WHO CARES? A STAKEHOLDER ANALYSIS OF NITROUS OXIDE EMISSIONS FROM AGRICULTURAL SOILS

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I. INTRODUCTION

Nitrous oxide, the chemical species of NO and NO_2 and jointly referred to as NO_x, a recognized greenhouse gas, is a scientifically accepted contributor to global warming trends and climate change. Investigations into sources of nitrous oxide have indicated that agriculture, specifically corn growing systems, impact the amount of nitrous oxide released into the atmosphere. As agriculture is directly impacted by climate change, regulation of nitrous oxide emissions from agricultural soils invites the development of complex policy solutions by involving a wide cross-section of unique stakeholders with discrete interests. This note will first examine the relevant science, followed by a discussion of the current policy and common law implications, and finally, present an analysis of stakeholder interests using the Iowa corn market from production to sale as an example to illustrate various interests.

II. NITROGEN CYCLE AND NUTRIENT FRAMEWORK

A. Atmospheric Nitrogen

In order to appropriately discuss various stakeholder interests in nitrous atmospheric emissions from agricultural soils involving the growing of corn, a basic understanding of the nitrogen cycle and its relevant processes must be developed. Nitrogen, also known as reactive nitrogen molecules, cycles through the atmosphere as various reactive and nonreactive species, all the while undergoing fixation and conversion processes.[1] In analyzing the fate of reactive nitrogen, it is estimated that "50% is removed by harvested crops, 23% is leached [nitrogen], 6% is volatilized as [ammonia], and 6% is released into the atmosphere as [nitrous oxides]."[2] It is estimated global nitrous oxide emissions occur in the amount of 45.9 Tg N $year^{-1}$ or 45.9 trillion grams of nitrogen per year.[3] Assuming there are no other anthropogenic, or human created, sources other than fossil fuel combustion, biomass burning, and agriculture, it can be estimated that 2.6 Tg N $year^{-1}$ are emitted from agricultural practices, which includes both livestock and cropping practices.[4] This amount of reactive nitrogen can have dual effects: it can increase radiative forcing or increase the change in energy in the atmosphere through the production of nitrous oxide, and it can also have a cooling effect through the formation of aerosols and subsequent decrease

1. *See* DAVID USSIRI & RATTAN LAL, SOIL EMISSION OF NITROUS OXIDE AND ITS MITIGATION 49 (Springer 2013) (ebook).

2. *Id.*

3. *Id.* at 51.

4. *See id.*

in stratospheric ozone. [5]

The process becomes more complicated as soil nitrogen is an abstract value which is constantly exiting and entering the soil, as well as changing in chemical form.[6] A brief description of each relevant process may be illustrative of the broad and overlapping environmental systems.

1. Nitrogen Fixation

Nitrogen fixation is the process by which atmospheric nitrogen (N_2) is converted to ammonium (NH_4^+) or other forms of reactive nitrogen.[7] This can occur via lightning, fertilizer production, or high temperature combustion fixation.[8] Perhaps of more relevant interest is the process of biological nitrogen fixation. This process converts inert atmospheric nitrogen (N_2) into ammonia (NH_3) through the use of bacteria, specifically, those which utilize nitrogenase, an enzyme which essentially completes the conversion process.[9] It is typically most favorable for plant nutrition if this bacteria can form a symbiotic relationship with the roots of plants.[10] When this relationship is symbiotic, the plant provides carbon to the bacteria and the bacteria in turn provides nitrogen to the plant. [11]

2. Nitrification

While the nitrogen cycle is in constant state of flux between all of its sub-components, it is helpful to examine the nitrogen cycle in terms of the process by which nitrogen is converted into useable species for purposes of plant nutrition. Nitrification follows fixation and is the biological oxidation of reduced nitrogen in the form of ammonia (NH_3) or ammonium (NH_4^+) to nitrite (NO_2^-) and then to nitrate (NO_3^-).[12] This conversion is necessary for plant development and growth as nitrates are readily absorbed by the plant for its nutritional needs.[13] As discussed later in more detail, these nitrates are subject to denitrification; however, nitrates are readily and abundantly available in soil, as fertilizers

5. *Id.* at 56.
6. *Id.*
7. *Id.* at 37.
8. *Id.* at 37.
9. *Id.* at 39.
10. *Id.*
11. *Id.*
12. *Id.* at 66.
13. *See* Guohua Xu et al., *Plant Nitrogen Assimilation and Use Efficiency*, 63 ANN. REV. PLANT BIOLOGY 154-56 (2012).

applied in ammonium form are quickly reduced to nitrate.[14] However, this limits the effectiveness of the fertilizer and causes concern for most stakeholders, such as farmers, environmentalists, and industry professionals.[15] It is estimated that "[n]early 90% of all added N fertilizers are applied in the NH_4^+ form, which is mostly nitrified [to nitrate form] within four weeks after application."[16] The bacterial processes within soil which complete nitrification are scientifically complex, and it is most important to recognize that the bacteria in question are affected by a number of variables such as partial pressure of oxygen, concentration of ammonium, ammonia or both, and pH of the soil—all of which are affected by the presence of plant roots in the soil.[17] The presence of the plant roots also provide organic material which is used as nutrients for these organisms to complete the conversion process.[18]

3. Denitrification

Denitrification is the reduction of nitrate or nitrite to nitrous oxides and inert nitrogen gas.[19] It is estimated that soils generally denitrify approximately 124 Tg N per year or thirty-five to forty percent of total nitrogen from land-based reactive nitrogen.[20] Though this statistic is not further simplified to delineate agricultural soils from non-agricultural soils, in systems that receive high inputs of nitrogen, there is an increase in denitrification and a subsequent increase in nitrous oxide emissions.[21] This process can be achieved through biological processes or chemical reactions,[22] however, the biological conversion is favored when organic matter, anaerobic (or oxygen limited conditions) conditions and nitrates or nitrites are present.[23] There is an argument to be made that denitrification is a beneficial process, however, it is generally accepted in the agricultural and environmental communities that denitrification has detrimental effects,[24] as "[b]etween 0 and 25% of fertilizer N can be lost as [nitrogen gas] or [nitrous oxide]."[25] Nevertheless, those examining the relevant science from a

