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Regenerative Agriculture –A Pathway for Addressing Nebraska's Water Quality and Soil Degradation Challenges

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Disclaimer: The following thesis was produced in the Environmental Studies Program as a student senior capstone project.

Regenerative Agriculture – A Pathway for Addressing Nebraska's Water Quality and Soil Degradation Challenges

by

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PREAMBLE

It is important to begin this thesis by acknowledging that the State of Nebraska is on stolen Native land. Furthermore, the University of Nebraska is a land-grant university that was ultimately given 89,920 acres of Native lands for the paltry sum of $11,194. To date, the University of Nebraska has benefited from a 51:1 profit ratio on the funds raised from its 1873 land grant, raising over $500,000 in endowment principle. I humbly acknowledge that the privilege of earning my degree at UNL came through the often violent and bloody displacement of multiple tribal nations (High Country News, 2020).

As shown in Figure 1 below, the University of Nebraska has built its campuses and programs on the past, present, and future homelands of the Pawnee, Ponca, Otoe-Missouria, Omaha, Dakota, Lakota, Kaw, Cheyenne, and Arapaho Peoples, as well as those of the relocated Ho-Chunk, Sac and Fox, and Iowa Peoples (Center for Great Plains Studies, 2023).

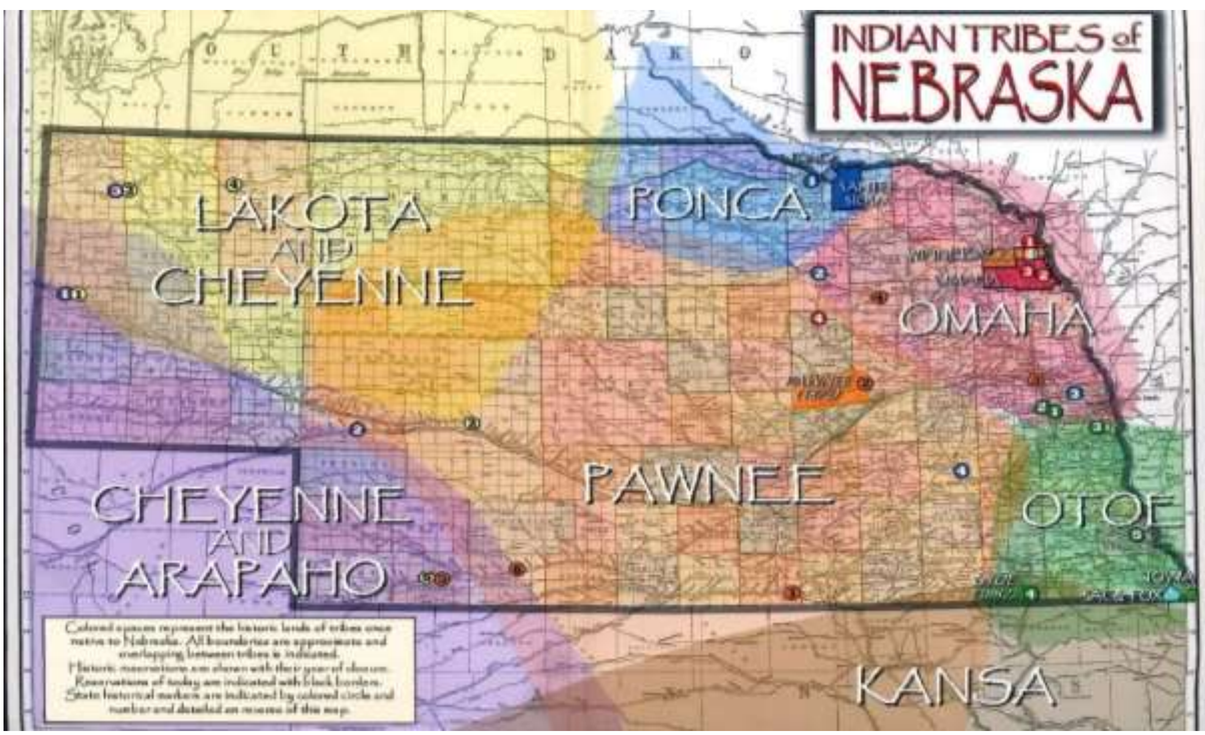

Figure 1. Map depicting some of the tribal affiliations with the land currently known as Nebraska. From *Land Acknowledgement Statement* by J. Barnes, 2019, Legal Aid of Nebraska. https://www.legalaidofnebraska.org/land-acknowledgement-statement/.

INTRODUCTION

Nebraska has a long history of being a proud agricultural state with diverse landscapes and robust natural resources. Home to five distinct ecoregions from the Shortgrass Prairie on the west end of the state, to the Tallgrass Prairie covering the eastern quarter, and the High Plains Aquifer that begins just above Nebraska's northern border, making it among the most productive agricultural land in the United States (Nebraska Invasive Species Program. 2023). These fertile soils have been stewarded by Nebraska families for generations and before that, by Indigenous families and communities since time immemorial. Nebraska's economy is largely based around agriculture, boasting 44,800 farm operations spread over 44.8 million acres that occupy 91% of the land in the state (Nebraska, 2023). These farms and ranches are home to a variety of crops and livestock including corn, soybeans, sunflowers, cattle, hogs and bison. In 2021 Nebraska Ag broke records when its net farm income exceeded $8 billion, and its exports were over $9 billion (Nebraska Department of Agriculture, 2020; United States Department of Agriculture,2022).

Nebraska has achieved much of its agricultural "success" through the use of conventional farming and monoculture methods that include seasonal tilling, leaving fields bare between harvest and planting, removal of grazing animals from croplands, the use of genetically modified seeds. These modern farming practices disregard the importance of soil organic matter content, instead depending on expensive inputs like chemical fertilizers, herbicides, pesticides, and fungicides to achieve high crop yields and weed suppression. While these practices may have resulted in growing a large number of calories in a short amount of time, they have also brought devastating long-term effects including farms that are less resilient to extreme weather like droughts, a long-term decrease in annual crop yields, and the loss of topsoil at a rate of four tons per acre per year, for the average American farm. These terrestrial costs also bring with them economic costs that have resulted in American farmers increasing their farm's debt by nearly 4% every year (Kiss the Ground, 2020).

