

Agricultural Demand and Water Sustainability: Responsible Use of the Ogallala Aquifer

A Sociotechnical Research Paper
presented to the faculty of the
School of Engineering and Applied Science
University of Virginia

by

Jay Perry

April 5, 2021

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

James Murray Perry IV

Sociotechnical advisor: Peter Norton, Department of Engineering and Society

Agricultural Demand and Water Sustainability: Responsible Use of the Ogallala Aquifer

What is the limit of responsible water use? Water politics has shaped many U.S. policies, laws, and court cases for more than a century. The Ogallala Aquifer, residing under the Great Plains of the United States, offers an extraordinary case study for how water politics have affected the economic, environmental, and social health of the region and nation.

The aquifer lies under 174,000 square miles and holds 978 trillion gallons of water. But the supply has been declining by 325 billion (.03%) annually for almost 50 years (Brambila, 2014). Agricultural irrigation is depleting the aquifer; states above the aquifer account for 40 percent of irrigated acreage in the U.S. (USDA, 2020). In the U.S., crops and livestock are valued at \$76 billion annually (Climate Hubs, 2017), providing a total of 22.8 million jobs (FB, 2019). At the present consumption rate, the aquifer may be depleted in 50 years (Brambila, 2014). Experts in education, environmental policy, and agricultural innovation are striving to protect the aquifer. Therefore, U.S. agriculture enterprises, conservationists, and others have competed in varying ways to draw the line between responsible and irresponsible use of the Ogallala Aquifer.

Agribusiness enterprises, large producers, agricultural associations (such as the Farm Bureau Federation), independent farmers, and conservation advocacies contribute to this resource management power struggle. Jeff Caldwell writes for AGCO, an agricultural company which urges farmers to “implement practical conservation measures” to “cut usage, while maintaining crop output” (Caldwell, 2016). The Natural Resources Conservation Service, a nonprofit, “supports targeted, local efforts to conserve the quality and quantity of water” (Dostie, 2020).

Agricultural enterprises include Tyson Fresh Meats, which announced success in verifying “sustainable cattle production practices” in the Midwest region (Tyson, 2020). Benson Hill is also working with conservation experts and advocates “to establish best practice principles” in gene editing to improve crop sustainability (Benson Hill, 2018).

Some independent farmers strive to reconcile aquifer conservation and high farm productivity. The National Farmers Union desires to “advocate for family farmers... and their communities” and support more innovative solutions than shifting the market or reducing capacity (NFU, 2019). The news outlet Civil Eats seeks to inform and educate the American public through op-ed articles to “shift the conversation around sustainable agriculture” (Civil Eats, 2020).

Participants struggle equally to gain control of the system and resource to advance their own agendas. They do this through exercising property rights, stage regulations, and convincing the public of their position. The conservation of the Ogallala Aquifer has therefore been evaluated as an environmental, economic, and social justice issue which produces several agendas pursued by participants; namely public advocacy, scientific innovation, and policy reform. All participants agree on the vital importance of the aquifer, but to some, access is regarded as a property right the infringement of which constitutes a violation of the nation’s founding principles, while to others, unsustainable depletion of the aquifer is an unpardonable theft from future generations.

Review of Research

Research on the problems of water conservation and resource property rights has been extensive. Lauer states that the vast majority of high plains producers already recognize groundwater depletion as a serious threat (Lauer et al., 2020). Terrell and Hornbeck state that the

discovery and subsequent depletion of one resource across a region creates economic hardship for the whole community (Terrell et al., 2002; Hornbeck et al., 2014). Cano et al. (2018) have proposed that measures to restore soil health and biology can reduce irrigation demand. Peterson et al. (2003) review the competing values governing aquifer conservation policy, finding that economic efficiency has prevailed over other values, including social equity and the duty of environmental preservation. Rad et al. (2020) showed that declining well levels result in lower average profits and increased downside risk to Midwest regional crops. Edwards et al. (2012) developed municipal water conservation models for communities that depend on the aquifer, proposing that by adhering to them, communities can delay or prevent aquifer depletion. Economists have proposed that voluntary water conservation programs can significantly reduce total water demand (Lansford et al., 1983). Howe (2002) has examined similar groundwater management cases, reaching conclusions applicable to the conservation of the Ogallala Aquifer.