14. USSIRI & LAL, *supra* note 1, at 66-67.
15. *See id.*
16. *Id.*
17. *Id.*
18. *Id.* at 68.
19. *Id.* at 75.
20. *Id.* at 76.
21. *Id.* at 73.
22. *Id.* at 76.
23. *Id.* at 77.
24. *Id.*
25. *Id.*

perspective concerned about water quality may argue that the removal of nitrates from the soil is a means to protect ground and surface waters from contamination.[26] The scientific counter position is that denitrification can produce intermediate nitrous oxide gases in sporadic amounts, thus, contributing significantly to ozone depletion and climate change.[27]

Denitrification occurs via a bacterial process, and a single bacteria species is capable of acting as a denitrifier, which is facilitated through a series of four enzymes, but it is possible that a single bacteria species may not contain all four enzymes needed for complete denitrification—i.e. nitrous oxide to inert nitrogen.[28] Therefore, it may be of necessary interest to promote soil conditions where a variety of bacteria can survive in order to reduce nitrous oxide emissions.[29] It is important to note not all bacteria or microorganisms "can reduce all possible [nitrous] oxides . . . . [For example, s]ome microorganisms produce [inert nitrogen gas], while others produce only N_2O."[30] The scientific variables affecting denitrification are well-known,[31] though research continues to question the implications of agricultural land management practices.[32] The use of nitrogen fertilizers has been shown to increase N_2O emission rates as fertilizer application rates increase.[33] When coupled with poor drainage, high application rates can lead to higher denitrification activity, and these high rates can also affect soil pH.[34] The type of fertilizer used can also impact the rate of denitrification as organic fertilizers have available carbon sources that promote the bacterial conversion of nitrous oxides into other species.[35]

B. Nutrient Considerations

Nitrogen is of particular concern when discussing factors affecting corn growth and health, as nitrogen is essential to obtaining high levels of overall plant nutrition and yield output. Nitrogen fertilizer is one of the most costly inputs to corn production and is often evaluated for efficiency based on a scheme, which spans the growing season.[36] Nitrogen use efficiency (NUE) is defined as

26. *Id.* at 78.
27. *Id.* at 78-79.
28. *Id.* at 79.
29. *See* KRISTIN OHLSON, THE SOIL WILL SAVE US 84-85 (2014).
30. USSIRI & LAL, *supra* note 1, at 79.
31. *Id.* at 81-83.
32. *See id.* at 83.
33. *Id.*
34. *Id.*
35. *Id.*
36. Jason DeBruin & Steve Butzen, *Nitrogen Uptake in Corn*, DUPONT PIONEER, https://www.pioneer.com/home/site/us/agronomy/library/n-uptake-corn/#timing (last visited

the partial nitrogen balance or amount of nitrogen exported from the field in the crops themselves, divided by the amount of nitrogen applied.[37] Nitrogen application rates have remained virtually constant at 140 pounds (lbs) of nitrogen per acre since the 1980s, though yields have continued to increase.[38] These improvements in NUE are likely due to better hybrid genetics and agronomic practices.[39] This nitrogen uptake occurs in two phases, pre-flowering and post-flowering.[40] The availability of nitrogen in the pre-flowering phase is critical to development of the ear, including number of kernels and kernel size.[41] DuPont Pioneer conducted a study in 2012, which indicated in cases where there is a low amount of nitrogen available in the post-flowering phase, the plant cannot fully support grain development.[42] The remaining required nitrogen comes from "[nitrogen] remobilized from the vegetative tissues (stalk, leaves, husks, and cob)," and a maximum of 63% of this leaf nitrogen could be remobilized to support grain development.[43] This information translates to a demand for nitrogen at all stages of the growing season, and thus, impacting the emissions of nitrous oxide from agricultural soils. "Losses due to volatilization and leaching may range from 0 to 50 lbs/acre/year depending on the growing environment."[44] With high-yield demands required for most areas of the United States and specifically Iowa, there is an increased importance of late-season nitrogen, and it is logical to develop a nitrogen-application strategy that meets the crop demand while limiting losses and maximizing N uptake.[45] DuPont Pioneer recommends the following strategy:

> Application of 70% of the total seasonal N requirement prior to planting should provide sufficient N for vegetative growth. Applying the remaining 30% as late during the growing season as equipment allows would likely be advantageous most years. This planned late application also provides the option of replacing N lost due to high rainfall conditions typical in May and

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Apr. 26, 2016).

37. HARTER ET AL., NITROGEN FERTILIZER LOADING TO GROUNDWATER IN THE CENTRAL VALLEY FREP PROJECT 11-0301, http://groundwaternitrate.ucdavis.edu/files/173452.pdf (last visited Apr. 11, 2016).

38. DeBruin & Butzen, *supra* note 36.

39. *Id.*

40. *See id.*

41. *Id.*

42. *Id.*

43. *Id.*

44. *Id.*

45. *See generally id.*

June in many locations.[46]

As this discussion of nitrogen application and uptake efficiency indicates, the dependency of corn production on nitrogen is not only high but is incredibly complicated and relies on several factors, which inevitably vary from year to year. Regardless, there is a large amount of nitrogen input to soils that has been shown to contribute to the emission of nitrous oxide emissions from agricultural soils. This high input of nitrogen to soils, for the purpose of this paper, is done through fertilizer application in corn growing systems and provides the foundation for the concern surrounding fertilizer use and its environmental impact on air pollution and quality.