Addressing Nebraska's increasing soil degradation and declining water quality have become top priorities for many farmers, policymakers, and natural resource managers throughout the State, as they realize the long-term viability of the local economy depends on the ability of the soil and water to continue supporting agricultural activities. In 2019, the Nebraska Healthy Soils Task Force was established as a 17-member group composed of representatives from government agencies, agricultural organizations, and agricultural producers in the state. The task force aimed to provide recommendations to close the "soil health gap," emphasizing the significance of soil and water resources and their connection to the economic future of farmers and ranchers. Their non-mandated recommendations focus on improving soil health, water quality and quantity, conservation, and erosion reduction through voluntary means in the hope of eventually increasing profitability for producers (The Nebraska Healthy Soils Task Force, 2020).

PURPOSE OF STUDY

On July 28, 2010, during its sixty-fourth session, the United Nations General Assembly formally adopted resolution 64/292, The human right to water and sanitation. This resolution "recognizes the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights." The state of Nebraska has a moral and political mandate to protect its citizens from health threats (Martin, 2008). The goal of this paper is to suggest Regenerative agriculture as the pathway that Nebraska can take to protect public health and food security, as well as ensure the sustainability of its agricultural-based economy for generations to come by making meaningful changes to policy and agricultural norms that will improve the condition of its soils and groundwater through collaborative efforts that recognize a diverse stakeholder group which seeks to incorporate both the best available science and indigenous ways of knowing. The guiding research question for this study is:

> How can Indigenous/ Regenerative agriculture practices be implemented in Nebraska to improve and protect the health and quality of the State's soil and water resources, thereby enhancing the resilience of an economy dependent on those resources?

WATER QUALITY

Hailed as the "Cornhusker State," Nebraskans have found a way to utilize corn in nearly every part of the supply chain from livestock feed to popcorn, and even ethanol fuel; and where corn grows, fertilizers, soybeans, and irrigation often follow. Nebraska's position at the northern end of the High Plains Aquifer has afforded it the luxury of irrigating more acres of cropland than any other U.S. state. In fact, over 90% of the water taken from the Aquifer is used for irrigating crops (Cano et. al, 2018; Morgan Wirth & Basche, 2020).

The prolific use of agrichemicals like nitrogen for fertilizer and atrazine for weed control, combined with intensive irrigation have led to dangerously high levels of contamination in the Nebraska groundwater, which is the primary source of drinking water for over 85% of the state's residents. High nitrate concentrations have been linked to several adverse health outcomes for children that include elevated cancer rates, congenital anomalies, and blue baby syndrome. Furthermore, the International Agency for Research on Cancer has stated on record since 2010, that nitrates probably cause cancer in humans. This opinion was recently supported by a multi-disciplinary team of researchers in 2022 that examined birth defect rates in Nebraska spanning over 19 years. Their report provides evidence for a positive correlation between high levels of agrichemicals like nitrate, uranium, arsenic and atrazine in drinking water and elevated birth defect rates (Ouattara et al., 2022). Contaminated drinking water is also a primary environmental concern for tribes in Nebraska, where nitrate and coliform bacteria levels have been a known to be above U.S. EPA maximum contamination levels (MCL) for decades (McGinnis & Davis, 2001).

The prolific use of fertilizer nutrients like phosphorus and nitrogen is also creating a hazard for grazing cattle in Nebraska. When these agrichemicals runoff into standing-water bodies like ponds, lakes and dugouts they have the opportunity to bask in the hot summer sun they allow cyanobacteria algae to bloom, or multiply very quickly, in the water using all of the available oxygen and eventually suffocating every other living thing in the water. Some species of cyanobacteria produce toxins that are harmful to most livestock, wildlife, songbirds, and humans. When this poisoned water is consumed, extreme neurological and hepatological [liver] symptoms usually onset within 20 minutes of ingestion and often lead to a painful death within 2-24 hours. There are currently no known cures for cyanotoxin poisoning (Timmerman, 2021).

Water isn't just essential for agriculture; it is essential for the survival of every living organism on Earth, including humans. The U.S. Geological Survey (n.d.) defines water quality as a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics. Humans require access to high-quality water that is "potable," or safe for humans to consume, which is defined as:

> water that has sufficiently low concentrations of microbiological, inorganic chemical, organic chemical, radiological or physical substances so that individuals drinking such water at normal levels of consumption, will not be exposed to disease organisms or other substances which may produce harmful physiological effects (Oregon Health Authority, 2023).

A standard that Nebraska is clearly not meeting when one considers the causal association that exists between a pregnant mother consuming water with high concentrations of nitrates [above U.S. EPA limit of 10 mg/L] and the occurrence of birth defects like neural tube defects and limb deficiencies. Figures 2 and 3 below illustrate the correlation between Nebraska watersheds with high nitrate concentrations, and the more than 80% of Nebraska watersheds that also have birth defect prevalence above the national average (Ouattara, Zahid et al., 2022).

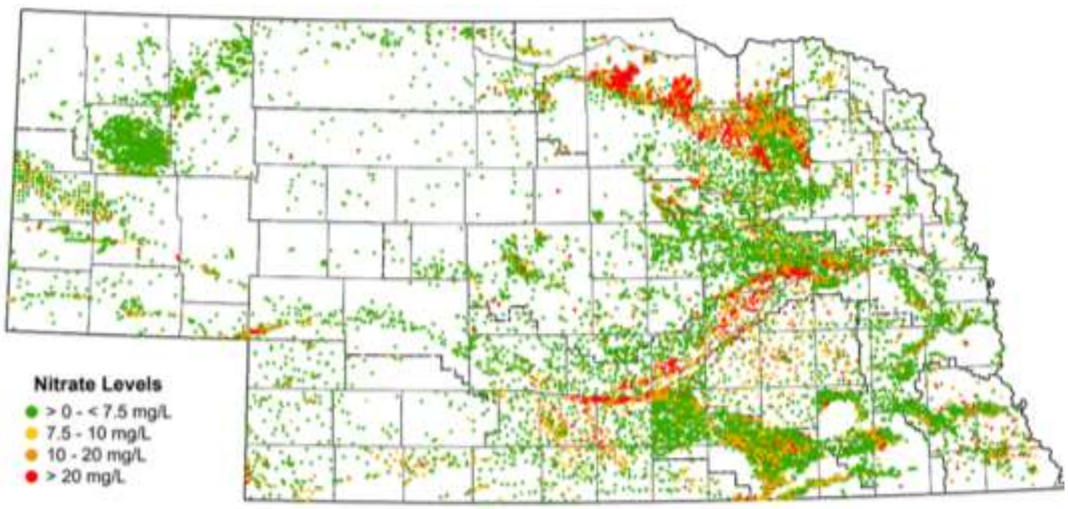

Figure 2. Groundwater Nitrate levels from recent sample of 18,247 wells from 2000-2019. From Nebraska Nitrate Working Groups - Summary and Call for Action by NDEE, 2020. https://water.unl.edu/article/nitrate/nebraska-nitrate-working-groups-summary-and-call-action.