Nizkorodov (2021) has evaluated sustainability efforts through California's water management to determine that such programs have potential environmental benefits, but significant economic setbacks. Australian water rights were studied by Hanemann et al. (2020) to contrast with the developing water property rights case in the western U.S. (especially California). In Brazil, Spinola et al. (2019) examined the implementation of cattle ranching on reserves in the Amazon to determine if the practice is a threat or a need. Sustainable forest management is investigated by Valipour et al. (2021) to determine factors most contributing to climate change from deforestation.

Economic Interests Prevent Modern Deterioration

Economic powers recognized their vested interest in taking care of the public through the application of resources and services. These corporations provide “good and necessary” products to the community and are a steady economic support that cements and advances their value to modern society. Through job provision and economic prosperity, area businesses engage the local and national populations. Texas census estimates show that “approximately 43%” of the High Plains region in Texas is employed in “animal production and aquaculture, oil and gas extraction and support activities for mining” (TCPA, 2020). Offutt Farms and Resnick Farms are the two largest farms by acreage in the U.S. who together own “380,000 farmland acres,” providing a total of \$4.7 billion in revenue to the local economy (R.D. Offutt Company, 2021; Successful Farming, 2021). The USDA ascertains that agriculture industries account for “10.9 percent of total U.S. employment” where the “national industry contribute[s] \$1.109 trillion to the U.S. gross domestic product” by way of corn, soybean, wheat, cotton, and tree nuts (USDA, 2020; AgAmerica Lending, 2021). The agricultural business has cemented itself as a staple of the American economy and it is evident that it produces goods and services that are highly desired by the nation’s consumers and the world as a whole.

Large enterprises that depend on the aquifer advocate for their use of the aquifer through establishing presences in local communities as well as regional representation. By negotiating with municipalities and state governments, economic groups ensure that they do not stray out of line. Independent researchers from *Choices Magazine* state that due to the Aquifer’s presence in multiple states, “local groundwater usage is governed by groundwater management districts (GMDs), generally controlled by local farmers” (Peterson et al., 2003). J.C. Peck writes that GMDs are also given “the power to enact management programmes and recommend regulations”

thereby giving final power for Aquifer use to GMDs (Peck, 2007). Local farmers, as part of unions and the industry as a whole, therefore control the use of the Aquifer as they see fit. Matthew Sanderson reports that the government is taking an active role in the depletion because “the government pays farmers to pull water from the Ogallala-High Plains Aquifer” and that “depletion is a structural problem embedded in agricultural policies” (Sanderson, 2020). Not only are the governing committees controlled by those directly in the industry, but the existing legislation is designed to pay the industry, even when overusing the Aquifer.

To coordinate the legal use of land and ensure that economic volatility does not ensue, corporate businesses in the aquifer region and the national community influence policy in their favor. Through the use of public policy and a reliance on customary tradition, companies have leveraged the political power of policy to justify their standard of aquifer use, among other resources. According to the Uniform Commercial code set forth as a uniformly adopted state law, water residing on owned land is claimed as “personal property, a system known as water rights” which grants those with rights to the land “a right to use the water” as they see fit (Peck, 2007). The Water Education Foundation in California notes that “water rights laws based on ownership of land bordering a waterway” has led to “unreasonable use” which in turn leads to water shortages and decaying environmental conditions (Water Education Foundation, 2021). On a national level, former President Trump signed legislation ordering farming companies to be given access to more water by “ordering... pumping rules be rewritten more quickly,” even at the expense of biological life and economic longevity (Sommer, 2019). On a local, state, and national level, policies are in place that actively benefit agricultural companies in the short term with increased production but present future problems as resources run out.