C. Water's Impacts and Interactions

Water quality is inextricably connected to air quality. The increase in anthropogenic nitrogen present in the nitrogen cycle is not only linked to air pollution but also to eutrophication of coastal waters and the creation of hypoxic zones.[47] Specifically, it is the cycling of nitrogen from agricultural soils to atmospheric nitrogen and its subsequent conversion from nitrous oxide to nitric/ nitrous acid through denitrification and lightning that impacts water quality.[48] Nitric or nitrous acid is a chemical compound, which more readily leaches into groundwater, rivers, and oceans.[49] The increase in reactive nitrogen from anthropogenic sources contributes to a variety of environmental effects such as: "noxious algal blooms, increase in water turbidity, [and] shifts in food webs and loss of fish stocks."[50] It also naturally follows that as more reactive nitrogen is present in surface waters, there is a greater increase in atmospheric emissions of nitrous oxide from these surface waters.[51]

Approximately 48 Tg of N per year leaches from soils into rivers, meeting estuaries, and then finally, the ocean.[52] As previously discussed, the primary contributor of reactive nitrogen in the soil is agricultural practices.[53] Therefore, there exists a generally accepted causal link between agricultural practices and reactive nitrogen present in not only atmospheric, but water systems as well.[54] The inference that reduction in reactive nitrogen present in agricultural soil will

46. *Id.*
47. *See* USSIRI & LAL, *supra* note 1, at 29.
48. *See id.* at 43-44.
49. *See id.* at 31.
50. *Id.* at 50.
51. *See id.*
52. *See id.* at 52.
53. *See id.* at 53.
54. *See id.* at 52-53.

reduce air and water pollution is one that follows logically from an understanding of the nitrogen and water cycles.[55]

D. Overlapping Considerations

Though this note is focused on a discussion of nitrous oxide emissions from agricultural soils, it would be imprudent to fail to acknowledge the synergistic effect of nitrous oxide emissions and soil carbon. There is a growing trend in understanding that soil carbon and ultimately, soil health, is linked to climate change.[56] Healthy soil is estimated by scientists to contain "as many as 75,000 species of bacteria" in a single "teaspoon, along with 25,000 species of fungi, 1,000 species of protozoa, and 100 species of tiny worms called nematodes . . . ."[57] These microorganisms, as previously discussed, play an important role in the nitrogen cycle, but also serve to connect plants to their necessary nutrients.[58] In the instance of nitrogen, the previous discussion illustrates that plants cannot obtain nitrogen from the air by themselves; they must rely on microorganisms and bacteria to convert atmospheric nitrogen into a useable form.[59] This landscape of bacteria, which promotes soil health ultimately "heals" soil quality, alleviating effects such as compaction, poor drainage, decrease in yields, and high levels of chemical inputs.[60] It stands to reason that if a healthy bacterial community is present in the soil, perhaps the nitrogen cycle may be able to complete a full transition from inert nitrogen back to inert nitrogen with minimal emissions of nitrous oxide.

III. CURRENT POLICY

A. Regulatory Framework

On a national level, the quality of air and its emissions are generally regulated by the Environmental Protection Agency (EPA). The EPA authored a 2007 document titled, "Major Existing EPA Laws and Programs That Could Affect Agricultural Producers."[61] This document, as the name suggests, details

55. *See id.* at 52.
56. *See* OHLSON, *supra* note 29, at 19.
57. *Id.* at 28.
58. *See id.* at 31.
59. *Id.* at 38.
60. *See id.* at 78-112.
61. *See generally* OFFICE OF THE ADM'R, AGRIC. COUNSELOR, EPA, MAJOR EXISTING EPA LAWS AND PROGRAMS THAT COULD AFFECT AGRICULTURAL PRODUCERS (2007), http://nepis.epa.gov/EPA/html/DLwait.htm?url=/Exe/ZyPDF.cgi/P1003E7I.PDF?Dockey=P1003E7I.PDF [hereinafter MAJOR EXISTING EPA LAWS].

the current legislation which may affect agricultural producers and their practices.[62] The Clean Air Act is the only relevant air pollution regulation mentioned in this document, and the discussion of nitrous oxide emissions is first framed in the context of State Implementation Plains (SIPS) and the associated variations, which may arise depending on the air quality issues in a particular area.[63] It should be noted nitrous oxide emissions are only directly mentioned in the context of Ozone National Ambient Air Quality Standards (NAAQS), and more specifically, in the context of animal production practices, pesticide application practices, and the use of stationary engines.[64] The language of the document leaves room for Title V permits as well as New Source Review (NSR) and Prevention of Significant Deterioration (PSD) to apply, "depending on how the agency defines farms and aggregates the emissions from them."[65]

Title V permits are required if the "aggregate of non-fugitive emissions of any regulated pollutant exceeds 100 tpy [tons per year]."[66] While the EPA does not define "non-fugitive" emissions, they have clarified the definition of "fugitive emissions."[67] According to Title 40 of the Code of Federal Regulations, Sections 70.2 and 71.2, fugitive emissions are defined as "those emissions which could not reasonably pass through a stack, chimney, vent, or other functionally-equivalent opening."[68] Fugitive emissions are also defined as "sources in chemical processes include[ing] valves, pumps, piping connectors, pressure relief valves, sampling connections, compressor seals, and open-ended lines."[69] The EPA also states that "[w]here emissions are not actually collected at a particular site, the question of whether the emissions are fugitive or nonfugitive should be based on a factual, case-by-case determination made by the permitting authority."[70] By these definitions, it then appears, in the context of agricultural soils, the determination of applicability of Title V permits would depend entirely on the designation of nitrous oxide emissions from soil as non-fugitive emissions. This designation may be logistically difficult because a general requirement of

62. *See generally id.*

63. *Id.* at 18.

64. *Id.*

65. *Id.* at 19.

66. *Id.* at 20.

67. *See generally* Memorandum from Thomas C. Curran, Dir., Info. Transfer & Program Integration Div. (MD-12) to Judith M. Katz, Dir., Air Prot. Div., Regional III (3AT00) (Feb. 10, 1999), www3.epa.gov/ttn/caaa/t5/memoranda/fug-def.pdf.

68. *Id.*

69. DAVID T. ALLEN & DAVID R. SHONNARD, GREEN ENGINEERING: ENVIRONMENTALLY CONSCIOUS DESIGN OF CHEMICAL PROCESSES 289 (2001).