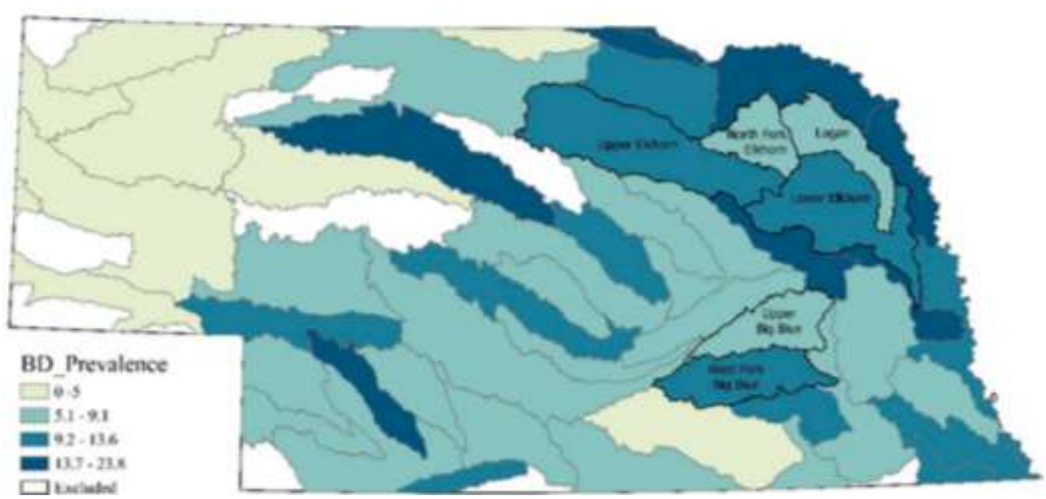

Figure 3. Birth defect prevalence in all Nebraska watersheds during 1995–2014. From Investigation of a Possible Relationship between Anthropogenic and Geogenic Water Contaminants and Birth Defects Occurrence in Rural Nebraska by Ouattara, Zahid et al., 2020, *Water, 14*(15), 2289. https://doi.org/10.3390/w14152289.

SOIL HEALTH

One cannot discuss Nebraska's groundwater quality without also examining the health of the soil, the uppermost layer of the earth's crust. Healthy soil performs several significant ecosystem services that include recycling, purifying, filtering, and storing water and vital nutrients for the entire planet, as seen in Figure 4. Soil is not merely dirt; Young et. al (2020) defines soil as the "dynamic living system which functions as the interface between land and sky, and the living and the dead. Soil is the repository of fertility and life on this planet." It is home to 15 of the 16 elements that are essential for plant life. Soil has structure and texture, acting as the super-highway for plants, it allows their roots to access nutrients and water needed for growth.

Figure 4. Pie chart illustrating the environmental services provided by soil. From Soil Functions, 2015, Food and Agriculture Organization of the United Nations. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.fao.org/3/AX374E/ax374e.pdf

Soil has 6 horizons, or layers, as seen below in Figure 5. The topmost layer is the O horizon, commonly known as humus or black gold, due to its dark brown to black color that is the result of high levels of organic carbon. This dark, rich layer is made up of organic matter that forms as dead animals, leaves, grass, and twigs fall to the ground and decompose over time. Worms, bacteria and fungi break down these once-living materials allowing the carbon, nitrogen, and other minerals they contained to be released to the topsoil below, called horizon A.

When healthy, this topsoil layer also has a high organic matter content, which is full of nutrients and biological activity for optimal root growth and plant support. As water hits the topsoil it percolates through the humus and into horizon A, making water soluble nutrients like nitrogen, sulfur, and chloride available to the plant's roots. The soil directly surrounding the roots is called the rhizosphere and when it's healthy it is teeming with microbes that feast on the cells, proteins and sugars that the plants have shed. These topsoil layers are vital to crop yields because they are where the majority of the plant's nutrient cycling and disease suppression occurs. Excess nutrient levels, that is nutrients that are beyond plant needs and soil storage ability, leach into the layers below ultimately finding their way into the groundwater (Young et al., 2020).

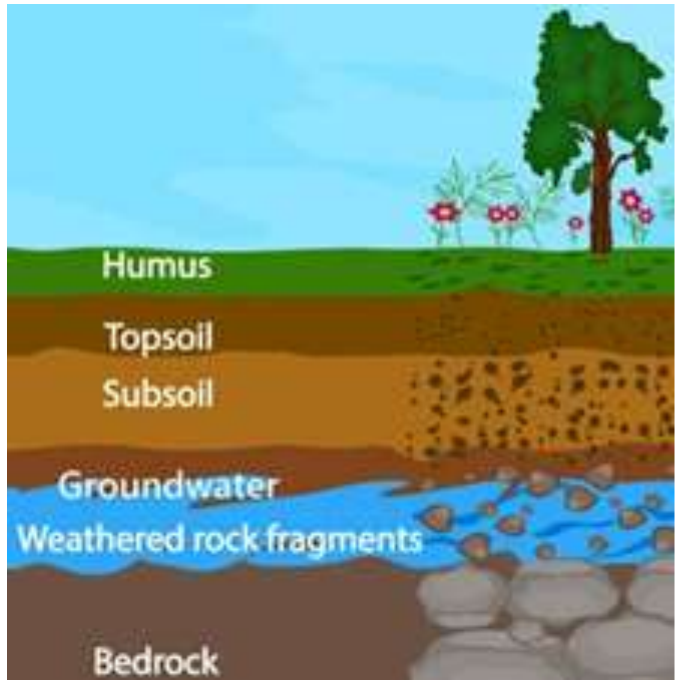

Figure 5. Illustration showing 5 layers of soil. From *Soil Horizons* by Science Facts, 2023. https://www.sciencefacts.net/soil-horizons.html.