Conservation Efforts Seek Future Stability

To stem the use of the Aquifer by economic powerhouses, local conservation groups have encouraged the public to become knowledgeable about sustainable practices and the reality of resource depletion. This public education initiative employed the use of grassroots events and an organized online presence. The 2021 Ogallala Virtual Summit was one such event where “over 200 [public] participants” gathered to “encourage momentum of activities related to advancing ag [agriculture] water management and sustaining the vitality of High Plains communities” (OgallalaWater, 2021). An organized online presence through the Ogallala Aquifer Program also contributes to general public education, which provides model simulations for the general public to experiment with and informs visitors of how funding may be provided to support the conservation effort (Texas A&M University, 2015). Kansas University educates the public through their HiPLAIN (High Plains Aquifer Information Network) online resource “dedicated to providing information, data, and resources related to the High Plains aquifer” (Kansas University, 2007). The motive of such groups is front and center; widespread availability of information would increase the spotlight on the Aquifer’s current usage.

Resource advocacy groups also actively attempt to depict those with property rights of resources as selfish and entitled opponents to the future of humanity. Various tactics used to accomplish this objective include empathetic nature media campaigns and exposure to the issue in multiple markets. The advocacy news group EcoWatch is quoted as saying that farmers are “overexploiting the aquifer” and threatening to create the “Great American Desert” (Leestma, 2019). EcoWatch also reports that “a catastrophic change” in water management by surrounding industries has led to complete changes in the wildlife that is able to live in the area (Leestma, 2019). Beyond print and local organizations, Julene Blair wrote an op-ed in the New York Times

specifically calling out the Keystone XL pipeline and Nebraskan farmers for polluting and drying up the Aquifer (Blair, 2011). These groups spread the message far and wide about the apparent culprit of the American economy and environment in the latter half of the 21st century.

Many nature advocacy groups recognize the connectivity of all conservation efforts and seek to create a global community which fights for many issues. They acknowledge that groups in one country may assist the cause in another and that issues are not relegated to region or population, but to humanity as a whole. With this vision in mind, aquifer groups have given and received assistance in partnership with other successful conservation efforts globally. The Kansas Geological Survey group compiles a list of related projects to the conservation of the Aquifer including projects for the Arkansas River Subbasin and desalination efforts in the Equus mineral beds (Kansas Geological Survey, 2017). Animal habitats are being affected too as researchers at Texas Tech University have indicated that “the water crisis that people are having in this region is affecting snowy plovers, too” (Erramouspe, 2018). The snowy plover is a migratory bird in the plains region that is experiencing high blood toxicity due to concentrated metals in the water supply (Erramouspe, 2018). The MIT Mission 2012 initiative related the Ogallala Aquifer conservation efforts to general clean water efforts saying, “as more pollutants seep into [the Aquifer], contaminated water will have serious detrimental effects on human health” (Massachusetts Institute of Technology, n.d.). Advocacy groups are resolute in their stance; the Aquifer depletion is harming more than just water quantity and the effects of current practices will be felt in every corner of future society.

Global conservation efforts seek to advance their agenda through the support of the general public and a younger generation. Younger spokespersons and a push against government relations with industry corporations have played large roles in recruiting people to the support of

conservation. Greta Thunberg is a young, active voice “inspiring young people to protest against climate change” who is quoted as telling current companies and lawmakers, “you are stealing their future in front of their very eyes” (Corporativa, 2021; Thunberg, 2018, 2:25). The Pew Research Center indicates that “young Americans are less trusting of key institutions like corporate companies” with 71% of people saying that “most people would try to take advantage of you” (Gramlich, 2020). This distrust in historic institutions and belief that older generations do not care about the future has been a large factor in the growing faction of young people involved in conservation efforts like the Ogallala Aquifer.

Advocacy Groups Learn from Similar Movements

Beyond the conservational use of the aquifer, many advocacy groups seek to showcase the effect that resource depletion has on disadvantaged groups. Organizations highlight the economic hardships and health hazards put upon certain groups by companies that are not regulated. These groups employ advertisement campaigns, scientific studies, and public activism to advance the notion that large companies overstep their moral limits. The World Resources Institute seeks to invite disenfranchised groups into the discussion of water scarcity through public activism and through electing public leaders from marginalized groups because “the injustices [marginalized groups] face due to water compound the economic and social pressures they already bear” (Schleifer et al., 2019). Oki et al. has conducted research to identify the populations most vulnerable to water crises, both in the U.S. and globally, reaching the conclusion that currently “40.7 million people are living in areas with concurrent severe economic and water-scarcity constraints” (Oki et al., 2020). The United Nations also campaigns for water conservation efforts on behalf of globally marginalized groups as “political turmoil,

