Water In The Great Plains

There are no easy answers to protecting our surface and underground water resources.

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***Summary:** Complex problems cannot be solved simplistically. Balancing the social, ecological, economic, and agricultural interests in water will be clearly complex. Protecting our surface and underground water sources will require a holistic approach. Solutions will be regionally based but implemented and applied appropriately on a farm scale.*

Water is an essentially fixed entity in the world. No more will be created. Water has, over time and civilizations, been worshiped, managed, and wasted. It has been responsible for the rise and fall of kingdoms and empires. It has been fought over and generously given as a source of life. As Benjamin Franklin once said, "When the well's dry, we know the worth of water." In this article we will take a fleeting glimpse into water and irrigation issues in the Great Plains.

Like other regions of the world, the Great Plains has to balance water for farming and water for its citizens. Farming feeds people and it economically supports those who provide food for the world's growing population. Irrigation increases yields, allows a myriad of crops to be grown, and mitigates weather uncertainties in crop production. Irrigation water is derived from surface water and deep wells. Wells extract water from subsurface aquifers but sometimes surface water and aquifers are intimately connected. Two examples of the complexities of these relationships are the interactions that come out of extracting water for irrigation from the Ogallala aquifer, and the legal, economic, and political conflicts from the Republican River system.

Overflow

Deficits of water are not the only problem in the Great Plains. In northern South Dakota and across North Dakota, lakes are increasing in surface area and depth due to increased precipitation and runoff over the past several decades. Devils Lake in northeast North Dakota is a good example of where too much water is a massive problem. Between 1993 and 2011, levels on Devils Lake rose 31.68 feet. Surface areas of the lake increased from 44,230 acres to 211,300 acres. That is an additional 261 square miles of land covered with water. The volume of water has grown by 7 times in that time period. North Dakota State University expects the water body to inundate an additional 10,000 acres in 2014 with millions of dollars lost in economic activity. Roads, highways, and railroads have been raised to avoid being permanently inundated. Hundreds of buildings have been lost to flooding or have been moved. Hundreds of residents have abandoned their homes and farms through "buyouts" where a state agency buys the land. Some have called it the "slow moving monster."