Soil health is "the ability of the soil to continue function as a vital living system within ecosystem and land-use boundaries, thereby sustaining biological productivity, maintaining air and water quality, and promoting plant, animal, and human health" (Khangura et al., 2023). A decline in soil health and quality is called soil degradation, which is characterized by a loss of soil structure and productivity that results in reduced water infiltration and soil ecosystem services like water purification and carbon sequestration. In Nebraska, one of the main contributors to soil degradation is erosion. Erosion is a natural process whereby wind and rain events remove particles of topsoil, taking nutrients and vital organic matter with it. Agricultural activities like plowing fields, removal of crop residues and overgrazing livestock cause significant increases in the amount, and rate, of soil erosion (The Nebraska Healthy Soils Task Force, 2020).

INDIGENOUS ENVIRONMENTALISM or "REGENERATIVE AGRICULTURE"

Omaha Tribe member and citizen of the Cherokee Nation, Taylor Keen teaches that Indigenous Environmentalism was the way of life for Native Americans on the Great Plains for thousands of years before Regenerative Agriculture became a popular term. The trees, crops and animals existed together in a symbiotic relationship, and tribes like the Winnebago and Omaha Nations cultivated and curated the land alongside of the plant nation, not in dominion to it. Their farming methods focused on soil health and included companion planting, minimal soil disturbance, purposeful livestock grazing, and prairie fire to increase biodiversity and reduce invasive species. "You call it Going Green; I call it Living Red" (Keen, 2023).

Regenerative agriculture is more descriptive than it is prescriptive. Requiring a change in perspective and focus that is described by Lal (2020) as "soil-centric rather than seed-centric and is based on the premise that the health of soil, plants, animals, and humans is one and indivisible." Regenerative agriculture, while lacking an official, agreed-upon definition, always seeks to utilize ecological systems to enhance soil organic matter and biodiversity, which promotes productivity and yield, while simultaneously increasing the soil's capacity to retain water and sequester carbon. These outcomes are achieved by incorporating the three broad pillars of sustainability: people, planet, and profit, into the key principles of Regenerative agriculture through a systems-based framework (Gosnell, 2021; Lal, 2020):

1. **Understand Context**: Context informs our decisions and brings clarity to our motivations and actions. Understanding the ecological, community, economic, climate, and spiritual contexts will provide a structure that serves to inform the other 6 principles and will help to minimize barriers to success that may arise.
2. **Minimize Disturbance**: Strategies to minimizing soil disturbance include implementing a no-till system, and reducing or even stopping the use chemical fertilizers, pesticides, fungicides, and herbicides to protect soil texture and structure for a healthy microbiome.
3. **Establish a Living Root System:** Living roots exude sugars which are the primary food source for soil organisms, allowing them to cycle nutrients and build a stable soil structure. Incorporating perennials will provide year-round support to the soil web.
4. **Provide Soil Armor:** Known as "cover cropping," this layer of protection makes the soil more resilient to harsh weather conditions like floods, droughts, and extreme hot and cold spells. Healthy soil residue prevents runoff-erosion, provides a secondary food source for soil microbes, and works hand-in-hand with the not-till principle to increase water infiltration, reduce weeds, and improve nutrient flow.
5. **Integrate Animals:** Integrating livestock through a planned grazing system allows animals to move across fields, distributing manure to fertilize the soil and increase its microbial content. A schedule that allows the livestock to eat only half of the forage biomass will preserve a high rate of photosynthesis and stimulate forage regrowth, increasing organic carbon compounds in the soil.
6. **Enhance Biodiversity:** Adding variety to a farm's plant and animal species will create an environment that more closely mimics nature's healthy and productive ecosystems. From

long-term projects like incorporating fruit and nut trees (agroforestry) into the farm's ecosystem, to shorter-term projects like installing owl boxes and beehives, increasing the agricultural biodiversity will support a farm's long-term climate resiliency and create sustainable long-term profitability with reduced annual inputs (Green Cover, 2023; Kiss the Ground, 2022).

7. **Indigenous Wisdom & Generational Wisdom:** We must honor the context and history of the land, taking care to acknowledge and consider the wisdom that came before us. Indigenous peoples are the world's leaders when it comes to cooperation and harmony between the land and the people. Only through inviting Indigenous people back into the conversation and learning what they have to teach about food sovereignty and protecting the land for future generations, will we find true success. (Rogers-Wright et al., 2023).

This set of approaches to agriculture, illustrated below in Figure 2, puts the focus on making the most of the naturally occurring interactions that take place between plants and the soil, in an attempt to break the reliance on costly external inputs like fertilizers, herbicides, fungicides and pesticides. The word regenerate is from the Latin words 're' and 'generare' which literally mean 'again' and 'create' respectively, and applied to the agricultural setting that is the literal goal; to create again the health and activity that the soil had before it was abused by conventional farming techniques. Regenerative agriculture seeks to re-create and maintain the biochemical cycles and interrelationships that historically existed between the soil, plants, animals, and humans (McLennon et al., 2021). The Native concept of reciprocity guided their interactions with Mother Earth, weaving its way not only into their actions but also permeating their language, as we can see in the word for 'plants' that was spoken in some Indigenous languages translates to English as, "those who take care of us" (Kimmerer, 2013).

