

Appendix T

Agriculture Sector Information

1. Executive Summary

The Rocky Mountain National Park (RMNP) Initiative was formed to study and recommend action on increasing deposition levels of nitrogen in the park. The participants in the initiative include the Colorado Department of Public Health and Environment, the National Park Service, the U.S. Forest Service, the U.S. Environmental Protection Agency Region 8 and a number of other interested stakeholders. Together, these participants agreed to pursue a collaborative process to address impacts to high-elevation ecosystems in RMNP due to atmospheric nitrogen deposition. One of the goals of the initiative is to develop a comprehensive strategy to reduce nitrogen deposition in the RMNP. This Agricultural Strategy represents one plan, developed in cooperation with agricultural experts and industry leaders, to help reduce emissions of nitrogen (ammonia) from livestock excreta and fertilizer used in crop production.

In addition to production agriculture, there are a number of natural and anthropogenic sources contributing to atmospheric nitrogen deposition in RMNP. Some of the natural sources include native soils, oceans and wild animals and anthropogenic sources include vehicles, industrial sources, biomass burning and waste disposal facilities. These sources emit nitrogen and nitrogen compounds including nitrate, ammonia, ammonia and nitrogen oxides.

From an agricultural perspective, ammonia can be emitted at several different stages of agricultural production. For purposes of this strategy, agricultural production is defined as livestock operations (including unmanipulated manure) and commercial (manmade) fertilizer used for crop production. The total amount of ammonia emissions varies significantly from one farm to another due to differences in management practices and the type of production taking place (i.e., livestock versus crop production). The use of best management practices (BMPs), or methods, structures or practices employed by farmers and ranchers can help prevent or reduce ammonia emissions and limit environmental impacts to water, air or land from resulting from livestock and crop production.

This Agricultural Strategy presents the recommendations of the RMNP Agriculture Team that formed in response to the overall RMNP Initiative. The team held a number of meetings to discuss issues specific to the agricultural industry and RMNP including concerns with the science and inventory data being used for planning purposes. The strategy begins with an overview of Colorado livestock and production agriculture to provide a historical perspective to this agricultural strategy. In addition, the strategy includes information on trends and current practices with respect to livestock and crop production; identifies gaps in air quality data, the science and research on best management practices. The last section of the strategy presents both short- and long-term goals for reducing ammonia emissions from livestock operations and crop production activities that are partially responsible for nitrogen deposition in RMNP.

2. Introduction

Agriculture plays a large role in Colorado’s economy and way of life. Nearly half of Colorado’s 66 million acres are farms and ranches. Colorado’s agriculture contributes over \$16 billion annually to the state’s economy and employs over 105,000 people. In 2004 there were 31,369 farms and ranches operated by 49,102 farmers and ranchers. Over half of Colorado’s farms and ranches range in size from 10 to 499 acres.¹ The average farm operator in Colorado is a 54-year-old male with a 991-acre farm worth \$757,613. After accounting for machinery and equipment, the value of crops, livestock sales, feed, seeds, fertilizer and other farm-related expenses, the average net farm income in 2003 was \$13,228.²

Colorado has close to 10,000 beef producers with the cattle industry serving as the single largest agricultural industry in the state. In addition to cattle, Colorado is the fourth largest potato producing state, as well as being one of the top three beer producing states and home to over 50 licensed wineries. A list of Colorado’s top 10 farm and ranch products for 2004 is provided in Table V-3.

In Colorado, agriculture means more than just food. Colorado’s farmers and ranches also contribute to the creation of products related to manufacturing, health care, education, recreation, transportation, construction and personal care.

Table 1: Colorado’s Top 10 Farm and Ranch Products for 2004

Colorado’s Top 10 Farm and Ranch Products for 2004 (Million dollars)		
Rank	Commodity	2004 Receipts
1.	Cattle & Calves	3,343
2.	Dairy	343
3.	Corn	285
4.	Greenhouse & Nursery	276
5.	Hogs & Pigs	206
6.	Wheat	186
7.	Hay	164
8.	Poultry & Eggs	116
9.	Sheep & Lambs	111
10.	Potatoes	102

Source: Colorado Department of Agriculture and USDA National Agricultural Statistics Service

3. Historical Overview

Commercial agriculture in Colorado started in the mid-19th century to serve the growing needs of the mining industry. Railroads reached Denver in 1870, bringing with it a faster transportation alternative to horse-drawn wagons and larger numbers of farmers to provide agricultural products to feed and clothe a rapidly expanding population.

Influenced by its history and variable resources, Colorado’s farms differ greatly by region. In general, the state is divided into six regions: South Platte; Eastern Plains;

¹ Source: Colorado Department of Agriculture and USDA National Agricultural Statistics Service

² Source: Colorado Department of Agriculture and USDA National Agricultural Statistics Service

Arkansas; San Luis Valley; Inter Mountain; and Western Slope. The average farm size for the state is approximately 1,175 acres, ranging from 812 acres in the San Luis Valley to 2,698 acres on the Eastern Plains.³ Aside from a few very large operations, the median farm size is 350 acres. According to USDA National Agriculture Statistics Service (1999) in 1998, there were approximately 2,942,230 irrigated acres in Colorado on 13,430 farms. On average, producers lease or rent an average of 14% of the irrigated acres with higher percentages of rented or leased acres in the regions comprising eastern Colorado. Over the last 10 years, agriculture has lost nearly two million acres of agricultural land to development and other uses – a trend that is expected to continue.