Ogallala formation

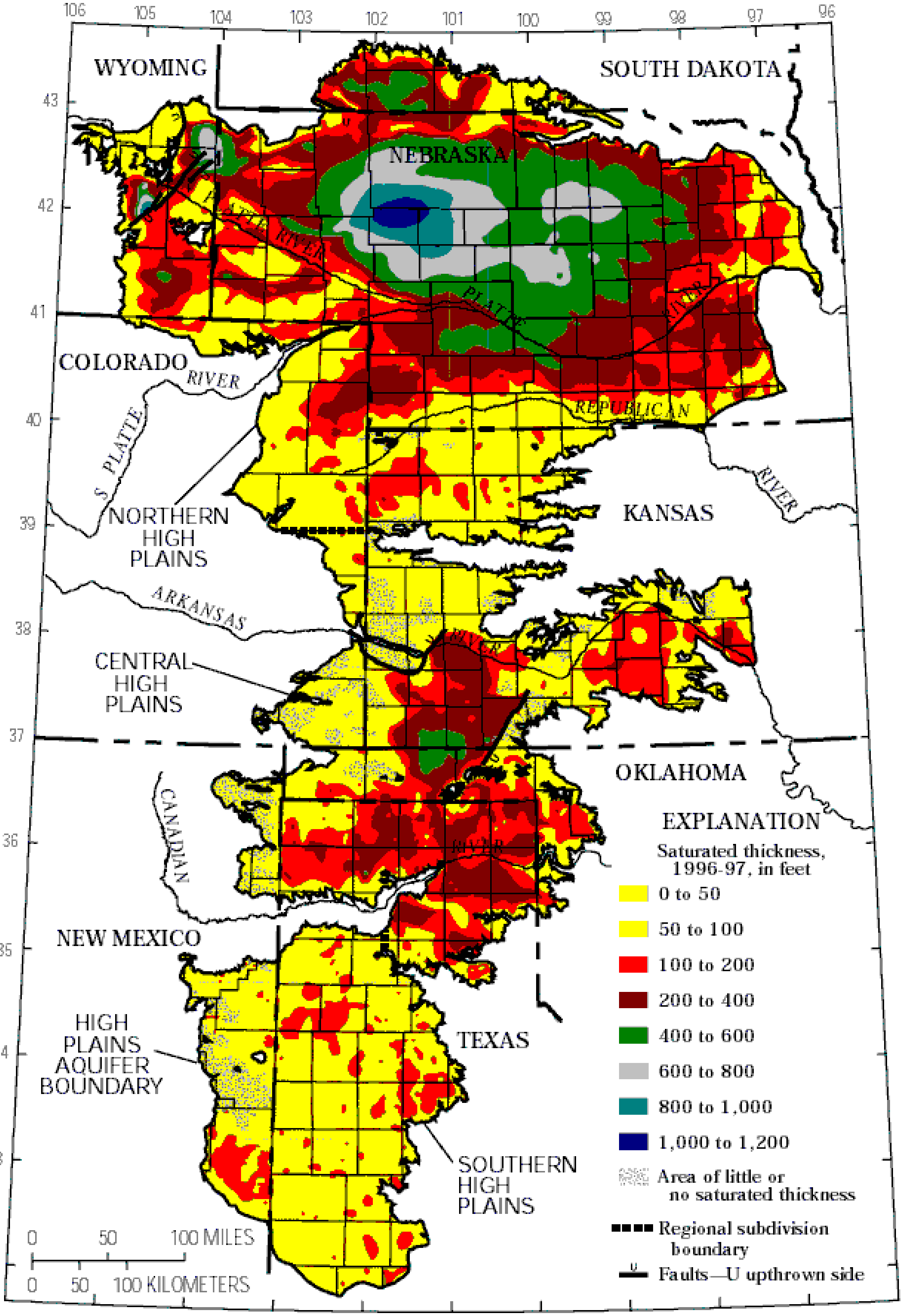
The largest of these aquifer systems, the Ogallala formation, is shown in Figure 1, with a concentration of water appearing underneath Nebraska. The steady increase in Nebraska irrigation led to that state being number one in the nation for irrigated cropland. The 2007 Census of Agriculture reported that Nebraska had more than 8.5 million acres under irrigation. Nebraska had more irrigated farmland acres than any other state, accounting for about one in every 6 acres of US irrigated farmland. The 2012 Census of Agriculture reported that Nebraska had about 8.2 million acres under irrigation and California had about 7.8 million acres. Between 1988 and 2007 corn accounted for 70 percent of the irrigated acres in Nebraska; soybeans accounted for 19 percent (Figure 2). A 2003 survey suggested that 72 percent of the irrigated acres were center pivot systems and 28 percent were gravity irrigation systems, with the most common gravity systems being furrow irrigation. Subsurface drip irrigation systems were used on only a small portion of the land.

1942 agreement

Progress has its consequences. It would've been impossible for anyone to predict the impacts of the increase in irrigation. In 1942, the states of Colorado, Nebraska, and Kansas joined together to form an agreement called the Republican River Compact. This was necessary before the Crops of Engineers would agree to build Harlan County Reservoir on the Republican River to reduce downstream flooding. A disastrous flood in May/June of 1935 killed an estimated 113 people and perhaps as many as 41,000 head of livestock.