70. Memorandum from Thomas C. Curran, *supra* note 67.

non-fugitive emissions is that they are collected and/or treated.[71] Collection and treatment methods for large surface areas, such as agricultural soils, are difficult to imagine in light of a large number of variables that would impact any such technology.

Additionally, NSR and PSD permits require an application for a "permit if [the] aggregate of non-fugitive emissions of any regulated pollutant exceeds a certain threshold amount depending on the attainment/non-attainment status of the area and on the pollutant."[72] These permits rely on the same definition of fugitive emissions versus non-fugitive emissions as previously discussed.[73] For NSR and/or PSD to apply to agricultural soil nitrous oxide emissions as well, the attainment/non-attainment status of the area, meaning areas which persistently exceed the national ambient air quality standards, may be designated as nonattainment.[74] Currently, the only area designated as nonattainment for nitrogen dioxide is the Los Angeles-South Coast Air Basin in California,[75] and proposed regulations and technical amendments do not address agriculture as a source of this pollution. [76]

This analysis of current air pollution regulation, which indicates the regulation of nitrous oxide emissions from agricultural soils, has not been fully developed. In the interest of developing a well-rounded and fair regulatory solution to this complex issue, it is beneficial to establish the identity of any stakeholders involved as well as their opinions and end goals. This consideration in the early stages of regulation development may lead to a regulatory framework that equitably balances the multiple interests of all parties affected by regulation of nitrous oxide emissions from agricultural soils. For illustrative purposes, an average corn growing system in Iowa has been selected to provide a set of circumstances to analyze stakeholder opinions and goals. This selection is not meant to be overly-narrow nor is it intended to illustrate any opinions or information out of context; it is merely intended to provide a model for considerations in regulatory development.

B. Common Law Implications

Before beginning an examination of stakeholders, it is beneficial to

71. *Id.*

72. MAJOR EXISTING EPA LAWS, *supra* note 61.

73. Memorandum from Thomas C. Curran, *supra* note 67.

74. *The Green Book Nonattainment Areas for Criteria Pollutants*, EPA, http://www.epa.gov/airquality/greenbook/ (last updated Apr. 8, 2016).

75. *Nitrogen Dioxide (1971) Maintenance State/Area/County Report (Redesignated Nonattainment)*, EPA, http://www.epa.gov/airquality/greenbook/nmcs.html (last updated Feb. 22, 2016).

76. *See generally* 40 C.F.R. § 81 (2015).

examine the potential common law that would allow for suit to be brought against historically non-point pollution sources. For example, a recent order from the Eastern District of Washington in the case of *Community Association for Restoration of the Environment, Inc. v. Cow Palace, LLC*., discusses the nitrogen cycle in detail and notes that "the parties dispute whether the conditions underlying the Dairy are conducive to denitrification."[77] In light of the evidence presented, the court concluded that denitrification from the concentrated animal feeding operation (CAFO) was unlikely, and even if the potential did exist, the range would be essentially insignificant.[78] The requirements of the Dairy Nutrient Management plan indicated the application rate and current nutrient levels were to be monitored;[79] however, of the 800 acres owned by the dairy, 553 acres were used to produce crops and were fertilized exclusively by manure from the dairy.[80] The court ultimately found that by not taking accurate samples to determine nitrogen content of the lagoon and by failing to apply manure to their acreage without regard to the residual nutrients, Cow Place, LLC, contributed to higher levels of nitrates in groundwater, in violation of the Resource Conversation and Recovery Act of 1976 (RCRA).[81] This decision could indicate that there is a shift in how courts and potential policy makers are viewing the definition of point source pollution. The court here held that the application of manure to fields and its subsequent run-off, historically a non-point source, fell under the regulatory structure of RCRA.[82] If this implication holds true, it could become a logical conclusion that atmospheric emissions of nitrous oxides from agricultural fields could constitute "enough" under the Clean Air Act.

IV. Stakeholder Analysis

A. Farmers

Farming practices in the United States have evolved dramatically since World War II and have begun to trend toward those which are more sustainable, thus promoting the concept of having means to provide for current needs, while still protecting the interest of future generations to provide for their own interests and needs.[83] Any realistic assessment and adoption of new practices, especially in

77. *Cmty. Ass'n for Restoration of the Env't, Inc. v. Cow Palace, LLC*, No. 13-CV-3016-TOR, 2015 WL 199345, at *2-3 (E.D. Wash. Jan. 14, 2015).

78. *Id.* at *3.

79. *Id.* at *5.

80. *Id.* at *6.

81. *See id.* at *38.

82. *Id.* at *44.

83. Susan A. Schneider, Food, Farming, and Sustainability: Readings in

the agricultural sector with its well established history and procedures, normally requires small, realistic steps with a defined end goal.[84] There also exists a competing interest against agricultural sustainability—global hunger. Approximately 805 million people globally, or one in nine people, are estimated to be chronically hungry.[85] Though efforts are made to support domestic production on an international scale and in countries where food security is of the utmost concern,[86] there are countries which are still dependent on the importation of cereal grains, such as corn grown in the Midwestern United States.[87] Corn producers and growers are certainly aware of this demand and the current state of world hunger.

An interview conducted with a farmer in rural Iowa with over thirty-five years of experience reveals this sentiment toward global hunger: "I farm because I want things to be here for years to come. I enjoy seeing crops grow on land I've worked hard to preserve. I like knowing I'm not chasing money. I'm producing something that benefits millions of people. I'm growing food for the world."[88] As evidenced by this interview and the global statistics regarding hunger, it is logical to conclude that for farmers to adopt any new agricultural practice, one of the steps must include an assessment of impact on crop yields, as a decrease in yield could signal both an increase in international crop prices and an increase in global hunger.

