigated acres were harvested cropland, representing about 6% of Oklahoma's harvested cropland acres. The balance of the irrigated farmland was pasture or other land.

Groundwater accounted for about 80% of total agricultural irrigation water use in 2008, and reliance on groundwater increased dramatically from 1970 to 1995. Groundwater permits (not exclusive to agriculture) expanded from less than 500 in 1972 permitting about 144,000 acre-feet per year to over 10,000 today permitting over 3 million acre-feet per year.[10]

Data from Census of Agriculture 1982 through 2007 show a gradual increase in irrigated land within the state over the 25 year period. Irrigation water use estimates from surveys before 2007 roughly correspond to the national Agricultural Statistics Service 2008 Farm and Ranch Irrigation Survey (FRIS) estimate of 1.1 acre-feet per acre of irrigated land. In 2008, irrigation amounts ranged from 0.7 to 1.4 acre-feet per acre (Table 1).

Economic value of irrigation

One method to assess the economic value of irrigation is to compare crop yields from irrigated and non-irrigated portions of farms on which some but not all of the harvested cropland is irrigated. The data show that crop yields on irrigated land are on average 69% higher than yields on non-irrigated portions of the same farms.

By comparing the market value of crops produced on irrigated and non-irrigated land, we estimate that irrigation increased the value of production by $221 per acre on average in 2008. The weighted average estimated value of irrigation water for these crops in 2008 was $203 per acre-feet. The total value of the eight irrigated crops listed in Table 1 was approximately $204 million. Based on these figures, an estimated $91 million over the potential returns from the same non-irrigated acreage was added to the state's economy in 2008. In some areas of the state rain-fed crop production is not feasible. In those areas agricultural production may drop to near zero in the absence of irrigation. The importance of water for agriculture is apparent when comparing irrigated and non-irrigated production of select crops like corn, for which irrigation produced a 141% yield increase on average, and cotton, for which irrigation produced a 123% yield increase on average (Table 1). These differences depend on location.

<u>Irrigation and groundwater</u>

Groundwater levels have declined 50 to 150 feet from predevelopment levels in portions of the High Plains aquifer, a major irrigation water source for the Panhandle[11]. With declining water levels come increased pumping costs. Given the high

**Table 1. Oklahoma 2008 statewide yields, irrigation amounts, prices received, and crop market values for selected major crops on irrigated and non-irrigated land.[12]**

| | Irrigated Yield | Non-Irrigated Yield | Unit | Average Irrigation | Price | Unit | Crop value Irrigated | Crop value Non-Irrigated | Increase in value | Value of water |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **ac-ft** | | | **$/ac** | **$/ac** | **$/ac** | **$/ac-ft** |
| **Wheat for grain or seed** | 49 | 32 | bu | 0.9 | 6.93 | $/bu | 340 | 222 | 118 | 131 |
| **Corn for grain or seed** | 188 | 78 | bu | 1.4 | 4.46 | $/bu | 838 | 348 | 491 | 350 |
| **Cotton** | 1180 | 529 | lbs | 1.3 | 0.415 | $/lb | 490 | 220 | 270 | 208 |
| **Pasture** | | | | 0.7 | | | | | | |
| **Other hay** | 2.7 | 2.8 | ton | 1 | 76 | $/ton | 205 | 213 | -8 | -8 |
| **Sorghum for grain or seed** | 67 | 36 | bu | 0.8 | 5.89 | $/cwt | 221 | 119 | 102 | 128 |
| **Soybeans for beans** | 44 | 30 | bu | 0.8 | 9.1 | $/bu | 400 | 273 | 127 | 159 |
| **Alfalfa** | 5.4 | 3.9 | ton | 1.3 | 150 | $/ton | 810 | 585 | 225 | 173 |
| *Source code* | *1* | *1* | | *2* | *3* | | *calculated* | *calculated* | *calculated* | *calculated* |