This multi-state agreement was ratified by Congress and approved by the Supreme Court. In it, the authors determined that Colorado was responsible for about 11 percent of the beneficial consumptive use of the Republican River drainage system. Nebraska was allocated about 40 percent and Kansas 41 percent. Despite best intentions of the states to adhere to the compact, progress is taking its toll. Colorado now pipes water from deep wells into the Republican River system and has been forced to drain the reservoir in Bonny Lake State Park, a locally popular recreation area, to make up for over-allocated consumption Nebraska is also diverting water from deep wells into Republican River feeder streams and yet is still the brunt of Kansas lawsuits claiming up to $72 million in damage. Prosecuting the defending lawsuits is expensive for all involved.

Figure 1. Ogallala aquifer system.



Much has changed on the land since the 1942 agreement. Spring water once flowed into the Republican River, keeping a steady flow throughout much of the year. Since 1942, deep wells and irrigation development in Colorado and Nebraska lowered water tables, which dried up many of the springs in the feeder streams. Soil and water conservation practices were applied to the land beginning in the late 1940s and continue through to the present time. Terraces and farm ponds kept soil and water on the farm, thus reducing runoff into the river. More recently, crop residual management, minimum tillage, and no-till farming methods have reduced runoff even further. "Reuse pits" were installed to collect runoff water from gravity irrigated fields with the water being recycled to use for irrigation again and again without leaving the farm. Inefficient gravity irrigation gave way to more efficient center pivot irrigation systems. Through the decades, the goal of soil and water conservationists who assist the growers was and is to reduce erosion by keeping rainwater and irrigation runoff to near zero, thus much less water reaches the river. On well-managed farms, water leaves the property only through evapotranspiration.

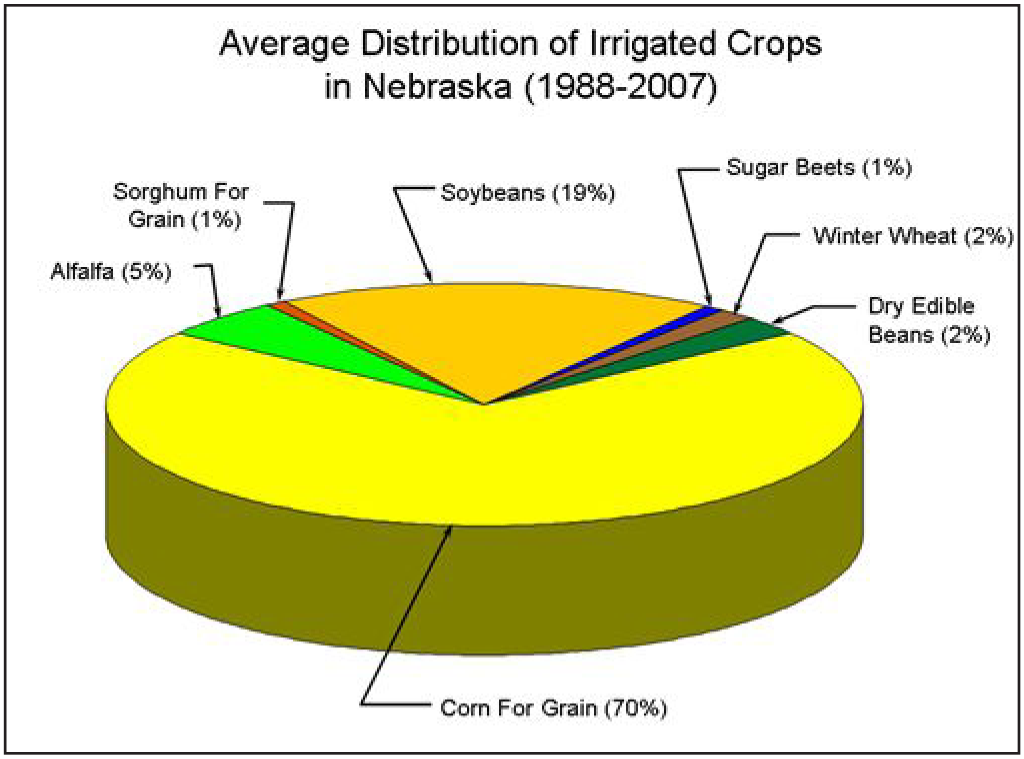


Figure 2. Corn accounts for 70% of irrigated corn acres.