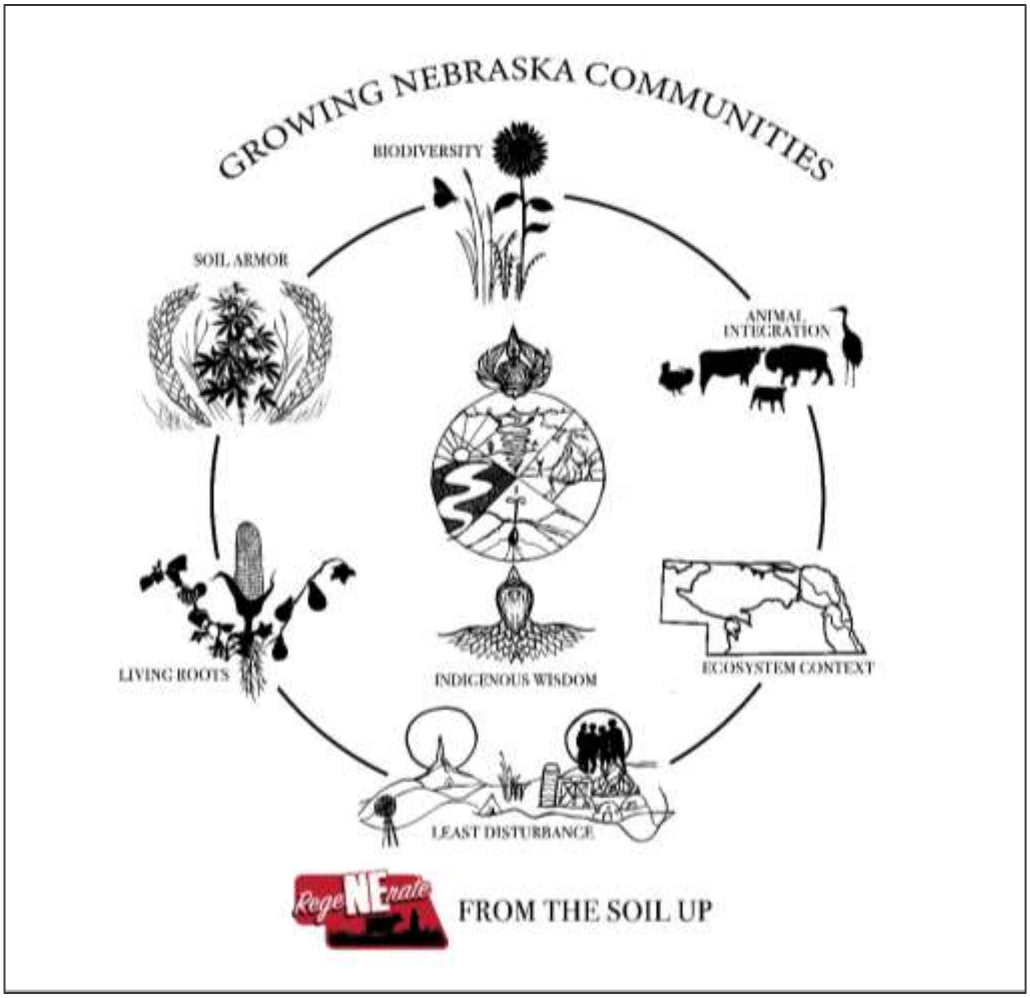

Figure 6. Regenerative agriculture principles illustrated as centering around Indigenous Wisdom. Image provided by Regenerate Nebraska, 2023.

Traditional Indigenous farming methods illustrate a deep understanding of the interdependence that exists between the soil and the plant nation. One example of this is the Four Sister cropping practiced by the Omaha and Winnebago tribes on the Great Plains who grew corn with beans, squash, and sunflowers planted in fields together. As the corn stalks grew tall, the climbing beans would grow up their stalks and reciprocate the favor by fixing nitrogen in the soil for the corn. The broad leaves of the squash provided groundcover for the beans and corn, helping to suppress weeds, prevent soil erosion, and increase the soil's ability to hold water, while the sunflowers planted along the perimeter of the plot provided support for the tall corn plants when the strong prairie winds blew through before harvest (Keen, 2023).

An advantage that Regenerative agriculture has over the conventional model of farming is that the application of the principles are always tailored to the local climate, unique landscape, and financial resources of each producer. Instead of exhausting the land and water, Regenerative agriculture integrates reciprocal processes in a manner that aligns with the idea of 'stewardship of the land,' for future generations, an ideal that resonates strongly with many of Nebraska's farmers. A recent statewide survey regarding the use of cover crops and incentives to adopt practices for soil health improvements among stakeholders and producers in Nebraska revealed stewardship of the land as a prevailing value, over economic factors like reduced crop insurance and increased land value. (Das, et al, 2021; McLennon, et al, 2021). The ideals of reciprocity and stewardship are both found in the Indigenous ways of knowing, as Indigenous author Robin Kimmerer of the Potawatomi Nation reminds us in her powerful book, Braiding Sweetgrass:

> As we consider these instructions, it is also good to recall that, when Skywoman arrived here, she did not come alone. She was pregnant. Knowing her grandchildren would inherit the world she left behind, she did not work for flourishing in her time only. It was through her actions of reciprocity, the give and take with the land, that the original immigrant became Indigenous. For all of us, becoming Indigenous to a place means living as if your children's future mattered, to take care of the land as if our lives, both material and spiritual, depended on it (Kimmerer, 2013, p. 9).