social unrest, civil war and terrorism” are possible outcomes should a water crisis lead to food shortages (Seametrics, 2018). Schaider et al. also suggests that water pollution exposure has a socioeconomic factor by stating that “low-income and minority communities often face disproportionately high pollutant exposures” (Schaider et al., 2019). Kansas State University researchers have applied this concept directly to a study showing that “nitrate levels in shallow wells [are] above US Environmental Protection Act standards” (KSU, 2020). The rural, poorer communities of the High Plains would evidently suffer economic hardships with water scarcity; meanwhile, Aquifer depletion will exacerbate the socioeconomic differences already present for disadvantaged groups.

Social justice campaigns in recent years have sought to sway public opinion on social issues through large scale media campaigns. Movements have enjoyed the use of social media graphics and public figure allies as keystone aspects of shifting the public attitude towards issues of social justice and inequality. The Black Lives Matter movement gained popularity as an idea over social media “roughly a quarter of adult social media users in the United States... changed their views because of something they saw on social media” (Perrin, 2020). The Ogallala Aquifer Advocates seek to accomplish the same goal by posting and spreading informative graphics on platforms like Instagram, Facebook and Twitter (OAA, 2012). Key celebrity advocates have also served to greatly advance social agendas such as Leonardo DiCaprio speaking for conservation at the 2016 Oscars ceremony or Matt Damon’s founding of Water.org to fund clean water in impoverished communities (Friedman, 2016; Water.org, 2021). Social advocates for the Ogallala Aquifer are adapting and continuing to learn from other movements in order to further spread their message, thus bringing a greater light upon this hidden issue.

Technology, Policy, and Public Interaction Intersect

Technology is a critical aspect of the efforts of both economic powers and sustainability efforts. One side seeks to innovate and improve existing means of production to stay skeptics and critics while the other cries out for the scrapping of existing means of production to be replaced by entirely new technologies. Those groups currently in control of the property rights are seeking to innovate technology so that less water is used overall. The agricultural technology business Benson Hill is actively seeking to “harness the natural diversity of plants” and “earn public trust in gene editing” to employ as updated tools in the farming industry, leading to a more sustainable future of the food industry (Benson Hill, 2018). Pork Business, the official farmer’s journal of the pork meat industry, states that “in the southern High Plains, farmers know they only have a few decades left” and that “drip irrigation instead of flood-irrigated” systems will be a major advancement (Pork Business, 2016). This insight showcases the agricultural industry’s desire to circumvent Jevon’s paradox by focusing on consumption reduction, rather than improved efficiency. On the other side of the conflict though, new startups like Babylon Micro-farms seek to replace existing farming techniques with alternatives like hydroponic farming to reduce water and land consumption (Babylon, n.d.). The Sustainable Agriculture Network is a group that is also working to “foster sustainable agriculture, biodiversity, conservation, and improved rural livelihoods” (SAN, n.d.). Technology solutions continue to be divided between these two groups as one seeks to stave off decline and public scrutiny as the other cries out for a systemic overhaul.

Policy engages all participants to drive progress forward, and must be agreed upon by consensus, but a beneficial compromise is rarely reached. Business corporations and other economic groups seek to expand corporate liberties in the realms of property rights and

economic control of the region. Meanwhile, advocacy groups and conservationists campaign for greater regulation of industries that are not viewed as “future-oriented” or “eco-friendly.”