*Sources:*

*1 Table 27 Crops Harvested from Irrigated Farms*

*2 Table 28 Estimated Quantity of Water Applied and Primary Method of Distribution by Selected Crops Harvested: 2008 and 2003*

*3 Oklahoma Data - Prices: Annual Prices Received 2008*

cost of pumping (e.g., the energy cost of groundwater pumping for irrigation in Oklahoma averages about $74 per acre in 2008), farmers have a natural incentive to conserve: to save money on natural gas and electricity that run irrigation pumps. Rising energy costs and opportunity costs for alternative uses may continue to push these costs to likely record levels. If groundwater levels continue to decline, some areas may see a decrease in irrigation amounts or a decrease in irrigated land area. This response will be accentuated during periods of drought.

<u>Conservation tillage</u>

Tillage practices are also part of the story of agriculture and water use, especially as producers increasingly shift to conservation tillage. No-till and conservation tillage refer to crop production practices that retain residue from previous crops on the soil surface. Such tillage practices could benefit not only rain-fed agriculture but also low pressure center pivot irrigation, subsurface drip irrigation, and furrow irrigation. Crop residue enhances water conservation, especially in semi-arid environments. Water savings from crop residue result from reduced runoff, increased soil moisture in the winter months when crop residue will trap snow, and reduced evaporation. Minimum tillage has another benefit—that of increased soil retention. This not only benefits the producer, it also preserves water quality. Sedimentation is the number one water pollutant in the state.

Future work

As with residential, commercial, and industrial water use, opportunities are available to further increase the use of water conservation practices and technologies by agriculture. Examples include more efficient runoff capture and reuse of irrigation water. Further economic analysis is needed to ascertain whether the gains and losses are significant. Irrigation system augmentation by municipal sources would allow for metering and leak detection, as well as provide a needed buffer during droughts.

### ***Agricultural production and water use: Livestock production***

Oklahoma's substantial livestock industries provide economic opportunities to landowners and the state. The dominant livestock industry is the beef sector with almost 5.5 million cattle and calves on farms and ranches. Livestock production and aquaculture account for about 12% of the water use in the state.[13] While the daily water intake per animal is an important part of the accounting, water is also important for waste disposal, animal cooling, and dust suppression. It is a truism that "water is the most important nutrient" with respect to livestock production.[14]

Beef production per cow has grown from about 480 pounds in 1984 to about 640 pounds in 2008.[15] Part of that success is based on the management of water intake by livestock. Oklahoma beef cow inventory has been generally trending upward since the 1990s, which is opposite the national trend. That suggests relatively favorable conditions for cattle production in Oklahoma, and part of that is based on water availability and effective water management.[16] Of all livestock freshwater withdrawals in the US, Oklahoma accounts for about 9%, or third behind California and Texas.

As population pressure expands in other states faster than in Oklahoma, it is likely that Oklahoma will become relatively more attractive for industrial expansion. This suggests that maintaining water access will be important to livestock producers. In 2000, livestock in Oklahoma used about 151 million gallons per day, with 53.6 million from ground water and 97.2 million from surface water. That amounts to about 169,000 acre-feet per year.[17]

Oklahoma recently surpassed Missouri to now rank second behind Texas in number of beef cows. Cattle numbers have been relatively stable in Oklahoma for several reasons. Small scale production is a relatively complementary enterprise for many part-time farmers. Oklahoma offers winter grazing of cows and stocker cattle that is unavailable in many northern beef producing states, and there are many market opportunities for cattle. However, the recent extreme drought in much of the state and resulting sell-off of livestock will cause short to intermediate downturns in numbers. This result further emphasizes the industry's sensitivity to the water resource, and need for caution as changes in access are considered through state policy action. Hogs and pigs in the state number about 2.4 million head, and are currently stable after an increase of large integrated operations over the preceding ten years. Dairy cows in Oklahoma are currently estimated at 67,000 head and have declined slowly in recent years. Chicken numbers in the state are currently about 48 million head and are found primarily on the east side of the state. Sheep and goats contribute about 201,000 head. There are approximately 165,000 horses in the state.