Zero-sum game

In the end, the Republican River controversy has resulted in a zero-sum game. Water consumed upstream cannot be used downstream and the benefit to the upstream user is to the detriment of those downstream. For many years, Nebraska argued that groundwater was not included in the Republican River Compact. Kansas filed suit in 1998 and the case wound its way to the United States Supreme Court. That case was settled in 2002 when the three states agreed to use a computer model using an algorithm including precipitation, stream flow, and assumed values for recharge from precipitation and subsurface leakage in and out of the Republican River area. The model also included water used by irrigators and others. Years of legal wrangling followed with Kansas notifying the other states in late 2007 of an alleged failure to comply with the settlement. Kansas proposed a remedy to groundwater and stream flow depletions and asked for a shutdown of all wells within 2.5 miles of the Republican River and its tributaries and a suspension of irrigation on lands added since 2000. The 2009 nonbinding arbitration meeting resulted in a no resolution conclusion among the three states.

The economics of water are staggering. David Cookson, Nebraska's chief deputy attorney general, said the shutdown of half of the irrigated acres in the Republican River basin would cost billions long-term in economic activity to the state. The number and value of irrigation-related transactions for seed fertilizer, herbicides, feed, machinery, insurance, and the sale of forage quickly mount. Not only agriculture is affected. There are also industrial, recreational, and municipal components that have a strong reliance on water.

The High Plains Aquifer is a waterlogged jumble of sand, clay, and gravel that begins beneath Wyoming and South Dakota and stretches to the Texas Panhandle. The Northern portions of the aquifer hold enough water for perhaps hundreds of years of irrigated agriculture. Most of the water lies under the Nebraska Sandhills, a mass of stable sand dunes covering a third of the state, an area not suitable for farming. As one travels south, pumping water is increasingly elusive. Kansas wells that used to pump 1,600 gallons to the surface every minute now may yield only 300 gallons or be completely dry. High Plains Texas irrigators find they have to drill deeper and deeper to extract water from the declining aquifer. From 1940 to 1980, the water table was lowered by more than 100 feet in parts of Texas, New Mexico, the Oklahoma panhandle, and Kansas. Follow-up studies show that the water table has dropped an additional 40 feet or more.

Replenishing the aquifer will require more than just a few seasons of rainy weather, as is often the case in surface waters. Rather, it could be hundreds or, more probable, thousands of years of rain required to restore aquifer levels even if no additional irrigation was allowed. The Great Plains area is not alone in ground water depletion. The USGS map (Figure 3) indicates known depletion areas.

The villain

The villain of this drama is the farmer's friend--the center-pivot irrigation system. The pivot makes irrigating crops easy in comparison to other systems and requires much less labor. The center-pivot irrigating system is, perhaps, the most efficient way to create an oasis. Center-pivot irrigation efficiency was improved by the addition of dropped nozzles, which reduce water lost to evaporation and drift. Paradoxically, it was often found that farmers ended up applying more groundwater to fields. Rather than reducing consumption, some farmers use the efficiency "savings" to expand irrigation into poor soils or grow higher value crops such as corn, alfalfa, and soybeans, which consume more water.

Texas researchers set out to determine how much water loss occurs in the air above the canopy, within the plant canopy, and from the soil surface. They compared different sprinkler devices and heights of sprinkler devices with respect to the crop canopy. Table 1 shows the water loss during irrigation and the application efficiency for 1) six-degree low angle impact sprinklers located on the sprinkler pipe, 2) spray heads located five feet above the ground, and 3) a Low

Energy Precision Application (LEPA) system using bubblers located one foot above the ground. Both the water loss and application efficiencies given are based on a daytime irrigation of one inch applied to mature corn under no-wind conditions. Evaporation from the soil during irrigation is assumed to be negligible for the low angle impact sprinkler and spray head, a result of evaporation demands being met by the water evaporating from plant leaves.

