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Feasibility Discussion of Potential Carbon Offsetting Options for Nebraska

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Contents

1. Background and Introduction

Conversations around carbon offsetting have proliferated in the past two decades from feasibility, relevance, qualification to the differing ethical perspectives across relative value systems. The carbon offsetting initiative was first started in 1989 in an agriforest in Guatemala of Central America, as an effort to offset carbon emissions from a coal- fired power plant that was being built in Connecticut [1]. Stimulated by policy and corporations expressing their commitment to carbon neutrality, the brief history of carbon offsetting involves three key development phases including the 1995 Kyoto Protocol, the 2005 European Union Emissions Trading Scheme and the 2015 Paris Agreement [2].

Carbon offsetting basically refers to a set of activities (which might have not otherwise taken place) that are aimed at mitigating the damage done when an equivalent amount of greenhouse gas emissions is released into the atmosphere by activities such as burning fossil fuels [1]. In other words, it is the reduction in Greenhouse Gas Emissions (GHGs), or an increase in carbon storage that is used to compensate for emissions that occur elsewhere. These offsetting activities could be undertaken by an individual, a company, a nonprofit organization or a government entity [3,4]. Included in the definition of carbon offsetting are emissions of carbon dioxide, methane, nitrous oxide, perfluorocarbons and hexafluoride among other greenhouse gases [3]. Given the context of this discussion, all these are regarded and referred to here as carbon emissions.

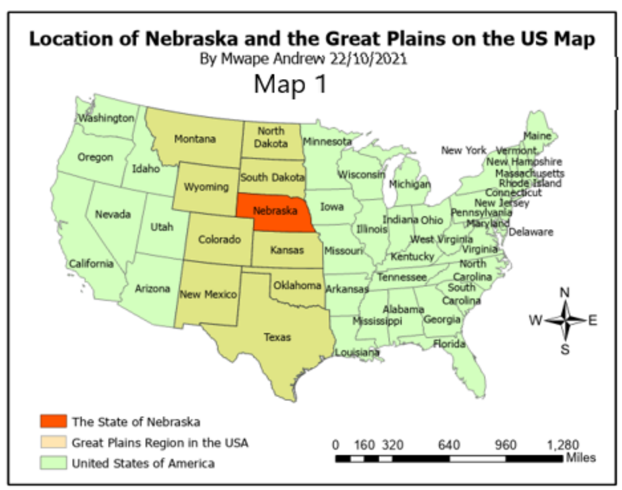
The unit measure of carbon in this discipline is called a carbon credit and the general trading of carbon credits is referred to as carbon marketing [4]. Generally, there are two types of carbon markets: the regulatory compliance and the voluntary market. The regulatory compliance market, also referred to as the mandatory carbon market is usually used by governments and companies that must account [5] for their Green House Gas (GHG) emissions. With this type of market, emission reduction regulations are mandatory in the respective country or region by law (for instance, carbon tax in South Africa). Unlike the regulatory compliance markets, voluntary markets are not mandatory[6] but are based on the voluntary will of individuals or corporate entities who feel the need to offset their carbon footprint [4]. Thus, carbon offsetting creates carbon credits (the right to emit) which are then traded on the carbon market.

To ensure ethical prudence and accuracy in the measurement of emissions and the integrity of transactions, there are several standards, specifications and mechanisms that determine and facilitate the certifications of carbon offsetting projects and the ability to participate and trade. Among the common ones in the US include the American Carbon Registry, Gold Standard, Climate Action Reserve and the Verified Carbon Standard among others [7].

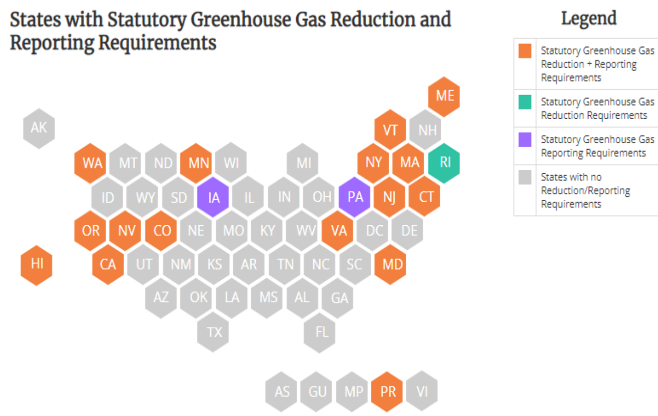
Given this background, as an individual or corporate entity seeking to pursue opportunities to invest or engage in carbon offsetting projects, it is important to know and understand the carbon offsetting options available and their feasibility for the area of interest. This article discusses the feasibility of carbon offsetting options in the state of Nebraska, USA considering the geologic features, location, and the natural resources in Nebraska. Included in the discussions also, are associated set up costs, carbon capture and storage efficiency of the offsetting options presented.