As previously discussed, corn yields are dependent on nitrogen fertilizers. However, as nitrogen fertilizers contribute to atmospheric nitrous oxide emissions, corn producers may need to implement new practices in order to help mitigate the impact on the environment, such as incorporating crop residue into the soil, using appropriate levels of tillage,[89] and utilizing precision agriculture technologies for variable rates of fertilizer application.[90] If a farmer has already implemented no-till and other best management practices as allowed for within their particular topography and yield goals, achievement of nitrous oxide

AGRICULTURAL LAW 30-31 (2011).

84. *Id.* at 31.

85. FOOD & AGRIC. ORG. ET AL., THE STATE OF FOOD INSECURITY IN THE WORLD: STRENGTHENING THE ENABLING ENVIRONMENT FOR FOOD SECURITY AND NUTRITION 8 (2014).

86. *Id.* at 13.

87. *See, e.g.*, FOOD & AGRIC. ORG. ET AL., *supra* note 85, at 37 (discussing Yemen's vulnerable dependence on cereal grain imports).

88. Telephone Interview with Robert K. Andersen, CEO, Andersen Family Farms, Inc. (July 2012).

89. SCHNEIDER, *supra* note 83.

90. *See generally* GEORGE W. REHM ET AL., UNIV. MINN. AGRIC. EXPERIMENT STATION, SOIL SAMPLING FOR VARIABLE RATE FERTILIZER AND LIME APPLICATION (2001), http://www.extension.umn.edu/agriculture/nutrient-management/docs/608-2001-1.pdf (last visited Apr. 27, 2016).

emissions will likely be achieved only through the adoption of variable fertilizer application. Variable fertilizer application can be used not only for nitrogen, but also for phosphorous and potassium which are also essential nutrients for corn growth.[91] The return on investment for upgrading planting and fertilizing systems to incorporate variable rate application is highest when fields experience significant highs and lows in nutrient levels across the field.[92] However, prior to adopting variable rate application, a baseline of nitrogen credits already present in the soil must be established through either grid sampling or management zone-based sampling.[93] Grid sampling is more expensive as a grid must be mapped over the entire plot, but it has the potential to provide nutrient data that is more precise and thus, is beneficial for variable rate application for several years.[94] In contrast, management zone-based planning divides the plot into information zones based on yields, soil surveys, and other variables, and each zone requires ten to fifteen soil core samples to be collected per zone, per year.[95] Although the data may be beneficial to farmers in the long term, immediate reductions are not typically seen.[96] To the contrary, inputs are increased in certain areas of the plot.[97] Each of these specific practices implemented to reduce nitrous oxide emissions inevitably add up to dollar signs in the eyes of farmers, and when they are faced with an already dire global hunger issue, the economic and social considerations likely outweigh the environmental considerations. From this perspective, successful regulatory proposals and structures will address mitigation of social harm in terms of global hunger while still enabling the producer to manage the production cost and inevitably the consumer cost of end products.

B. Environmental Groups

Although no specific regulation regarding nitrous oxide emissions from agricultural soils has been enacted, environmental groups are considered to be on the forefront of raising awareness for the existence and implications of greenhouse gas emissions and promoting regulatory solutions for emission mitigation. For example, the EPA states twenty-four percent of greenhouse gas

91. Paul Schrimpf, *Why VRA Fertilizer is Still a Tough Sell*, PRECISION AG (Dec. 19, 2012), http://www.precisionag.com/equipment/why-vra-fertilizer-is-still-a-tough-sell/.

92. *Id.*

93. Richard B. Ferguson et al., *Guidelines For Soil Sampling*, INST. OF AGRIC. & NAT'L RES., UNIV. OF NEB. – LINCOLN EXTENSION (2007), http://extensionpublications.unl.edu/assets/pdf/g1740.pdf (last visited Apr. 27, 2016).

94. *Id.*

95. *Id.*

96. *Id.*

97. Telephone Interview with Robert K. Andersen, *supra* note 88.

emissions come mostly from agriculture and other land use.[98] Broadly speaking, it should be noted that greenhouse gases also include carbon dioxide, methane, and fluorinated gases, as well as any other gaseous substance that may trap heat in the atmosphere.[99] While it is unclear what portion of this twenty-four percent is considered to be produced by nitrous oxide emissions, specifically from agricultural soils, it is clear that the EPA believes something should be done to reduce air pollution and promote the adoption of air quality regulations in agricultural states like Iowa.[100] It is their position that greenhouse gas emissions can be reduced "through highly successful partnerships and common-sense regulatory initiatives."[101] Although some agricultural states have not taken a specific stance on emission of nitrous oxides from agricultural soils, it can be reasoned from the Iowa Environmental Council's position paper that at least some states (Iowa) would be in favor of reducing fertilizer application to help with greenhouse gas emissions.[102]

C. Farm-Interest Groups

It is logical to conclude that, by definition, farm interest groups are organizations which support and advocate for the opinion and welfare of farmers. Organizations such as these include the Iowa Farm Bureau Federation, Iowa Corn Growers, and others which possess educational as well as policy advocate functions. With respect to the concept of nitrous oxide emissions from agricultural soils, the Iowa Farm Bureau has not produced a definitive opinion available to the public via its website. However, a model of an acceptable solution is available through its position on farming providing a solution to climate change with respect to carbon sequestration. Rather than a broad sweeping regulation regarding carbon emissions, Farm Bureau supports incentives, like the now non-existent Chicago Climate Exchange.[103] Admitted farmers, represented by Iowa Farm Bureau within the Chicago Climate, who completed no-till practices on all their farm ground for five years were able to provide extra carbon dioxide reductions to the market that companies were able

98. *Global Greenhouse Gas Emissions Data*, EPA, www3.epa.gov/climatechange/ghgemissions/global.html (last visited Apr. 24, 2016).

99. *Overview of Greenhouse Gases*, EPA, http://www.epa.gov/climatechange/ghgemissions/gases.html (last visited Apr. 24, 2016).

100. *See Global Greenhouse Gas Emissions Data*, *supra* note 98.

101. *See What EPA is Doing about Climate Change*, EPA, www3.epa.gov/climatechange/EPAactivities.html (last visited Apr. 24, 2016).