METHODS & LITERATURE REVIEW

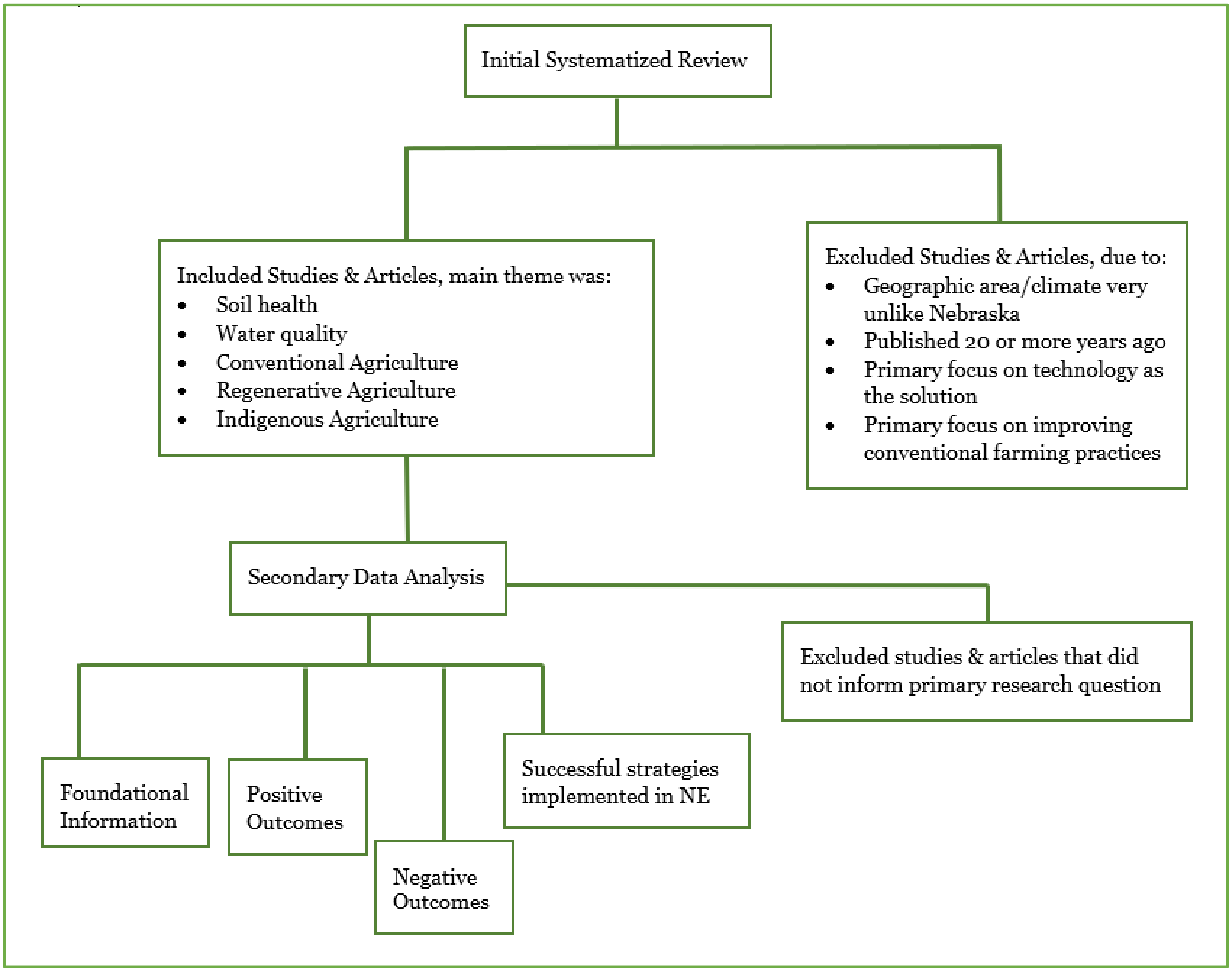

Figure 7. Flowchart illustrating the Literature Review process for study.

Mixed methods were used to implement this study. First a systematized literature review was performed to gather quantitative and qualitative data regarding Nebraska's soil health, water quality, and agriculture practices of conventional, Regenerative, and Indigenous agricultural methods. Then a secondary data analysis was performed to analyze the positive and negative impacts of conventional, Regenerative, and Indigenous agricultural methods on the land and people of Nebraska. Finally, to gain contextual feedback regarding the successes and failures of applying Regenerative agriculture methods, semi-structured interviews and online data were gathered for two farms in Nebraska that are currently implementing Regenerative agricultural methods. Due to the literature-based nature of secondary data analysis, the author has chosen to combine the Methods and Literature Review sections of this paper to avoid redundancy and promote cohesion for the reader.

The secondary data analysis was meant to examine existing literature as it pertains to data regarding the current status of Nebraska's soil health and water quality, making note of who the primary users of those resources are and what effects of their use has had on those resources. Additionally, literature was examined for successful strategies implemented by agricultural producers that have disrupted the harmful positive feedback loops caused by conventional farming and ranching practices, including how these constructive shifts in attitudes and actions might be supported in meaningful ways. As stated by Xiao and Watson (2107), the focus of the initial literature review was not on assessing the quality of the primary data, but rather on gathering relevant information to provide context and substance to the research question that is the focus of this paper:

> How can Indigenous/ Regenerative agriculture practices be implemented in Nebraska to improve and protect the health and quality of the State's soil and water resources, thereby enhancing the resilience of an economy dependent on those resources?

Between January 2022 and April 2023, a systematic literature review was performed to find key literature using Google, Google Scholar, Research Gate, and Elsevier. Search terms were "Regenerative agriculture," "Nebraska soil quality," "Nebraska soil degradation," Nebraska water quality," "Nebraska Regenerative agriculture," "case study Regenerative agriculture," "soil ecology," "soil health," "soil microbiome," "High Plains Aquifer," "Nebraska economy," "biodiversity," "Regenerative farms Nebraska," "conventional farming practices," "topsoil health," "water policy Nebraska," "agrichemicals in drinking water," "water quality," "birth defect prevalence," "nitrate concentration," "Nebraska soil erosion," "soil erosion," "Nebraska soil loss," "soil loss," "no-till."

Literature was reviewed for inclusion that contained current data and trends or demonstrated historical timelines of events and practices that have led to both positive and negative outcomes. Literature was considered at first due to parallel themes like sustainability and conservation, but then later discarded if those studies did not inform the guiding research question. Quality assessment of the included literature was then done by assessing the study's "internal validity," as described by Xiao & Watson (2017), checking to ensure that the study is free from methodological biases in its design, implementation, analysis, and conclusion that would encourage one set of results in favor of another set.

Literature was excluded if it was specific to a geographical area quite unlike Nebraska or was more than 20 years old. Literature was also excluded if the study was focused on using precision technology like soil moisture sensors, that are designed to improve the success rate of conventional agriculture practices and methods.

Literature was grouped into three specific themes: water quality, soil health, and Regenerative agriculture methods or practices. Literature was also included regarding Indigenous farming methods in acknowledgement that Regenerative agriculture principles and practices are not a recent, white invention but rather a return to the methods and Ways of Knowing that Indigenous communities have been using for thousands of years.

The semi-structured interview was conducted by the author of this paper, who holds a current certification in human subjects' research (CITI, 2023) as set by the requirements of the University of Nebraska-Lincoln. Anonymity was not a goal of the researcher, nor a concern of the participant farmer Graham Christensen, as he feels his identity and status as a fifth-generation Nebraska farmer and an established leader in the agricultural community, is a key factor in helping other Nebraska farmers adopt Regenerative agriculture methods on their farms. This is a belief Christensen has shared openly, saying in an earlier interview, "We want to be able to talk, Nebraskan to Nebraskan, and use our ability to be from here and a part of this culture to see…how our people in our state are part of the solution" (Harpel, 2021). His belief is supported by Sadowski et al. (2014), who found that "leaders take om the roll of experts and moral role models, and by doing so they can influence the rest of their respective groups to act in cooperative and morally good ways."

RESULTS

The results of this paper will be discussed by answering the guiding research question, "How can Indigenous/ Regenerative agriculture practices be implemented in Nebraska to improve and protect the health and quality of the State's soil and water resources, thereby enhancing the resilience of an economy dependent on those resources," through the lens of two case studies that examine the current implementation efforts on two Nebraska farms, as well as two recently-published studies that are specific to the implementation of Indigenous/Regenerative agriculture principles in Nebraska.