1.1. About Nebraska

Characterized by a high plateau of grasslands, the towering dunes of the Sandhills and the panhandle's dramatic rock formations, the state of Nebraska is a Midwestern state in the northern Great Plains of the United States of America (Map 1) [8]. According to the Koppen Climate Classification, Nebraska is classified as Dfa (hot summer climate) and is administered by the High Plains Regional Climate Center (HPRCC) [9]. With an estimated population of 1,961,504 as of 2020, Nebraska sits on expanse of 77,358 mi^2, with over 90% of the land under private ownership [10,11].



In terms of economic positioning, Nebraska is described as a transitioning economy since World War 2. However, the state is mostly characterized by the manufacturing, agricultural, processing, and transportation industries [12].



According to a study by *(*Eric r Holley and Adam j Liska*),* Nebraska's net emissions were found to have increased from 56.2 million metric tons of carbon dioxide equivalents (36 MMtCO_2e) in 1990 to 87.4 MMtCO_2e in 2016 with 55% coming from agriculture, 23.7% from energy generation (due to the use of coal) and 21% from other industries with an average increase rate of 1.21 MMtCO_2e per year [13]. As of 2021, the state of Nebraska has not committed to any executive action to document, report and reduce emissions to meet the 26% projected emission reduction target by 2025[14]. Given this background, it is therefore important to explore options that will highlight the feasibility of emission reductions in the state of Nebraska to encourage investment and participation through both the executive action as well as individual efforts (especially given that over 90% of the land in the state is privately owned). It is important to mention here that carbon offsetting is not the only ultimate solution to ensuring carbon neutrality, rather, a collective combination of both offsets and emission reduction strategies from individuals, the state agencies, and private organizations will ensure Nebraska's carbon Neutrality. In other words, reduce what you can, offset what you cannot.

1.2. Carbon Offsetting Options

There have been continuous improvements to the already existing and development of new ways to offset greenhouse gas emissions. Depending on the intention, mode of action and resources needed, the reduction of atmospheric greenhouse gas emissions can be classified into two[15] categories. The first involves offsets from managing and reducing carbon footprint through production process management, clean and efficient use of resources and the implementation of policies that promote the reduction of current and future emissions. For instance, emission caps placed on companies and/or countries[16]. The second category involves projects and programs established to capture greenhouse gas emissions that are already in the atmosphere. Examples of emission offsetting options in this category include, regenerative agriculture [17], reafforestation or forest management, direct air capture, clean energy projects. The latter is what will be discussed in this report.

1.2.1. Regenerative agriculture

Regenerative agriculture encompasses a wide range of crop farming and rangeland management practices that are aimed at restoring and sustainably managing soil health to foster the storage and sequestration of carbon emissions by the soil[17]. In this option, farmers and landowners are paid under the voluntary carbon markets to engage in agricultural practices that reduce GHG emissions from agricultural equipment, as well as enhance the capture and storage of carbon emissions by the soil. The quantification varies across regions depend on the soil types, regional climate and the actual agricultural practices involved. Agricultural practices that qualify for carbon offsetting can be classified into four categories including the following:

- **Conservation agriculture:** Farmers engage in reduced or no till, introduce cover crops, minimize residue mulching, engage in complex crop rotations, and the use of drip fertigation among other activities[18].

- **Integration of crops and trees with livestock:** Instead of only engaging in crop or livestock farming alone, farmers integrate the two and engage in agricultural practices that promote the storage of soil carbon. Some of these activities include managed grazing, agroforestry, ley farming, fodder trees, silvo-pasture and the use of live fences.
- **Restoration of soil health:** Soil health is critical to soil carbon sequestration and storage, in this category, agricultural practices that enhance soil health and promote soil carbon storage are used to merit carbon credits. Some of these practices include cropland retirement i.e., under the Conservation Reserve Program[19], afforestation of denudated hills and wetland restoration due to agricultural practices[20].
- **Re-carbonation of the terrestrial biosphere:** in this category, farmers improve soil biomass by either introducing organisms or plants that enhance the sequestration and storage of soil carbon. The introduction of biochar into the soil also enhances the capturing capability and storage of atmospheric carbon emissions into a more stable form and at the same time, improve crop yield[3].