Camp, Dresser & McKee Inc. (CDM) projects modest (<10%) growth in the numbers of beef cattle, swine, sheep and chickens, and 65% growth in the numbers of dairy cows. Given the current numbers of dairy cows relative to beef cows, that change will not substantially increase water needs for the livestock industries of the state if other demands for water (e.g., irrigation to produce feed for dairy) holds constant. National trends for increased per capita poultry consumption are balanced with trends for a decline in per capita red meat consumption so water needs for each of these industries will likely balance one another over the next 50 years. While water use is likely to become more efficient with technology adoption, industry expansion might still increase total water demand by livestock.

Future Issues for Livestock Industries

External forces, the primary issues for the future of livestock in the state, could have a significant impact on the size and scope of the livestock industries of Oklahoma. The availability of markets for livestock, the legislative and regulatory climate for livestock operations and the availability of reasonably priced feed are factors that are essential to the vitality of livestock industries. Milk produced in Oklahoma is processed for local distribution whereas some milk is processed in Texas and Arkansas. A milk hauling fee puts those producers at a competitive disadvantage. Recent industry developments may have a significant impact on dairy production in the State of Oklahoma.[18] This demonstrates that unpredictable change in the industry can greatly alter water needs in a relatively short period of time.

### *Agricultural production and water use: Horticulture*

Horticulture and urban landscaping compete more directly with other water users than other segments of agriculture because they are most likely in or near rapidly growing, urban areas of the state. Estimates show lawn watering to account for about 50% of municipal and city water use during the growing season.[19] Domestic landscaping, a sector that contributes more than its share to the state's aesthetics and general quality of life, has contributed to greenhouse and nursery cash receipts growth from about $3.4 million in 1960 to $165.7 million in 2008. Unlike many agronomic crops that can be grown without irrigation, vegetable crops generally need supplemental irrigation because of consumer expectations for high, consistent quality produce, but vegetable crops are a minor user of water.

Water conservation measures for residential and commercial properties have a great potential for reducing the total state water usage while maintaining acceptable lawn quality. With over 1.3 million residences in Oklahoma, lawns may exceed 325,000 acres. Moreover, large areas of previously non-irrigated pasture and cropland are being converted to irrigated homeowner and commercial landscapes so that irrigated turfgrass will increase water use.

Many citizens consider landscape water use a low priority when compared with human consumption, health, safety, industrial, agricultural, and environmental quality uses. When citizens are asked to describe an ideal home, the majority state nicely landscaped yard. Homeowners can significantly reduce outdoor water use by following watering recommendations based upon local Oklahoma climate data and turfgrass and plant materials typically adapted to Oklahoma climate. However, changing behavior patterns involves understanding economic motives, social customs, and traditional practice. Based on historical peak water use data for Tulsa and Oklahoma City, a 10% reduction in landscape water would have resulted in a savings of about 9.5 million gallons of water per day (assuming about 50% of the 190 million gallons was for outdoor use).

Turfgrass production is a major industry in Oklahoma. According to the 2008 US Census of Agriculture, 71 sod production facilities were in business in Oklahoma during 2007. In 2007, 17,871 acres of turfgrass brought in $40,923,250. Operations year 2007 is believed to represent both a historic high and a future target indicating full economic recovery. Gardening ranks as the top hobby in the U.S., so horticultural water use will increase with the growing population. Horticultural activities not only bolster real estate values but provide psychological value often difficult to assign a dollar amount but nevertheless invaluable.

Water-saving practices include use of organic and/or inorganic mulches coupled with landscape fabric barriers, use of hydrogels in select locations, and others. Drip irrigation, becoming commonplace in certain agricultural settings, should be considered more often by homeowners. Efficient irrigation design and management will be imperative. Where above-ground drip irrigation is not feasible, research needs to be conducted on distribution uniformity and output of above-ground irrigation systems.