To realize the full potential of LEPA systems, growers must plant the crop in a pattern matching the irrigation track. Drop tubes must be placed at a height of 12 to 18 inches between every other crop row. Water must be discharged in the bubble mode or through socks to avoid wetting plant leaves. The surface storage must be created to prevent any runoff and maintain infiltration uniformity. On-farm efficiency is lower than that reported by research institutions. USDA/ARS publications suggest that efficiencies of 95 to 98 percent of the sprinkler water being available for crop use are attainable by growers.

Table 1: Sprinkler water losses and application efficiency for 1-inch water application.

Water Loss Component	Low-Angle Impact Sprinkler Water Loss	Spray Head Water loss	LEPA Water Loss
Air Evaporation and Drift	0.03 in.	0.01 in.	0.00 in.
Net Canopy Evaporation	0.08 in.	0.03 in.	0.00 in.
Plant Interception	0.04 in.	0.04 in.	0.00 in.
Evaporation From Soil	Negligible	Negligible	0.02 in.
Total Water Loss	0.15 in.	0.08 in.	0.02 in.
Application Efficiency	85%	92%	98%

Drip irrigation

Perhaps the most efficient method of irrigation is drip irrigation or subsurface drip irrigation (SDI). Drip irrigation delivers water through the use of pressurized polyethylene tubing, also known as drip line, and drippers that run close to the plants and can be placed either on the soil service or below ground. Generally, only the immediate root zone is wetted and the system allows precise application of water soluble fertilizers and other agricultural chemicals. Growers can achieve yield