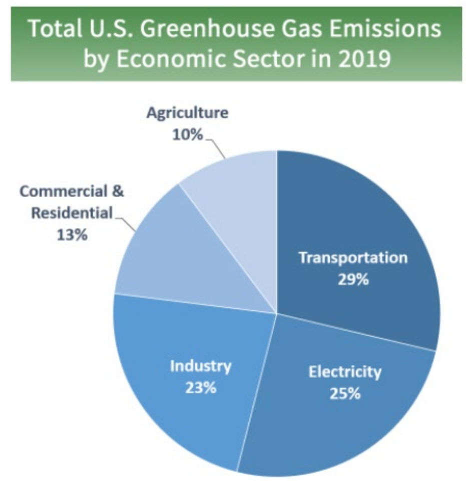
1.2.2. Reafforestation and/or forest management

Trees are said to be among the best atmospheric carbon capturing sinks[21]. According to the US Forest Service, at least 866 million tons of carbon is sequestered by forests, which is around 14% of the total US emissions per year[22,23]. In forest carbon sequestration, trees capture carbon emissions from the atmosphere and locks it up in the tree. The capturing and storage of emissions in forests varies across tree species and age. In terms of permanence, when trees are cut, part of the stored carbon is released into the atmosphere, however, managed forests ensure the protection of trees and thus, the long-term storage of emissions.

In this option, individuals or entities interested in carbon credits can either manage an already existing forest or plant new trees and employ forest management activities that will maximize the capturing and storage of carbon in the forest. Emission credits from this emission offsetting option are often traded on the voluntary carbon market.

1.2.3. Energy

In the US, the energy sector contributes about 25% of the total greenhouse gas emissions, ranking second from transportation with 29% [24]. Much of these emissions can be attributed to the use of fossil fuels, mostly coal and natural gas. In this option, clean energy generation projects (such as wind and solar) that help avoid and/or reduce greenhouse gas emissions can participate in carbon marketing. Since power supply flows through the grid, the energy generated though these projects are fed into the grid. Because of the renewable aspect to it, Renewable Energy Credits (RECs) are given for every 1MWh supplied[25,26]. When customers are buying electricity, they can voluntarily buy RECs together with electricity to offset their energy carbon footprint [25].



1.2.4. Direct air capture

Direct air capture is a technological method that uses chemical reactions to capture emissions (Carbon dioxide CO_2) from the air[27]. The basic principle of this option is that when the chemical comes in contact with air, the chemical selectively reacts with CO_2, leaving the rest of the air in the atmosphere. Usually, the captured CO_2 is either locked up in the earth's geologic systems or improved for other uses such as in the lab. Direct Air Capture offers a more permanent storage[28] option compared to forestry and agriculture. Setting up this technology involves significant investment capital and places significant demands on energy and water use for its efficient operation[29]. However, compared to other carbon sequestration options like forestry and agriculture, Direct Air capture requires less land per ton of carbon removed, ensuring reduced food insecurity and ecological disturbance. In this option, the CO_2 removed from the atmosphere is quantified and qualified to trade on the voluntary or compliance markets.

2. Discussion

Decisions about what carbon offsetting options are feasible vary depending on the needs and expected outcomes. If the purpose of participating in carbon offsetting or marketing is to reduce greenhouse gasses and ensure ecological sustainability without compromising food security, factors such as investment costs, retains, and ethical considerations would not matter to a larger extent. On the other hand, if the sole interest is profit making, these factors might require an objective scrutiny of the available carbon offsetting options and their feasibility to yield meaningful retains. However, irrespective of whether the sole objective is profit making or not, the efficiency and investment factors of each offsetting option cannot be overlooked. This said, the highlighted carbon offsetting options are discussed in terms of their relative estimated investment capital and emission offsetting efficiency in the context of the state of Nebraska.

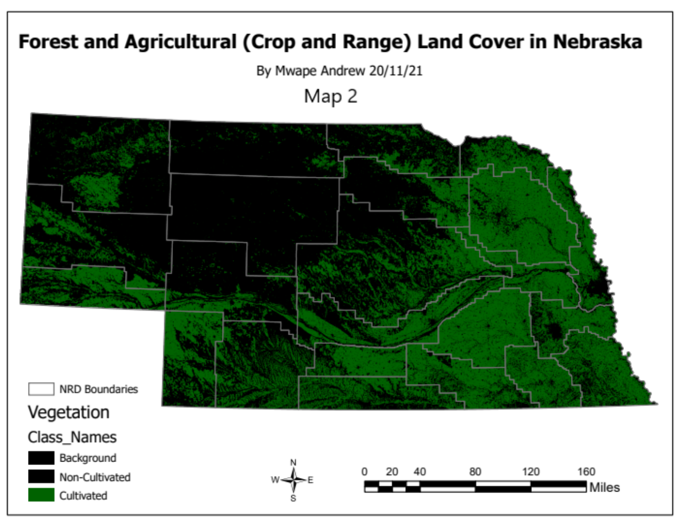
2.1. Regenerative agriculture and Forest Management