Stormwater runoff and contaminants from runoff urban landscapes will continue to be major issues for the state’s water resources. Therefore, we expect to see increasing adoption of bioretention cells and rain gardens in both commercial and homeowner landscapes.

### *Agricultural production and water use: Forests and rangeland*

Forests and rangelands are economically important to Oklahoma, they represent the image of Oklahoma and its culture, and they contribute to the quality of life valued by Oklahoma residents, the tourism industry, and those migrating to the growing Southwest. They also supply an array of essential ecosystem services. Commercial value of forests was about $534,000 in 1960 and $4.7 million in 2008[20] . Total annual value of forestry industry shipments is nearly $400 million.[21] Forests and rangelands provide forage for livestock and wildlife and fisheries-based recreation, with each exceeding $1 billion per year. Other ecosystem services include water-based recreation, watershed protection, biodiversity, and carbon sequestration. Because forests account for about 60% of global terrestrial carbon sequestered, and rangelands store an additional 10 to 30% of global soil organic carbon[22], forests and rangelands account for the major pool of sequestered terrestrial carbon.

Because of their immense land area, forests and rangeland also meaningfully contribute to Oklahoma's water picture. Composing more than 50% of the state's rural land area, forests (9.2 million acres) and rangelands (14 million acres, not including grazed woodland and pastureland managed as rangeland) far exceed the watershed area of any other cover type in Oklahoma, including cropland (20%).[23] Moreover, with proper management, forest and rangeland watersheds produce the highest quality water, much better than cropland or urban land-use alternatives. Effective management of stocking rates of grazing animals and reduced selective grazing of riparian areas can contribute to improving water quality.

Values associated with forests and rangelands are changing rapidly. Timber and forage are likely to remain primary economic values, but forests and rangelands are increasingly valued for non-production benefits. Recreation has become increasingly important as urban centers expand from Texas into Oklahoma and as urbanites seek less congested housing sites, open space, and recreational experiences. Access to water, including recreational water, is a major asset affecting land value that will only increase in the future.

Because use and management of forests and rangelands exert a strong influence on water resources, change in use and management will precipitate changes in water resources. For example, changing from non-irrigated grasslands to high output systems like switchgrass or sorghum managed for bioenergy crops will require more water. Previously unmarketable native vegetation (e.g., hardwoods in the cross-timbers, eastern redcedar in grassland) that now covers millions of acres in Oklahoma might fill a market niche and change land use and cover. This change in cover type and use would change both water quality and water yield.

Rapid expansion of eastern redcedar is comparable to a "Green Glacier" moving from the south and east to the north and west.[24] Eastern redcedar might combine with climate-change-type drought to produce a novel version of the Dust Bowl combined with stand-replacing crown fire and other extreme events.[25] Oklahoma rangelands are adapted to recurrent drought, fire, and periodic intense grazing, so rangeland managers can sustain rangeland productivity with appropriate land management practices including prescribed burning and grazing. A great deal of uncertainty remains, however, about the effects of eastern redcedar encroachment under extreme precipitation regimes.

### *Recreation on agriculture-dependent land and water bodies*

Water resources provide fishing and hunting opportunities for Oklahoma citizens, and they were responsible for generating nearly $2.5 billion in recreational revenue in 2006. Streams, rivers, ponds, and reservoirs provide fishing experiences for the state's anglers, but they also attract nonresidents. According to the US Fish and Wildlife Service, total 2006 recreational expenditures in Oklahoma was about $1.4 billion (fishing accounted for $504,786,000; hunting $476,657,000; and wildlife watching $328,660,000).[26]

Outdoor recreation is one of the fastest growing businesses in Oklahoma.[27] Even though the demand is increasing for lake recreation in Oklahoma, only a few recent studies have analyzed the demand for lake recreation as well as welfare effects from lake use in terms of recreation[28]. Non-market values of water resources are often substantial. High quality sites with few substitutes nearby, such as the Upper Illinois River float trips or the lower Illinois River trout fishery, can have higher value to users and to the local economy than small lakes with primarily local patrons.