The first case study examined Christenson Farms Inc., an 800-acre previously-conventional-commodity crop farm located in the northeastern part of the state near Lyons, Nebraska. Homesteaded in 1867, this fifth-generation farm has been in continuous operation for 156 years and is now managed by the Christensen brothers Graham and Max. Self-described as a farmer, an entrepreneur, and a community organizer and activist, Graham believes that by working together, Nebraska's farmers are uniquely situated to mitigate many of the negative climate impacts caused by the over-industrialization of agriculture, while simultaneously creating economic prosperity for all Nebraskans.

In an effort to incorporate the principles and methods of Indigenous/Regenerative farming on their conventional corn/soybean farm, Graham and Max have crafted a long-term plan that includes the restoration and build-up of an area of land that has proven to be particularly susceptible to erosion and planted a shelter belt to protect old growth forest and shrubs. They are working to convert a portion land into permanent cattle pasture, and while they work towards the principle of bringing livestock back to the farm permanently, the Christensens have partnered with a neighboring farmer to graze his cattle on their land, an arrangement that benefits both farms and the cattle. One of the first Indigenous/Regenerative principles the Christensens adopted was reducing soil disturbance by ending the practice of tilling their fields 15 years ago; since then, they have nearly eliminated their use of chemical inputs like fungicides, insecticides, and herbicides. In an effort to establish a living root system, provide soil armor, and enhance biodiversity on the farm, the Graham and Max have planted hundreds of fruit, nut, and evergreen trees and put a variety of cover crops, including perennial rye, on 88% of their fields. A more detailed account of Christensen Farms Inc.'s motivations, successes and challenges can be seen below in Table 1.

MOTIVATIONS	WINS	CHALLENGES
• Combat climate change • Stop soil erosion • Increase soil's water holding capacity • Improve soil structure • Reduce chemical use • Public health • Water quality • Increase farm's resiliency to extreme weather events like drought and flooding	• Installed farm's first solar system in 2012, has transitioned farm to 65% solar, reducing the farm's dependency on fossil fuels • No-till for 15 years • Has begun planned cattle grazing • Cover crops on 88% of the fields, 700 of the 800 acres • Successful use of perennial rye as cover crop • 100% glyphosate-free cash crops • Eliminated use of fungicides • Eliminated use of insecticides • Reduced herbicide use • Non-GMO corn for 12 years • Non-GMO soybeans – 3rd year • 100-tree hazelnut orchard • 225 more trees planted April 2023 • Planted Maya Milpa Garden for increased biodiversity and pollinator habitat • Federal Environmental Quality Incentives Program (EQIP): helps integrate cows for rotational grazing	• Prevented from going to 100% solar due to state and local public power restrictions • Weed control in bean fields • No subsidies for legumes, small greens, organic crops • USDA Conservation Service Program: won't allow fall harvest of rye instead of soybeans or relay cropping • Federal EQIP won't fund the mobile fencing needed for rotational grazing • USDA Conservation Service Program: won't allow fall harvest of rye instead of soybeans or relay cropping

Table 1. An overview of the motivations, successes, and challenges faced by Christensen Farms Inc. in their pursuit of transitioning their farming practices away from conventional methods and towards an Indigenous/Regenerative agricultural model. Graham Christensen, interview April, 2023.

The second case study examines Ficke Cattle Company (FCC), a 600-acre, second-generation beef-cattle farm located in Pleasant Dale, Nebraska. Managed by the Ficke family patriarch Del, FCC specializes in a trademarked, composite breed of cattle that are bred to be fertile, functional, and efficient and thrive on a diet consisting entirely of grasses and forage. FCC is a non-irrigated farm that prioritizes the farm's ecosystem through focusing on soil health and water-retention capabilities that include a 95 percent reduction in chemical weed control and a 100 percent no-till approach (Ficke, n.d.).

Over the past ten years FCC has achieved some major, quantifiable successes like a 60 percent increase in pasture carrying capacity, a 4.3 percent increase in soil organic matter, and an 833 percent increase in soil water-holding capacity. These accomplishments have been realized due to the implementation of Indigenous/Regenerative principles like enhancing plant biodiversity on the farm and integrating animals. FCC cultivates a variety of cover crops including cereal rye, hairy vetch, peas, radishes, turnips, and various legumes which are allowed to mature before the cattle are brought into graze. Allowing the cover crops to mature has two primary benefits, first it fixes nitrogen in the plants' biomass so that as it decomposes it will be available in the topsoil for the future crops, additionally because the nitrogen is fixed and stable in plant biomass, it will not be able to leach down into the water table.

When the cattle are brought onto the field for grazing, they are enjoying premium cattle forage that produces a high-quality beef product. As the cattle graze, their manure provides a high-quality food source for the soil microbiome which supports the soil's health through increased organic matter content that has resulted in a high level of biological activity, including a robust earthworm population. As the earthworms move through the soil, they increase the soil's aggregate size and stability, water infiltration, and water-holding capacity. Soil on the FCC property has a recorded infiltration rate of 13.3 inches of water per hour, as opposed to the more typical rates of 1.43-2.13 inches per hour that are commonly found on Nebraska agricultural soils (Ficke, n.d.; Green Acres Cover Crops, 2016; UNL Extension, 2018).

The transition from conventional farming to an Indigenous/Regenerative model has proved to be both environmentally and economically sustainable for Ficke Cattle Co., resulting in profit margins that increased as the farm's Indigenous/Regenerative practices increased. The health of the soil has created unprecedented flexibility for FCC, allowing them to seamlessly go between cover crops, grazing, and row cropping. Dale Ficke estimates that when they plant corn on a field it yields a minimum of 70 bushels/acre, netting upwards of $200 per acre; if yields start to fall to an undesirable amount, they simple re-graze the field, restoring the soil's health and ability to bring yields back above the 70 bushel/acre mark (Green Acres Cover Crops, 2016).

DISCUSSION

The results of this study, both the qualitative and quantitative data, provide robust support for the viability and practicality of implementing Indigenous/Regenerative (IR) agricultural practices on farms in Nebraska. The improvement in soil health is palpable on the Christensen and Ficke farms, and furthermore, both farms have been able to maintain their economic viability during and after transitioning to IR methods and practices. In both the case studies and peer-reviewed literature, farmers explain that government rules and limitations are often their biggest barrier to successfully implementing IR principles, because any deviation from pre-approved crops or planting/harvest dates will negate the available crop insurance and subsidies that they depend on to survive the unpredictability of crop yields due to weather conditions/events and pest and disease occurrence.