In June 2021, the Growing Climate Solutions Act of 2021 cleared the US Senate. The Act is meant to encourage and support farmer, rancher and private forest landowner participation in carbon marketing [30]. Although the act is yet to be enacted, Nebraska seems to have a growing interest base of vendors and farmers, some of whom, are already practicing regenerative agriculture and trading on the voluntary market. Examples of vendors present in Nebraska include Indigo Ag and Terra Ag, among others.

Compared to Direct Air Capture, Regenerative Agriculture captures and locks up carbon emissions over a long period of time. In terms of permanence, it is the least efficient option because carbon is stored in the upper layers of the soil, any disturbance to the soil results in the loss of stored carbon. However, Regenerative Agriculture has more potential to reduce greenhouse gas emissions through the reduced use of fossil fuels from reduced tilling and carbon based fertilizers[3]. In terms of efficiency, it is estimated that croplands have estimates of 0.2 to 0.6 tons of CO_2 per acre per year and 0.12 to 0.52 tons of CO_2 per acre per year for rangeland depending on the soil type and conservation practices used[31]. Emission offsetting/reduction from Regenerative Agriculture requires significant amounts of land to make meaningful earnings for the farmer and CO_2 tonnages to be sequestered. Often, these projects are caried out on already cleared lands and mostly, fields practicing active tilling. Practicing Regenerative Agriculture may come as an opportunity cost on food security and farmer retains, however the past few years have seen improvements in carbon prices on emissions from agriculture to encourage more farmer participation.

The cost of setting up farmland for Regenerative Agricultural purposes varies depending on factors such as whether the land is already being used for farming with active tilling or not, land ownership, soil health and activities to be employed. If the land is already on active tilling, it may require more time and resources to stabilize the soil and build enough biomass to enable carbon capture and storage [30]. If the land is owned by the farmer (not rented), production costs will be lower because there will not be rental costs.

For Nebraska, landownership might raise production costs, as significant amounts of agricultural land are owned and leased out by absentee landowners.

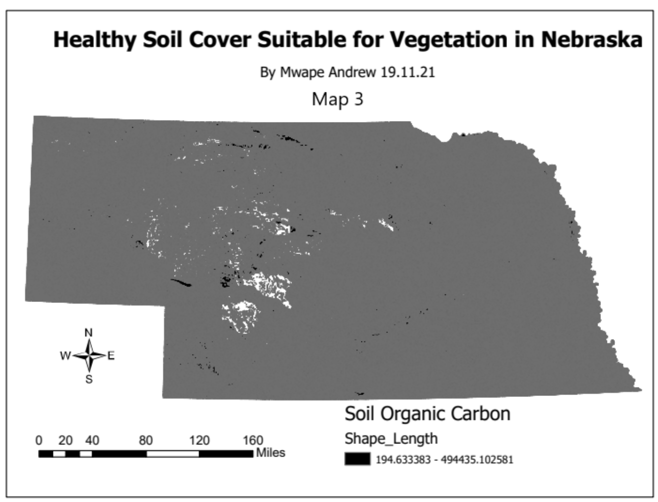


In the case of Nebraska, characterized by 45.2 million acres of agricultural land (both crop and rangelands) as shown in map 2, a collective participation in regenerative agriculture would amount to significant avoided and reduced emissions of over 27.12MtCO_2 per year [10,31].

2.2. Reforestation and/or Forest Management

Forestry offers the most reliable natural way of capturing and storing greenhouse gas emissions. Trading with emissions from forestry or forest management can happen either from managing an already existing forest or planting new trees (reafforestation). Indigenous species and older trees sequester more carbon than younger trees, thus the reason to manage forests so that trees are protected from exploitation [22]. In the US, forest land (Including urban and wood forests) represent the largest carbon sink, offsetting more than 16% of the total greenhouse gas emissions per year [22], with an estimated carbon storage of about 71.67tCO_2 per acre [32]. However, there is growing concerns of whether this will remain a reality for the coming decades due to landcover changes across the US.

The state of Nebraska is characterized by about 3 million acres of forest and non-forest land with trees. Investments in planting trees and/or managing the already existing forests would merit participation on the voluntary markets. This may include planting new trees in areas that have recently/ long been cleared or assisting the regeneration of natural trees. Map 3 shows the soil organic carbon distribution across the state of Nebraska. The map shows that, even though the landcover map (Map 2) for the state shows green, much of it is crop and grasslands which have limited capacity to capture and store carbon. This then shows the need for more forest management projects that will allow a buildup of soil organic carbon for an enhanced carbon emission capture capacity and storage. The cost of setting up forestry projects depend on the climate; soil type and the survival power of the tree species being planted.