Environmental groups seek public policy that promote these ends, such as taxes and subsidies. A recent Supreme Court case ruled in favor of increasing a business’s property rights through the ability to bar union workers from the premises (Stohr, 2021). The Owner’s Counsel of America seeks to protect the legal right to property for farmers, ranchers and agribusiness owners from eminent domain, “the power to take privately-owned property for a public purpose” provided compensation is given to the previous owner (OCA, 2020). The OCA not only handles active cases but is seeking to push a “Property Owner’s Bill of Rights” into formal legislation to increase private business’s property rights (OCA, 2020). Legislation for individual rights and a decrease in oversight are the manner in which agribusinesses are attempting to maintain control of the Aquifer. On the other side, conservationists made strides when the Texas Supreme Court ruled that pumping limits on private land were legal to preserve the Aquifer’s viability, though this has experienced property rights pushback as water property rights are revisited (Galbraith, 2012). Policy continues to shift back and forth to this day and neither side has clearly beaten the other.

Both businesses with large resource consumption and individual aquifer participants seek the public’s approval by educating them of their individual arguments. While corporations pour immense funds and time into transparency policies and efforts, advocacy groups seek to exploit the shadowy corners of these industries in an attempt to persuade consumers to remove their current financial support. The petrochemical industry is a large example of this, where Gillies makes the point that “transparency encourages strong selling practices” in an effort to increase transparency for the sake of PR and sales (Gillies, 2012). Tracy of the Texas Water Resources

Institute is quoted as saying that farmers need “productive and transparent dialogue to move forward” and protect their own interests (Ledbetter, 2021). However, Katherine Paul writes for Common Dreams, a progressive media outlet, that commercial operations “foul the state’s waterways” through “animal waste and antibiotics...or nitrates and pesticides” that “destroy our most precious natural resource” (Paul, 2019). The NRDC is one organization that seeks to put out educational materials and lead seminars and conferences to gain public favor in limiting agribusiness liberties (Lindwall, 2019).

Conclusion

The approach to management of the Ogallala Aquifer has inspired new forms of technical data processing and social relations as the participants tackle the problem from unique, albeit opposing angles. One of the key lessons observed in this process is analyzing a problem as more than its surface-level conflict of interests. Appreciating the diversity of realms to which social, and especially resource management, problems belong allows for a more wholistic approach that will identify the parts that are truly necessary to meet. Civil right and energy infrastructure movements are causes that should examine the participants in this case study. Wildlife, forestry and climate conservation efforts have much to learn from the Ogallala Aquifer case. Further action must be taken to ensure aquifer preservation. Immediate actions for those seeking Aquifer conservation and a halt to agricultural overuse include policy implementations that allow for compromise by agribusiness and create funding for companies that seek to reduce environmental impact through process change. Agricultural participants will want to continue to seek innovation and the ability to reduce production equitably to avoid falling out of favor with the public and becoming abandoned in the future market. Education efforts remain an important goal

to advance conservation efforts beyond the aquifer. Only through engaging all facets of the aquifer problem will any participant succeed in their agendas, to the benefit or ruin of the Aquifer, the planet and future human society.

References

- AgAmerica Lending. (2021, March 28). Top 10 produce crops grown in the U.S.: AGAMERICA. <https://agamerica.com/blog/power-of-10-top-10-produce-crops-in-the-u-s/>
- Babylon. (n.d.). Hydroponic grow system. <https://www.babylonmicrofarms.com/about>
- Bair, J. (2011, December 01). Running dry on the Great Plains. <https://www.nytimes.com/2011/12/01/opinion/polluting-the-ogallala-aquifer.html>
- Benson Hill. (2018, October 08). A New Generation of Food Innovators with a Fresh Perspective. <https://bensonhill.com/2018/08/07/a-new-generation-of-food-innovators-with-a-fresh-perspective/>
- Brambila, N. (2014, August 09). Drying times: Could the rapidly depleting Ogallala Aquifer run dry? <https://www.lubbockonline.com/article/20140809/NEWS/308099828>
- Caldwell, J., & Riedel, C. (2016). Saving the Ogallala Aquifer: Farm Life. <https://myfarmlife.com/2016/saving-ogallala-aquifer/>
- Cano, A., & Núñez, A., & Acosta-Martinez, V., & Schipanski, M., & Ghimire, R., & Rice, C., & West, C. (2018). Current Knowledge and Future Research Directions to Link Soil Health and Water Conservation in the Ogallala Aquifer Region. *Geoderma*, 328(Oct), 109-118. ScienceDirect.
- Civil Eats: Sustainable Food News Resource. (2020, October 27). <https://civileats.com/about/>
- Climate Hubs. (2017). Agriculture in the Midwest. <https://www.climatehubs.usda.gov/hubs/midwest/topic/agriculture-midwest>
- Corporativa, I. (2021). Young people rise up against climate change. <https://www.iberdrola.com/social-commitment/greta-thunberg-environmental-activist>
- Dostie, D. (2020). Natural Resources Conservation Service. <https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/initiatives/?cid=stelprdb1048809>
- Edwards, J. A., Pumphrey, R. G., Barbato, L., Kurkalova, L. A., & Murkey, M. L. (2012). Building a Simple General Model of Municipal Water Conservation Policy for Communities Overlying the Ogallala Aquifer. *Natural Resources Journal*, 52(1), 135-155. JSTOR.
- EPA (2020, September 10). Environmental Protection Agency. Global Greenhouse Gas Emissions Data. <https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>