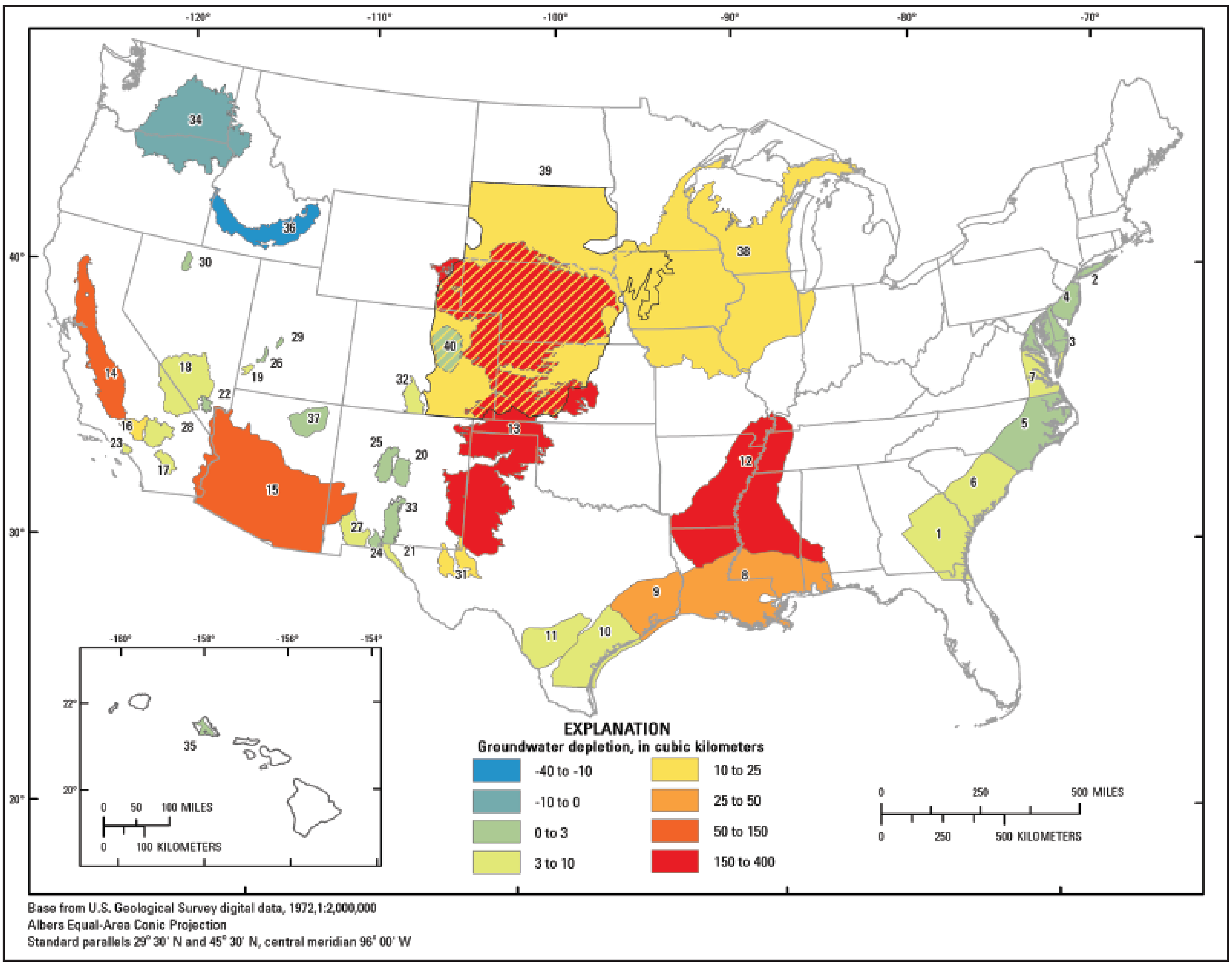


Figure 3. Map of the United States (excluding Alaska) showing cumulative grounwater depletion, 1900 through 2008, in 40 assessed aquifer systems or subareas. Index numbers are defined in table 1. Colors are hatched in the Dakota aquifer (area 39) where the aquifer overlaps with other aquifers having different values of depletion.

goals of up to 100 percent, water savings of up to 40 to 80 percent, and associated fertilizer, pesticide, and labor savings over conventional irrigation systems. It is potentially the most efficient irrigation system available, but that efficiency depends on the irrigation system itself, its proper design, installation, and management. Only if designed, installed, and managed correctly can SDI be more efficient than any other irrigation system.

Drip lines are buried 13 to 18 inches below the soil surface so the soil surface stays dry and practically no irrigation water is lost due to evaporation. Because of the potential for high irrigation efficiency, it may be a good alternative for areas where irrigation water is limited. Researchers in Kansas have reported that net irrigation needs could be reduced by 25 percent with SDI, while maintaining high corn yields. Increased water use efficiency reduces pumping cost. Since no excess irrigation water is applied, nutrient leaching, with it potential to enter into surface and subsurface waters, is minimized.

SDI can be automated to apply fertilizers and other chemicals such as acids, chlorine, and even pesticides with irrigation water. SDI systems are often managed to apply small amounts of water and other inputs daily or even several times a day. Spoon feeding water and nutrients could, theoretically, result in increased yields and decreased nutrient and water losses.

One of the main disadvantages of SDI is its high initial cost. The University of Nebraska estimates an average gross cost of between $500 and $800 per acre. Center pivot systems cost about half as much per acre. Kansas estimations suggest that as the fields become smaller SDI becomes more cost-effective. However, even with smaller fields it may be more cost-effective to just dryland farm and not irrigate at all. Much depends on the value of the crop grown and the availability of water. SDI lends itself well to specialty and tree crops under limited water situations.