The State of Oklahoma has over 300 multipurpose lakes, more man-made lakes than any other state, and over one million surface acres of water.[29] Although many of these reservoirs were initially built for hydropower and flood control, explicitly managing for recreational use may be merited, particularly in times of drought. An optimization model for Tenkiller Ferry Reservoir showed that, when using a conservative estimate of $50/day recreational value per user, managing the lake for all uses, including recreation resulted in the highest value to society.[30] Neither municipal water supply nor recreation were listed as primary uses when the dam was built. When recreational values are directly included in the maximization of competing uses, it is possible to gain nearly $300 million of additional value from the lake resource over a 50-year period. The gain in recreation values when the reservoir was explicitly managed to maintain visitors was $88 million in exchange for a reduction of $26.6 million in municipal benefit and $0.6 million in power generation.

Values for habitat and ecosystem services not related to recreation also merit protection of water supply, although no economic studies have been conducted in Oklahoma to explicitly measure these values. Surface water in streams, rivers and wetlands may also generate "non-use" values by supporting indigenous species and serving other purposes not related to direct use. Non-use values are defined as any value generated by a natural area that does not involve physical consumption of the resource.

Oklahoma has 316,806 ponds ranging in size from 1 to 100 acres, which positions Oklahoma as number two among states in number of ponds and number one among states in pond density.[31] Ponds are highly valued by landowners, whether agricultural, recreational, or homeowners, because of the diverse amenities they provide. Property values are enhanced by the mere presence of ponds within eyesight of a residence. Wetlands of various forms provide important ecosystem services. Wetlands improve water quality, provide habitat for many fish and wildlife species, decrease soil erosion and flooding impacts, provide recreational opportunities and, in some instances, recharge groundwater aquifers. Federally assisted watershed projects have been led by USDA-Natural Resource Conservation Service since 1944.[32] Project infrastructure (more than two thousand dams) in Oklahoma exceeds $2 billion that provides over $72 million in benefits annually including flood control, water supply, erosion control, recreation, wetlands, and wildlife.

***Current & future trends***

Water Supply and the Human Population

On average, Oklahoma appears to have plenty of water, and supply far outweighs demand. On the supply side, the state receives on average 127 million acre-feet of precipitation annually. The state also has 23 major groundwater basins with an estimated 320 million acre-feet of water, 1120 square miles of surface water in lakes and ponds, and more than 78,000 miles of rivers and streams. On the demand side, only 2.6 million acre-feet per year of stream water is allocated for use. About 34 million acre-feet per year flows out of state via the Arkansas and Red River basins.[33]

The population of Oklahoma is expected to approach 5 million people by 2060.[34] The pressure to shift land and water resources out of agriculture along the rural-urban fringes of population growth areas will only intensify. Some of the shift will occur voluntarily as resource owners seek the highest value for resource use. Pressure will increase from both the market and from state policies to transfer water to urban areas of the state and as sales to neighboring states.

Oklahoma Foreign Agricultural Exports, 2008[35]

Surplus Oklahoma agricultural production, that which exceeds consumption, provides healthy opportunities for foreign exports but also is highly dependent on water availability. An initial scan of the data suggests, for example, that Oklahoma is in food surplus for beef and wheat production, so much of this production is exported.
While the US has growing deficits in total trade with the rest of the world, agriculture has continued to be a bright spot as one of the few sectors that maintains a trade surplus.

Agricultural productivity in the US has doubled in the past 50 years, reducing the pressure on arable land and irrigation water. As funds for research and development are reduced, limits will rapidly become apparent. Some analysts already see a slowdown in the rate of productivity increases, which suggests that relatively rural states like Oklahoma are poised to become increasingly important in feeding a hungry planet.

Actions that limit agricultural acreage or water access for agricultural production will jeopardize not only the opportunities but the food surplus-food deficit situation.