Another barrier to implementing IR practices on Nebraska farms is that many farmers have become experts in conventional farming methods and are unsure what IR practices to implement first. This uncertainty can be around any of the Principles, such as: what cover crops are appropriate for their specific region and soil type (Context), how to prepare fields for planting with no-till methods (Minimize Disturbance), how to implement cover cropping when relay planting isn't allowed, and yet, without using relay planting there isn't enough growing season left after fall harvest for a cover crop to establish it's root system (Soil Armor), or how to incorporate perennials when those crops are excluded from a program's allowable crops (Living

Root System), or how to incorporate livestock into their current practices if they don't have a place or the resources to support livestock on their commodity crop farm (Integrate Animals), additionally they may lack the knowledge or labor capacity to plant fruit trees or take up beekeeping (biodiversity), or older generations that had knowledge about IR farming methods and techniques may passed away before they shared their knowledge about "old ways of farming" (Indigenous/Generational Wisdom).

A recent cover crop study (Koehloer-Cole et al., 2023) that examined the success of planting cover crops in rotation with corn and soy crops had a major methodological flaw because the study isolated one IR principle, Soil Armor [ie. cover crops] and found that cover crops often reduced the soil's nutrient and moisture content, thereby decreasing subsequent corn/soy yields. This is logical result/conclusion because the study failed to include a test field that employed additional IR principles that are needed as co-supports to cover crops like Integrating Livestock and Establishing a Living Root System. Livestock applies nutrients directly to the soil via manure deposits and perennial plant roots exude a primary food source for soil bacteria and worms. Soil biota and worms are the biggest creators of soil structure, which is the direct mechanism for increasing the soil's water-holding capacity. By neglecting the role of main contributors to soil productivity, they ensured that their study would reveal an often-negative impact from planting cover crops. None of the IR principles are meant to stand alone. The illustration of the IR Principles, as seen in Figure 6, are deliberately put in a circular formation because their relationship to each other is symbiotic, not linear or mutually exclusive.

The results from the water quality portion of this study give strong indication that a State-level mandate is needed to require well testing for any real estate transaction that includes a well on the property. The results of such a test would not serve to stop the sale, but rather to ensure the buyer's right to know if the water supply on the real estate is safe for consumption, or if it will require the installation of an often-expensive water treatment system. This is not unlike a housing inspection that is provided before the sale of a house, it is a measure intended to protect the buyer's right to know exactly what they are buying before they invest thousands, or even hundreds of thousands of dollars in that real estate.

At the Federal level greater care and effort needs to be taken when designing incentive programs to ensure that they will be accessible to ag producers. An example of a well-intended but inaccessible program is the Federal Environmental Quality Incentives Program that provides funding for rotational grazing but doesn't cover the fencing needed by the producer to actually implement rotational grazing (Christensen, 2023).

SUMMARY & CONCLUSIONS

This study sought to establish the current state of soil, water, and human health in the state of Nebraska by comparing scientific and governmental assessment levels to current scientific definitions of soil health, water quality, and human health. Finding the state of all three to be in substantial misalignment with current scientific definitions of health and quality, this research sought to examine how can Indigenous/Regenerative agriculture practices could be implemented in Nebraska to improve and protect the health and quality of the State's peoples, soil, and water resources, thereby enhancing the resilience of an economy dependent on those resources.

The results of this study showed that not only is it possible for Indigenous/Regenerative principles to be successfully implemented in Nebraska, but those principles *are already* being used by a small sector of innovative agricultural leaders who are seeing positive results and benefits at both the personal and community level.

While these IR frontrunners are having successes, they are also experiencing challenges in access and implementation of IR methods and practices. Many of these barriers to full implementation come down to restrictions of practice at the political policy level, specifically in regard to limits imposed by federal crop insurance and subsidies. Other major barriers were around the lack of funds and or labor necessary to learn IR methods, to purchase needed supplies, or have enough growing season left to allow a crop's roots to establish themselves in the soil before the harsh winter weather sets in.

Further study is recommended for what meaningful changes can be made to the federal crop insurance and subsidy programs, that will allow agricultural producers more flexibility and autonomy in what crops they plant each year, as well as when the producer chooses to plant their crops. Additionally, further study is recommended to examine what meaningful incentives the State of Nebraska could offer to agricultural producers to minimize their risk of implementing IR principles and practices on their farm.

In light of current scientific knowledge and advice, it is the opinion of this author that the time has come for Nebraska to more-closely control and limit the use of chemical inputs that are known to be hazardous to the health of humans and animals including birds and pollinator insects, as well as inputs that further degrade the quality of the soil and water. After decades of monitoring by state and local agencies including Nebraska's Natural Resource Districts and Extension offices, and in light of current scientific research, there is no question about what is causing the State's unusually high rates of birth defect and pediatric cancer incidents, or the State's current extreme soil erosion rates. It is time for the governing bodies to stop handing off the baton of blame and begin taking drastic steps to stop the damage to the people, land and waters of Nebraska, and begin bold and sweeping remediation efforts focused on reducing cancer and birth defect rates through rural water treatment options, rebuilding the soil's health and ending the agrichemicals pollution being funneled into the State's ground and surface waters.

In order for meaningful changes to be made in the current agricultural complex, stakeholder groups must include the diverse group ag producers in Nebraska that are directly impacted by changes, incentives, and restrictions to agricultural programs and norms. Furthermore, it is *imperative* that the current power structures acknowledge the historical and modern contributions and knowledge of Nebraska's Indigenous communities by actively seeking to include them in all stakeholder groups and remediation/solution efforts.

This study has fanned the flame of my pursuit towards justice for marginalized groups in Nebraska, and around the world. It has served to further inform my perspective of local and global communities and food security, and provided me with a more robust, science-based, reciprocal systems approach to the inextricable connectivity that exists between humans, animals, and the Earth. The concept of sustainability has become a core motivator and guiding value as it is taught by Indigenous communities throughout the world, considering in every decision, "Will this be to the benefit of the seventh generation?" (Krznaric, 2020, p. 86).

In researching and writing this paper I have learned that I am capable and deserving of a seat at the table; that I can trust my mental, physical, emotional, and spiritual strengths and intuitions. It has strengthened my resolve to build a bigger table and always come a'toting an extra chair or two.

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