SDI systems are being installed in field corners where center pivots cannot reach. A typical pivot irrigates about 134 acres out of a 160-acre quarter section. After taking out country road right–of-ways there might be 24 or 25 acres of excellent soil in the corners that aren't irrigated. Farming the corners as dryland creates management challenges. An SDI system can complement the center pivot by bringing the field corners under irrigation. This simplifies management when all acres in the field are irrigated. The entire quarter section will have similar seeding and fertilizer rates. It also simplifies record keeping for crop insurance and farm program benefits.

Deficit irrigation

Deficit irrigation is the practice of applying less water than a crop needs for a full yield potential. Studies have shown that a reduction in irrigation is usually less than the reduction in yield. The marginal productivity of irrigation water is lower when water application reaches full irrigation. Applying 75 percent of full irrigation may result in 90 percent of the fully irrigated yield. One study, based on 28 years of corn production data, showed that applications of 50 percent of the non-yield limiting irrigation rate reduced yield only 13 percent. Yield variability at lower irrigation levels is usually higher and in the previous study mentioned year-to- year yield variance increased fourfold. Deficit irrigation at lower levels increases economic and weather uncertainties. Dryland yields, as a fraction of fully irrigated yields (relative yield), are more variable than deficit irrigated yields. So, deficit irrigation mitigates some of the economic and weather uncertainties, but not to the extent of fully irrigated conditions.

Under deficit irrigation conditions, corn grown in rotation with another crop is often found to yield better than corn following corn. In one study in Western Nebraska, under semiarid conditions, corn in a wheat-corn-soybean rotation was able to use more stored soil water than the continuous corn crop. Increased use of stored soil water led to less dependence on irrigation.

Water quality

It is not just the quantity of water, too little or too much, but the quality that is getting much attention. As the water table is drawn down, total dissolved solids have been increasing. In areas vulnerable to leaching, nitrates and hazardous chemicals have been increasing in concentration to levels adverse to human health. Increasing nitrate levels have been especially serious in areas of Nebraska and Kansas. Nitrogen fertilizers and animal manure applied to farmland susceptible to leaching are the main contributors. Herbicides such as atrazine and metolachor are commonly found in both surface and ground waters. Carbon tetrachloride and ethylene dibromide, used to fumigate grain, are found under or near grain elevators. Chemicals associated with military bases and associated industries such as RDX and TNT and the commonly used degreaser trichloroethylene are found in some areas. Large trichloroethylene plumes in Hastings, Nebraska, and Wichita, Kansas, are the result of industrial solvent disposal.

Modern farming practices are demonstrating their ability to improve water quality. Groundwater nitrate concentrations are an example. Certain areas in Nebraska, like the Central Platte Valley, have been using more environmentally friendly farming techniques such as not applying nitrogen in the fall, using nitrification inhibitors, and applying scientifically justified nitrogen rates. Once elevated, levels of groundwater nitrate are markedly lower due to implementation of sound research. The evidence is clear in the Central Platte Valley, because the aquifer is close to the surface and changes can be observed in a geologically short period of time. Other areas where the vadose zone is much larger will take much longer to see change.

Summing up

Balancing the social, ecological, economic, and agricultural interests in water is clearly complex. Agreements become unworkable as time goes on. Efforts to improve irrigation efficacy result in higher consumption of groundwater and aquifer depletion. Compliance with watershed agreements results in the expense of transferring water from one source to another and the draining of recreational impoundments. Reductions and moratoriums on wellhead development result in fewer calories for food and feed. It seems that simply allowing market forces to operate does not adequately balance the social, economic, and environmental needs for the sustainable use of water. Even our legal system seems inadequate to provide enduring solutions.

Complex problems cannot be solved simplistically. Protecting our surface and underground water sources, our environment, and mankind will require a holistic approach. Solutions will be regionally based but implemented and applied appropriately on a farm scale. Components to the solution include increasing irrigation efficiency, deficit irrigation, crop rotations, using surface water sources that may be more abundant, planting less water-hungry crops and crop combinations, withdrawing some land from irrigation, and improving crop water use efficiency through advanced plant breeding techniques.

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