State climate and precipitation trends

Oklahoma, especially Oklahoma agriculture, has served as a unique laboratory for testing technologies and innovations to respond to extreme weather variability. The Dust Bowl brought agriculture and the state's economy to their knees at a time when the Great Depression was already having a severe impact. The experience fostered scientific discovery and application of soil and water conservation management. By the 21st century, conservation may seem an over-used and trivialized concept, but it may be more important than ever because, the era of abundant, free water has passed.

The last 20 years of the 20th century experienced above-average precipitation for the 100 year-climate record. Producers, agribusiness managers, land owners, public decision makers and others who grew into their careers during that period likely perceived that period as the norm and used that reference point to inform their decisions related to water use and water management. But in fact, the prolonged wet period was an aberration from the norm in which wet periods and dry periods have cycled every 10 to 20 years. The first few years of the 21st century suggest Oklahoma is re-entering the more below-average cyclical phase.[36]

Water conservation is important for municipalities throughout Oklahoma. The Oklahoma Climatological Survey (OCS) reports that climate change will affect Oklahoma and will likely result in higher temperatures during the year, an increase in heat and drought intensity and duration, and an increased need for supplemental irrigation water for agricultural crop production and landscape management.

### *Forecasting water supply and demand: Assumptions and methods used in the CDM study*

In discussions between Camp Dresser McKee and faculty of OSU's Division of Agricultural Sciences and Natural Resources, CDM agreed with the faculty's concerns that some methods and assumptions were likely to generate erroneous model predictions over the course of the 50-year planning period. For example, privacy concerns could have resulted in under-reporting of land area in agricultural production in those counties in which a few producers account for the bulk of agricultural production. The model assumes precipitation will not vary over time and will remain at the level experienced in the past 30 years, a time period in which precipitation was considerably above the long-term average. Narrowly defining agriculture to the agronomic crops and primary livestock species that are reported in the Census of Agriculture excludes some increasingly important commodities and other ecosystem services.

Therefore, we recommended a robust modeling effort that would examine potential alternative scenarios so that potential outcomes in both supply and demand could be better anticipated. Among other factors, scenarios should include climate variation, variable price of commodities and input costs including cost of irrigation, changes in government policy affecting land use and irrigation (e.g., land set-aside programs), expanded commodity markets (e.g., biofuel crops requiring irrigation), change in water demand driven by land-use and land-cover change (e.g., redcedar encroachment), and technology innovation adoption by farmers and ranchers to more efficiently use water for commodity production.

The CDM water supply model fails to reflect potential water supply variability driven by a multitude of factors in rural agricultural landscapes (e.g., water yield variability in space and time as a function of change in cropping systems) and in urban landscapes (e.g., water yield as a function of stormwater management and landscape management). As with water demand, a more robust modeling effort is needed to capture the range of possible levels of water supply to adequately prepare Oklahomans for its water future.[37]

The Oklahoma Comprehensive Water Plan projections are largely based on work done by the consulting firm Camp, Dresser, McKee. Given the limited resources, the results are a useful first step in beginning to plan for future water use. However, agricultural water demand projections seemed to lack scientific assumptions. The forecasts for irrigation and livestock are actually technical assumptions that demand growth will not increase, rather than scientifically defensible projections based on trends and alternative growth paths. Basically, the technical rules are as follows:

a. Livestock data from the Ag Census of 1997, 2002, and 2007 were reviewed and the highest reported number, the historical maximum was then assumed to be the build-out inventory for 2060", with some minor adjustments (OCWP draft, Section 5, page 5-3).
b. Crop Irrigation similarly, the maximum number of acres irrigated from 1987 to 2007 is assumed to represent the build-out irrigated acres in 2060", with minor adjustments (OCWP draft, Section 5, page 5-13).