2.3. Energy

According to the Nebraska state profile and energy estimates by the US Energy Information Administration (EIA), Nebraska obtained 51% of its in-state electricity net generation from coal, 24% from wind, 17% from nuclear and about 8% from hydropower and natural gas in the year 2020 [33]. This just goes to highlight the state's carbon footprint from energy generation. In the past few years, there has been notable efforts, developments and successes for solar and wind energy projects (such as the Kimball Wind and the Kozad solar Projects [34]). The cost of setting up wind turbines depends on the scale and desired energy output. On average, setting up a commercial wind turbine with a 2-3MW electricity output will cost between $2.6-$4 million [35]. For solar energy, setting up a 3MWh power output project in the US will cost an estimate of $600,000 to $650,000 [36]. Because of the growing demand for clean energy and concern for emission reduction, set up costs for renewable energy projects have been, and are expected to go down. This is because of the incentives (i.e., tax) that are given for such projects. Also, the growing concerns have triggered investments in the production industry of clean energy plant equipment (solar panels and turbine blades), balancing up the production-demand ration.

Given the climate (extreme summer and winter), and landcover characteristics of Nebraska with open and flat land, the state holds an advantage for investments in solar and wind power generation. According to the National Renewable Energy Laboratory (NREL), Nebraska is ranked 13th in the nation with the greatest potential from solar power [37]. Compared to direct air capture, solar and wind energy projects need more land and comes with more ecological and environmental concerns. For instance, Wind turbines are said to interfere with the diversity of bird species, while solar farms come with significant land cover changes that might threaten food security and interfere with groundwater recharge rates due to the loss of grasslands and soils disturbances [38].

2.4. Direct air capture

Direct air capture, a negative emission technology is one of the most efficient and expensive options for removing greenhouse emissions from the atmosphere. Even though it arguably requires less land to set up, operational costs (of about \$600/tCO_2[29]) are high due to the high energy and safety demands of the technology. However, scenario studies have shown how this conventional operation cost can be reduced to about half ≤\$300/tCO_2[28] through the exploitation of low-temperature heat from geothermal and nuclear power plants. In terms of efficiency, the Direct Air Capture technology is one of the most efficient and effective ways of removing CO_2 emissions from the atmosphere with an estimate of about 1MtCO_2/year for an average plant. This option has the short-term CO_2 removal advantage and also, the permanence advantage in terms of storage, compared to other options (when atmospheric CO_2 is captured and locked up in the deep geologic systems of the earth). In terms of its development feasibility in Nebraska, the technology can be set up near geothermal power plants to take advantage of the reduced energy costs from geothermal energy. Even though the state of Nebraska does not have a lot of large-scale geothermal energy plants, the few individual plants can be used for the development of direct air capture projects that would even lead to a significant reduction of pipeline transportation of emissions.

Having discussed the potential carbon offsetting options for the state of Nebraska, table 1 shows general ranking summaries of these options in terms of their relative capacity to capture and store GHGs, initial set up (and operational costs) and their land-use change implications.

Table 1: Ranking summaries of carbon offsetting options

Carbon offsetting option	Efficiency ranking (GHG capture and storage capacity)	Set-up cost ranking (Per tCO_2 captured)	Ranking of land-use change demand (Per tCO_2 captured)
Direct air capture (DAC)	1	1	4
Reforestation and forest management	2	4	2
Energy generation	3	2	3
Regenerative agriculture	4	3	1

3.0. Conclusion

Highlighting the advantages and disadvantages of carbon offsetting options in the context of the state of Nebraska, this discussion shows that the choice and decisions about which option is better than the other depends on the interests at play and expected outcomes of the participation in carbon markets. However, irrespective of the motive to engage in emission reduction projects for carbon marketing, factors such as cost, and project efficiency can never be overlooked. Given the options discussed in this report, Nebraska has a lot of potential for carbon offsetting or emission reduction projects that would not only reduce and remove greenhouse gases from the atmosphere but also, provide economic benefits such as employment creation and healthy food production in the state.

As a way of emphasis, carbon offsetting is not the only ultimate solution to ensuring carbon neutrality, rather, a collective combination of both offsets and emission reduction strategies from individuals, state departments and private organizations will ensure Nebraska's carbon Neutrality. In other words, reduce what you can, offset what you cannot.

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