102. *See generally What EPA is Doing about Climate Change*, *supra* note 101.

103. David Biello, *Can Farming Provide a Solution to Climate Change?*, IOWA FARM BUREAU (Aug. 5, 2013), http://www.iowafarmbureau.com/articles/95938/can-farming-provide-a-solution-to-climate-change.

to purchase to offset industrial pollution outputs.[104] However, the Chicago Climate Exchange closed its cap-and-trade system for carbon emissions on December 31, 2010, making it difficult for farmers to continue to participate in this sort of mitigation system.[105] While benefits of carbon sequestration via no-till practices are readily quantifiable and widely considered to be well-established within the agricultural sector, this is not necessarily the case for nitrous oxide emissions from agricultural soils. This may raise concerns for the Iowa Farm Bureau as well as other farm interest organizations, should a situation such as the Chicago Climate Exchange arise in the future as a market-based incentive for nitrous oxide emissions.

The Iowa Corn Growers Association has also not directly addressed nitrous oxide emissions from agricultural soils but does advocate for nutrient reduction strategies which may be more initially cost-effective for producers prior to requiring variable rate application.[106] General management practices such as nitrogen application rate reductions, the use of a nitrification inhibitor, sidedress fertilizer application, as well as land use practices and specific edge-of-field practices are all strategies which may help overall nutrient reduction.[107] For purposes of general understanding, a nitrification inhibitor is a "[chemical] that slow[s] down or delay[s] the nitrification process . . . ."[108] Additionally, sidedress fertilizer application is done between rows of an already growing crop.[109] As a farm interest group, the Iowa Corn Growers Association evaluates such production practices not only in terms of percent of nitrogen reduction but also in terms of percent change in corn yield, noting not all practices may sustain yields at current levels or increase yields in the long term.[110] Though many of these practices are largely motivated by an additional need for improved water quality, a reduction in fertilizer application may also simultaneously reduce air pollution.

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104. *Id.*

105. Nathanial Gronewold, *Chicago Climate Exchange Closes Nation's First Cap-And-Trade System but Keeps Eye to the Future*, N.Y. TIMES (Jan. 3, 2011), www.nytimes.com/cwire/2011/01/03/03climatewire-chicago-climate-exchange-closes-but-keeps-ey-78598.html?pagewanted=all.

106. IOWA CORN GROWERS ASS'N, REDUCING NUTRIENT LOSS: SCIENCE SHOWS WHAT WORKS 1 (2013), https://www.cals.iastate.edu/sites/default/files/misc/183758/sp435.pdf.

107. *Id.*

108. D.W. Nelson & D. Huber, *Nitrification Inhibitors for Corn Production*, NAT. CORN HANDBOOK 1 (2001), http://corn.agronomy.wisc.edu/Management/pdfs/NCH55.pdf.

109. *Sidedress Applications*, CORNELL UNIV., http://courses.cit.cornell.edu/css412/mod5/ext_m5_pg7.htm (last visited Apr. 24, 2016).

110. IOWA CORN GROWERS ASS'N, *supra* note 106, at 1-2.

D. Seed and Chemical Industries

Corn plants can only be so efficient with the nitrogen fertilizer applied. However, seed companies have begun work on increasing nitrogen uptake efficiency of corn in the post-flowering stage and new hybrids of corn have been shown to perform better in this area.[111] However, there is still a concern for maintaining a pool of available nitrogen in the soil to allow for ideal conditions throughout the growing season.[112] Though DuPont Pioneer and other similar companies advocate for best practices when it comes to nitrogen fertilizer application,[113] there is still a push to consider genomics and identifying the traits associated with nitrogen efficiency within the corn gene map.[114] The idea behind nitrogen efficient crops is a "super line of corn that powers more yield with less nitrogen."[115] Field trials with so-called "NitroGenes" saw an increase of 6.9 percent in corn yield and an 8.8 percent increase in average nitrogen utilization.[116] With corn yields in Iowa averaging 168 bushels per acre in 2012,[117] this increase in yield percentage would theoretically raise average yields to 180 bushels per acre in Iowa alone.

The implementation of nitrogen efficient genes also appears to align itself with the growing trend among chemical and fertilizer companies to support a push for sustainable and environmentally-minded agriculture. Monsanto has adopted a commitment to sustainable agriculture, including goals such as "[d]eveloping improved seeds and agronomic practices to help farmers double yields by 2030 from year 2000 levels for corn . . . ."[118] Once again, the overall reduction of nutrient application will inevitably reduce the amount of nitrous oxides emitted from the soil into the atmosphere. However, there may be some resistance from fertilizer manufacturers and distributers in the instance that less nitrogen fertilizer is required and thus, less is purchased. The demand for ammonia may not disappear completely as ammonia is still required for a large number of industrial chemical processes including scrubbing for the removal of

111. DeBruin & Butzen, *supra* note 36.

112. *Id.*

113. *Id.*

114. Kenna Rathai, *Gene Research to Improve Nitrogen Efficiency Shows Promise*, CORN+SOYBEAN DIG. (2013), http://www.cornandsoybeandigest.com/fertilizer/gene-research-improve-nitrogen-efficiency-shows-promise.

115. *Id.*

116. *Id.*

117. ANN JOHANNS, IOWA STATE UNIV. EXTENSION, IOWA CORN AND SOYBEAN COUNTY YIELDS 2 (2014), http://www.extension.iastate.edu/agdm/crops/pdf/a1-14.pdf.

118. OUR COMMITMENTS TO SUSTAINABLE AGRICULTURE, MONSANTO INC. 1 (2013), http://www.monsanto.com/sitecollectiondocuments/sustainable-agriculture-white-paper.pdf.

other greenhouse gases and hazardous air pollutants such as particulate matter.[119]

E. Governmental Interest

As previously discussed, no current regulatory framework exists for nitrous oxide emissions from agricultural soils. However, it is widely accepted and understood that, for a regulatory framework to succeed, it must be established and promulgated at both the federal and state level for circumstances such as these. In beginning to examine the governmental interest in regulation of nitrous oxide emissions from corn growing systems, federal implications and administrative agencies involved will be examined first, followed by state agencies specifically involved in Iowa agriculture regulation.