- Erramouspe, H. (2018, June 29). Depletion of Ogallala Aquifer Affecting Region's Migratory Birds. <https://today.ttu.edu/posts/2018/06/snowy-plover#:~:text=It%20is%20impacting%20some%20of,Plains%2C%20including%20the%20snowy%20plover.&text=These%20regional%20saline%20lakes%20have,the%20lakes%20are%20drying%20up>.
- FB (2019, March 21). Farm Bureau. Feeding the Economy: Agricultural Jobs by State. <https://www.fb.org/market-intel/feeding-the-economy-agricultural-jobs-by-state>
- Friedman, L. (2016, February 29). Leonardo DiCaprio USES Oscar speech to Urge action on climate change. <https://www.scientificamerican.com/article/leonardo-dicaprio-uses-oscar-speech-to-urge-action-on-climate-change/>
- Galbraith, K. (2012, March 18). Farmers and regulators square off in battle over Ogallala aquifer rules. <https://www.texastribune.org/2012/03/18/texas-farmers-regulators-battle-over-ogallala/>
- Gilbert, N. (2012). One-third of our greenhouse gas emissions come from agriculture. <https://www.nature.com/news/one-third-of-our-greenhouse-gas-emissions-come-from-agriculture-1.11708>
- Gillies, A. (April 2012). *The Case for Transparency in National Oil Company Crude Sales* (Issue brief).
- Gramlich, J. (2020, May 30). Young Americans are less trusting of other people – and key institutions – than their elders. <https://www.pewresearch.org/fact-tank/2019/08/06/young-americans-are-less-trusting-of-other-people-and-key-institutions-than-their-elders/>
- Hanemann, M., & Young, M. (2020). Water rights reform and WATER MARKETING: Australia vs the US West. *Oxford Review of Economic Policy*, 36(1), 108-131. doi:10.1093/oxrep/grz037
- Hornbeck, R., & Keskin, P. (2014). The Historically Evolving Impact of the Ogallala Aquifer: Agricultural Adaptation to Groundwater and Drought. *American Economic Journal: Applied Economics*, 6(1), 190-219. JSTOR.
- Howe, C. W. (2002). Policy Issues and Institutional Impediments in the Management of Groundwater: Lessons from Case Studies. *Environment and Development Economics*, 7(4), 625-641.
- Jevons, W. S. (1865). *The Coal Question*. London, UK: Macmilan & Co. London.
- Kansas Geological Survey. (2017, August 8). Kansas geological Survey. <http://www.kgs.ku.edu/HighPlains/complete/index.shtml>