In other words, the 2060 demand estimates are generally extensions of recent use. There was no attempt to develop scientific forecasts based on trend analysis and scientific knowledge of cutting-edge research, efficiency gains or industry plans. Our concern is that the public and decision makers could misinterpret the basis of the 2060 demand and what the results mean. Trend analysis and alternative scenarios based on industry activity would be an improvement by providing a relevant range of projected needs over the 50 year horizon. Imagine if the 1960 water plan would have forecast 2010 agricultural demand using similar technical rules. The projections would have missed the build up in the hog and poultry industries, expanded use of irrigation in such crops as cotton, corn and alfalfa, efficiency gains in improved technology, as well as the aberration of a relatively wet two decades at the end of the 20th century.

Not including sensitivity analysis or alternative scenario analysis clouds thoughtful consideration of management and policy alternatives and implications, especially with respect to economic development potential and evolution of water rights/law.

### *The road ahead: conclusions and opportunities for future work*

A review of the evolution of agriculture in Oklahoma clearly supports the premise that water access has been and will continue to be essential to the success of agriculture and to the future of the state's economy. It is a simple fact that water access is pure potential—access translates into economic opportunity for agriculture. Therefore, economic consequences of reduced access should be recognized by addressing how changes in water law arising from the Comprehensive Water Plan will affect pricing and access to current and potential users.

The following questions highlight some of the more fertile research and extension-educational needs and opportunities that can address this issue and other issues related to water and agriculture as the Comprehensive Water Plan is implemented and before the next water plan is constructed.

- What is the annual water balance for each of the state's gauged watersheds including the fraction of precipitation diverted to runoff and to groundwater recharge in each watershed and the efficiency of precipitation use?
- What is the influence of farmland management, irrigation, and conservation practices on rainfall partitioning and water production of Oklahoma watersheds?
- How will changes in land use (e.g., no-till crop production, bioenergy feedstock production) and land cover (e.g., ex-urban and urban expansion, eastern redcedar encroachment) influence the hydrology of watersheds across the state?
- How will climate change/climate variability and the interaction with change in land use and land cover influence the state's water balance?
- How can Cooperative Extension programming be developed and delivered to assist ranchers, farmers, other landowners, and rural communities to adopt management practices that will increase resiliency and reduce vulnerability to climate variability including drought?
- How might change in production, market and regulatory environments (e.g., dust control mandates that require water use) influence water demand in agriculture including the livestock sector?
- What horticultural, household, and community practices can be phased in over time to reduce statewide water consumption and improve water quality?
- How can reservoir pools and in-stream flows be optimized to minimize use conflicts and optimize benefits to all interests (i.e., aquatic ecosystem integrity, municipal water supply, and power generation)?
- Assuming exurban development continues and in the form of small acreages and ranchettes, to what extent will it influence ground water use, especially riparian water use through demand created by large, irrigated gardens and other domestic-use demands for water as allowed in the current statute?
- How might robust modeling of alternative scenarios be used to predict supply and demand to better anticipate change? Alternative scenarios should include, for example, climate variation, variable price of commodities and input costs including cost of irrigation, change in government policy, expanded commodity markets, change in water demand driven by land-use and land-cover change,

and technology innovation adoption by farmers and ranchers to reduce water use.

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[1] Study based on report prepared by the Division of Agricultural Sciences and Natural Resources (DASNR) Water Center, Oklahoma State University, with leadership of Secretary Peach at the Oklahoma Department of Agriculture, Food and Forestry (ODAFF), and cooperation and support of the Oklahoma Cattlemen Association, Oklahoma Farm Bureau, American Farmers & Ranchers, Oklahoma Pork Producers. Report co-authors/coordinators include: OSU: Dave Engle, Larry D. Sanders, Tyson Ochsner, Mike Schnelle, Art Stoecker, Damian Adams, Ron Kensinger, Mike Smolen, Shannon Ferrell, Tracy Boyer, Ex-officio: Robert Whitson, Robert Westerman;
ODAFF: Terry Peach, Blayne Arthur; Industry: Terry Detrick, Scott Dewald, Marla Peek, Roy Lee Lindsey.

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