1. Federal

a. USDA

At a federal level, the United States Department of Agriculture (USDA) is the preeminent administrative agency responsible for regulation of agricultural activities. A variety of conservation programs already exist, though none appear to focus specifically on nitrous oxide emissions from agricultural soils—perhaps this is due to the relatively new nature of this discovery and the associated difficulties of quantifying emissions on a field-by-field basis. The USDA has published materials on methods for estimating direct and indirect soil nitrous oxide emissions from wetland rice although there is no indication if this research has been expanded to include corn growing systems.[120] Perhaps of greater interests are the conservation standards published by the USDA. Only one explicitly addresses nutrient management,[121] and none address nitrous oxide emissions outright. [122]

Based on these findings, it could be argued that the USDA is simply waiting for associated science to become more widely accepted for the public to begin to push for regulation, or it simply does not find this to be a pressing issue at the moment. It can be assumed that, based on the history of other conversation

119. *See Ammonia Scrubbers*, POLLUTION SYS. INDUS. AIR SOLUTIONS, www.pollutionsystems.com/ammonia-scrubbers.html (last visited Apr. 24, 2016).

120. *See* USDA, QUANTIFYING GREENHOUSE GAS FLUXES IN AGRICULTURE AND FORESTRY: METHODS FOR ENTITY-SCALE INVENTORY (Marlen Eve et al. eds., 2014), http://www.usda.gov/oce/climate_change/Quantifying_GHG/USDATB1939_07072014.pdf.

121. *See Conservation Practices*, USDA, http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/references/?cid=nrcs143_026849 (last visited Apr. 24, 2016).

122. *See id.*

programs, any program involving nitrous oxide emissions may begin as a voluntary or grant program with incentives for farms to implement management practices that will reduce nitrous oxide emissions from agricultural soils.

b. EPA

The EPA readily asserts that nitrous oxide emissions from agricultural soils accounted for 74% of total nitrous oxide emissions in the United States in 2012.[123] The EPA also estimates that total emissions within the United States is expected to increase by five percent between 2005 and 2020 and will largely be driven by agricultural activities.[124] The EPA solution currently does not reflect a proposal of wide-spread regulation but rather the adoption of nutrient reduction practices and more efficient fertilizer application, as well as better manure management plans for livestock operations.[125] This position could be attributed to a lack of reliable, reproducible data which accounts for all significant variables or a focus by the EPA on other pressing environmental issues.

2. State

a. Iowa DNR

The Iowa Department of Natural Resources (DNR) has a dedicated Air Quality Division which acknowledges that nitrous oxide is formed from "soil cultivation practices, especially the use of commercial and organic fertilizers"[126] and attributes twenty-seven percent of greenhouse gas emissions in Iowa to agriculture.[127] Nevertheless, the infrastructure for the State Implementation Plan (SIP) for 2010 nitrogen dioxide NAAQS, submitted to the EPA on July 23, 2013, does not discuss these nitrous oxide emissions present from agricultural soils.[128]

The lack of commentary and guidance provided by the Iowa DNR on this

123. *Overview of Greenhouse Gases*, *supra* note 99.

124. *Id.*

125. *Id.*

126. *See generally* IOWA DNR, ESTIMATION OF GREENHOUSE GAS EMISSIONS: RECOMMENDED METHODS FOR SELECTED STATIONARY SOURCE CATEGORIES 23 (2014), http://www.iowadnr.gov/InsideDNR/RegulatoryAIr/GreenhouseGasEmissions/GHGEstimationTools/aspx.

127. *2014 Iowa GHG Emissions by Sector*, IOWA DNR, www.iowadnr.gov/Environmental-Protection/Air-Quality/Greenhouse-Gas-Emissions (last visited Apr. 24, 2016).

128. *See generally Iowa State Implementation Plan Revision for the 2010 NO2 National Ambient Air Quality Standards*, IOWA DNR, http://www.iowadnr.gov/InsideDNR/RegulatoryAir/ImplementationPlans.aspx (last visited Apr. 24, 2016).

matter does not necessarily reflect a lack of concern regarding nitrous oxide emissions from agricultural soils, but rather it could reflect a possibility that the agency is awaiting more data and better field-by-field monitoring techniques before beginning to propose standards and regulations or a focus on water quality issues.

b. Iowa Department of Agriculture and Land Stewardship

Similar to the Iowa DNR, the Iowa Department of Agriculture and Land Stewardship (IDALS) has been fairly silent on nitrous oxide emissions from agricultural soils. IDALS has advocated for the practice of wetland development that would reduce surface water runoff and phosphorous loss which in turn may also reduce the amount of nitrous oxide emissions.[129] In addition, there are numerous conservation projects promoted through IDALS as well as the Commercial Feed & Fertilizer Bureau that specifically regulate commercial fertilizer sales within the state of Iowa.[130] The conservation programs advocated by IDALS indicate that implementation of best practices with regards to nitrous oxide emissions from soil is likely a favorable position for this agency when they decide it is time to address this issue.

F. University and Education Entities

There are two segments of education entities that are likely to have a stake in the regulation of nitrous oxide emissions from agricultural soils: university research groups and extension education services. Since many current regulations of greenhouse gas emissions have been substantiated by science and research and this is an emerging area of potential regulation, university research groups will likely provide the foundation for the regulation by attempting to quantify emissions on a field-by-field basis. For example, research groups at the University of Iowa have been exploring the environmental impacts of atmospheric nitrogen species and have attempted to account for agricultural practices in developing models of nitrous oxide emissions over time.[131] Inevitably, as stronger data is gathered, aggregated, and analyzed, a more robust regulatory framework can develop, as stakeholders have a better grasp on the

129. BILL NORTHEY & WENDY WINTERSTEEN, PROPOSAL IS NEXT STEP TO IMPROVE WATER QUALITY, IOWA DEP'T AGRIC. & LAND STEWARDSHIP 1 (2010), http://iowalandscapeinitiative.com/pdf/Northey_Wintersteen%20ImproveWaterQualityRegisterFeb19.pdf.