- Kansas State University. (2020, January 07). Rural water wells in High plains Aquifer show large increase in nitrate levels.
<https://www.sciencedaily.com/releases/2020/01/200107122259.htm>
- Kansas University. (2007, October 7). High Plains Aquifer Information Network. Retrieved April 03, 2021, from <http://www.kgs.ku.edu/HighPlains/index.shtml>
- Lansford, R. R., Gollehon, N. R., Mapel, C., Creel, B. J., & Ben-David, S. (1983). The On-Farm Economic Impacts of the Declining Ogallala Aquifer for the New Mexico High Plains. *Journal of ASFMRA*, 47(1), 31-36. JSTOR.
- Lauer, S., & Sanderson, M. R. (2020). Producer Attitudes Towards Groundwater Conservation in the US Ogallala-High Plains. *Groundwater*, 58(4), 674-680. Web of Science.
- Ledbetter, K. (2021, March 18). Ogallala Aquifer: Situation to manage, not problem to solve.
<https://agrifetoday.tamu.edu/2021/03/19/ogallala-aquifer-situation-to-manage-not-problem-to-solve/>
- Leestma, D. (2019, December 18). Why these 8 states could soon form the 'great American desert'. <https://www.ecowatch.com/ogallala-aquifer-depletion-2511600266.html#toggle-gdpr>
- Lindwall, C. (2019, July 31). Industrial agricultural pollution 101.
<https://www.nrdc.org/stories/industrial-agricultural-pollution-101>
- Massachusetts Institute of Technology. (n.d.). Mission 2012.
<http://web.mit.edu/12.000/www/m2012/finalwebsite/problem/groundwater.shtml>
- NFU. (2019, Aug. 13). National Farmers Union. About Us. <https://nfu.org/about/>
- Nizkorodov, E. (2021). Evaluating risk allocation and project impacts of sustainability-oriented water PUBLIC–PRIVATE partnerships in Southern California: A comparative case analysis [Abstract]. *World Development*, 140, 105232.
doi:10.1016/j.worlddev.2020.105232
- OAA. Ogallala Aquifers Advocates. (2012, April 08). *Ogallala Aquifer Advocates Instagram*.
<https://www.instagram.com/ogallalaaquiferadvocates/>
- OCA. Owner's Counsel of America. (2020, April 22). Property rights Attorney, farmers & Ranchers Representation. <https://www.ownerscounsel.com/about-oca/who-we-represent/farmers-and-ranchers/>
- OgallalaWater. (2021, February 26). 2021 Ogallala Aquifer Summit.
<https://ogallalawater.org/2021-ogallala-aquifer-summit/>

- Oki, T., & Quioco, R. E. (2020). Economically challenged and water scarce: Identification of global populations most vulnerable to water crises [Abstract]. *International Journal of Water Resources Development*, 36(2-3), 416-428. doi:10.1080/07900627.2019.1698413
- OSU & Schulz, R. (2019, July 02). The Ohio State University. Spotlight on Chemistry: Environmental Impact of Industrial Reactions. <https://u.osu.edu/cbcundergrad/2019/06/19/environmental-impact-of-industrial-reactions/>
- OWID (2020). Our World in Data. World GDP over the last two millennia. <https://ourworldindata.org/grapher/world-gdp-over-the-last-two-millennia?time=1900..2015>
- Paul, K. (2019, December 18). From 'sea to Shining Sea,' industrial AG Fouls America's Waterways. <https://www.ecowatch.com/industrial-agriculture-water-pollution-2551396477.html>
- Peck, J. (2007). *Groundwater Management in the USA*. doi:10.1079/9781845931728.0296
- Perrin, A. (2020, October 16). 23% of users in U.S. say social media led them to change views on an issue; Some cite Black Lives Matter. <https://www.pewresearch.org/fact-tank/2020/10/15/23-of-users-in-us-say-social-media-led-them-to-change-views-on-issue-some-cite-black-lives-matter/>
- Peterson J. M., & Marsh T. L., & Williams J. R. (2003). Conserving the Ogallala Aquifer: Efficiency, Equity, and Moral Motives. *Choices*, 18(1), 15-18. JSTOR.
- Pork Business. (2016, September 20). Every last Drop Counts. <https://www.porkbusiness.com/news/industry/every-last-drop-counts>
- R.D. Offutt Company. (2021, April 04). <https://www.rdoffutfarms.com/>
- Rad, M. R., & Araya, A., & Zambreski, Z. T. (2020). Downside Risk of Aquifer Depletion. *Irrigation Science*. Web of Science.
- SAN. Sustainable Agriculture Network. (n.d.). Our priorities. <https://www.sustainableagriculture.eco/our-priorities>
- Sanderson, M. R. (2020, November 18). The government pays farmers to pull water from the OGALLALA-HIGH plains aquifer - now they're depleting it. <https://www.greenbiz.com/article/government-pays-farmers-pull-water-ogallala-high-plains-aquifer-now-theyre-depleting-it>
- Schaider, L. A., Swetschinski, L., Campbell, C., & Rudel, R. A. (2019). Environmental justice and drinking Water QUALITY: Are There socioeconomic disparities in nitrate levels in U.S. drinking water? [Abstract]. *Environmental Health*, 18(1). doi:10.1186/s12940-018-0442-6

- Schleifer, L., & Otto, B. (2019, September 13). Water can exacerbate inequality-or it can help solve it. <https://www.wri.org/blog/2019/03/water-can-exacerbate-inequality-or-it-can-help-solve-it>
- Seametrics. (2018). 5 consequences of a global water shortage. <https://www.seametrics.com/blog/water-shortage-consequences/>
- Sommer, L. (2019, March 11). Trump administration shortcuts science to give California farmers more water. <https://www.npr.org/2019/03/11/701205836/trump-administration-shortcuts-science-to-give-california-farmers-more-water>
- Spinola, J. N., & Carneiro, A. F. (2019). Technical evaluation of a PV-DIESEL hybrid system with energy Storage: Case study in the tapajós-arapiuns extractive Reserve, Amazon, Brazil [Abstract]. *Energies*, 51(11), 224-226. doi:10.3390/en13112969
- Stohr, G. (2021, March 20). Farmworker Clash Pits Union Access, Property Rights at Top Court. <https://www.bloomberg.com/news/articles/2021-03-20/farmworker-clash-pits-union-access-property-rights-at-top-court>
- Successful Farming. (2021, January 17). Top 5 farms with the Largest acreage in the U.S. <https://www.agriculture.com/farm-management/farm-land/top-5-farms-with-the-largest-acreage-in-the-us>
- TCPA. Texas Comptroller of Public Accounts. (2020). The high plains region2020 regional report. <https://comptroller.texas.gov/economy/economic-data/regions/2020/high-plains.php>
- Terrell, B. L., & Johnson, P. N., & Segarra, E. (2002). Ogallala Aquifer Depletion: Economic Impact on the Texas High Plains. *Water Policy*, 4(1), 33-46. ScienceDirect.
- Texas A&M University. (2015). Ogallala aquifer Program. <https://ogallala.tamu.edu/>
- Thunberg, G. (2018, December 18). *Address to the U.N. Plenary* [Speech audio recording]. YouTube. <https://www.youtube.com/watch?v=HzeekxtyFOY>
- Tyson Fresh Meats. (2020, Sep. 9). Tyson Foods Becomes First U.S. Food Company to Verify Sustainable Cattle Production Practices at Scale. <https://ir.tyson.com/news/news-details/2020/Tyson-Foods-Becomes-First-U.S.-Food-Company-to-Verify-Sustainable-Cattle-Production-Practices-at-Scale/default.aspx>
- USDA. U.S. Department of Agriculture. (2020). Ag and food sectors and the economy. <https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy/>
- USDA. (2020). United States Department of Agriculture. Irrigation & Water Use. <https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/>

Valipour, M., Johnson, C. E., Battles, J. J., Campbell, J. L., Fahey, T. J., Fakhraei, H., & Driscoll, C. T. (2021). Simulation of the effects of forest harvesting under changing climate to inform long-term sustainable forest management using a biogeochemical model [Abstract]. *Science of The Total Environment*, 767, 144881.
doi:10.1016/j.scitotenv.2020.144881

Water Education Foundation. (2021). Water rights in California.
<https://www.watereducation.org/aquapedia/water-rights-california>

Water.org. (2021). About Water.org - learn about our Water NGO. <https://water.org/about-us/>

Yuen, B., & Kumssa, A. (2010). Africa and Asia: Two of the World's Fastest Growing Regions. *Climate Change and Sustainable Urban Development in Africa and Asia*, 3-18.
doi:10.1007/978-90-481-9867-2_1