130. *See generally* IOWA DEP'T OF AGRIC., COMMERCIAL FEED & FERTILIZER BUREAU, http://www.iowaagriculture.gov/feedandfertilizer.asp (last visited Apr. 24, 2016).

131. Charles O. Stanier, *Research Interests*, UNIV. IOWA COLL. OF ENG'G, user.engineering.uiowa.edu/~cs_proj/research_int.htm (last visited Apr. 24, 2016).

actual phenomenon being implicated by the potential regulation.

Ideally, prior to the necessity of regulation of nitrous oxide emissions from agricultural soils, the Iowa State University Extension education services would provide information to producers regarding the occurrence of emissions and best management practices which can be used to mitigate emissions. Iowa State University Extension notes agricultural soil management practices contribute to the amount of nitrous oxide emissions.[132] As an organization, they advocate for more efficient use of nitrogen fertilizer, likely through best management practices, rather than the implementation of broadly drawn regulations.[133]

G. Public

The public's complicated and multi-faceted interest in nitrous oxide emissions from agricultural soils is not something that has well documented and accredited with written support, though this does not diminish the public's stake in the issue. There are numerous viewpoints but only a few will be examined here in light of considerations raised by other stakeholders' perspectives.

First, there is a public interest in the regulation of nitrous oxide emissions from agricultural soils in that nitrous oxide depletes the ozone, thus spurring climate change. However, a Pew Research study revealed that the "American public routinely ranks dealing with global warming low on its list of priorities for the president and Congress. This year, it ranked second to last among 20 issues raised."[134] While the number of Americans who believe that climate change is a real and prevalent phenomenon is increasing, only fifty percent of the population believes human activity is contributing to global warming.[135] This, coupled with concerns surrounding genetically modified organisms, could raise potential concerns about implementation of emission mitigation practices and use of genetic traits to further reduce emissions. This issue will not likely enter the public sphere until regulations concerning nitrous oxide emissions are proposed.

132. Eugene Takle & Don Hofstrand, *Global Warming: Agriculture's Impact on Greenhouse Gas Emissions*, IOWA STATE UNIV. EXTENSION & OUTREACH (Apr. 2008), https://www.extension.iastate.edu/agdm/articles/others/TakApr08.html.

133. *Id.*

134. Bruce Drake, *Most Americans Believe Climate Change is Real, but Fewer See it as a Threat*, PEW RESEARCH CTR. (June 27, 2013), http://www.pewresearch.org/fact-tank/2013/06/27/most-americans-believe-climate-change-is-real-but-fewer-see-it-as-a-threat/ (last visited Apr. 24, 2016).

135. Cary Funk & Lee Rainee, *Public and Scientists' Views on Science and Society*, PEW RESEARCH CTR. 47 (2015), www.pewinternet.org/files/2015/01/PI_ScienceandSociety_Report_012915.pdf.

V. ANALYSIS AND RECOMMENDATIONS

In analyzing the stakeholders involved in the potential regulation of nitrous oxide emissions from agricultural soils, it appears that many parties involved are currently on a similar page. Based on the foregoing discussion, it is clear that most parties agree that implementation of best management practices including wetland development, use of nitrification inhibitors, and sidedress fertilizer application will be beneficial as a starting place for mitigation of nitrous oxide emissions. Steps for implementing such best management will need to begin with an evident acceptance by the stakeholders that this is an occurring phenomenon with significant environmental impacts. Such an acceptance and outward endorsement by environmental groups, farm-interest groups, and regulatory bodies would likely precipitate voluntary adoption of mitigating practices by growers. Such a step on the growers' part would necessarily involve a front-end scientific analysis of the practice in an effort to substantiate claims of a reduction in nitrous oxide emissions. An interpretation of this data and organization into education materials would also be required for effective dissemination of information to the grower.

If voluntary adaptation is something that is not practicable for more intensive projects such as wetland development or projects that may require the cooperation of multiple growers, early stage regulation through voluntary grants may be an effective tool to incentivize the adoption of such practices. A possible barrier is the requirement of hoops, such as paperwork and site visits. Thus, a more efficient method may need to be designed. The increased use in GPS monitoring amongst growers may provide a platform to gather information for such grant applications or a compliance mechanism that would be more streamlined for the grower. The support of farm-interest groups would be crucial in creating interest and acceptance of participation in such grant programs amongst growers. Nevertheless, voluntary adaptation of practices known to theoretically reduce nitrous oxide emissions may be the common ground these stakeholders reach in order to begin the conversation of who truly cares about reduction of nitrous oxide emissions from agricultural soils.

Additionally, it is a possibility that because a method for quantification of these emissions on field-by-field basis has not yet been developed and thoroughly tested, regulatory bodies may be reluctant to implement standards and rules. It is important to note that this analysis of stakeholders has been conducted with current perceptions of climate change. If the effects of climate change continue to increase, regulation may be initiated at the top of the regulatory hierarchy, and the interests and views of the stakeholders, along with the weight and deference afforded the same, would shift dramatically.

VI. Conclusion

In answering the question of “who cares,” the short answer is, “currently not many people care.” But people did not “care” about the effects of nitrogen runoff, air pollution from coal fired power plants, or smog producing automobiles until they were aware of and understood the problems. Once this issue is better documented and more commonly known and understood, the amount of people who care can be expected to grow exponentially. The question is, will there already be a regulatory framework in place that adequately addresses the problem in a way that takes into account all of the various stakeholders? Or will the situation be too dire or misunderstood in a way that misvalues the various shareholders’ interests? The weight these scenarios should be afforded must be considered at the outset of discussing regulatory frameworks. The answer to the question of “who cares” will depend, in large part, on who ultimately winds up caring.