4. Livestock Production Overview

Commercial cattle feeding in Colorado originated after World War I as a method of utilizing crop surpluses. During World War II, the war effort created jobs and the money to buy beef. Producers had to meet the domestic needs, as well as beef demanded of the war effort. The cattle feeding business grew as demand for beef grew and as a means of supplying beef year-round, instead of just seasonally. Further advancing the growth of the industry was the development of refrigerated cars that allowed western dressed beef to be transported to the eastern markets. Prior to this development, live cattle had to be transported to eastern packing houses at significantly greater cost. Refrigeration also allowed supermarkets to offer meat in self-service counters year round, not just seasonally.

“Large commercial feedyards were pioneered after World War II in the Southwest (southern California and Arizona). The concept then spread into the Plains in the 1960s and 1970s. Until the 1970s, cattle feeding was centered in the Corn Belt primarily in farmer/feeder-type operations and in the larger feedyards on the west coast. Through the 1960s, commercial cattle feeding increased in the Plains, and by the mid 1970s, the region was the leader in cattle feeding and has continued to capture market share.

In the Corn Belt and on the West Coast, cattle-on-feed numbers peaked in the early 1970s. During the same time frame, cattle-on-feed numbers were steady or increased in Colorado, Texas, Kansas and Nebraska. One of the primary reasons for this shift in cattle feeding between regions was the dramatic growth in the construction of large, modern packing plants in the Plains states, which replaced aging, smaller facilities in the Corn Belt and West Coast. These plants have extensive boxing capacity and lower fabrication costs.

Other major factors that contributed to the growth of the cattle feeding industry in Colorado were a good climate, availability of good quality water, good feed supply, good

³ CSU Agriculture Experiment Station, “Survey of Irrigation, Nutrient and Pesticide Management Practices in Colorado, November 2005

feeder cattle supply from close proximity, availability of packing plants, distance from urban development and good financing.”⁴

5. Crop Production Overview

Colorado producers grow a diverse set of crops such as corn, alfalfa, wheat, hay, potatoes, pinto beans, onions, barley, sugar beets, sorghum, millet, sunflowers, melons, wine grapes, various vegetables and a number of other crops.

Nitrogen is the essential element that plants and crops rely on for plant growth and sustainable crop yields. When natural sources of nutrients, such as manure or other organic residues are not sufficiently available to supplement essential elements to plants, commercial fertilizer is a cost-effective way to enhance soil and provide plants with the necessary nutrients for growth. For purposes of this agriculture strategy, commercial fertilizer is considered to be any manmade formula or product distributed for further distribution or ultimate use as a plant nutrient, intended to promote plant growth. Unmanipulated animal manure, or manure, can also act as a fertilizer, but is considered a separate product throughout this document.

When applied at the proper application and plant uptake rate, both manure and commercial fertilizers are unlikely to contribute to ground or surface water pollution because of nearly complete uptake of the nutrients by growing plants. The method used to incorporate fertilizer into soil can impact the amount of volatilization of ammonium and other nitrogen compounds. Realizing the potential impact that fertilizer can have as a result of improper or excessive use of fertilizer, Colorado’s fertilizer industry, the Colorado State University’s Cooperative Extension and the Colorado Department of Agriculture have worked to educate producers on the benefits of best management practices (BMPs) to further minimize impacts to air, water and land, to keep fertilizer costs minimized for operators.

Along the Front Range and eastern plains of Colorado, the use of commercial fertilizer has changed significantly over the past five years due to drought conditions and the rising costs of commercial fertilizer. Proper nutrient management can make a significant difference to the environmental outcomes of both manure and commercial fertilizer use. Management practices such as accounting for crop nitrogen needs, applying appropriate rates of fertilizer application and applying nitrogen when and where the crop can use it most efficiently are basic BMPs used by producers and a great starting point for addressing potential impacts from the use of commercial fertilizers.

6. Trends

a. Livestock Production Trends (1970 – 2005)

Growth in the livestock industry of all species in Colorado has been constant or “flat” for the last several years. In 1970, the inventory⁵ for “All Cattle and Calves” was 3,212,000. This number includes cattle on feed, dairy cows and range cattle. Inventory peaked in 1974 at 3,744,000 head and today stands at 2,500,000 head.

⁴ “A Journey Back – A History of Cattle Feeding in Colorado & the United States”, Dr. John K. Matsushima with W.D. Farr, 1995

⁵ Source: USDA National Agricultural Statistics Service

Cattle on feed in the state have gone from a 1970 total of 795,000 representing 838 feedlots with 184 lots holding 1,000 plus head to today's inventory of roughly 1,120,000 head, representing 260 feedlots with 155 feedlots having 1,000 plus head. This total number of cattle on feed has remained constant over the last several years.

The dairy industry in the state has gone from 6,000 operations with 81,000 head in 1970 to 600 dairy operations with 101,000 head in 2005.

Range cattle have declined from a high of 1,006,000 in 1970 to 685,000 in 2005.

The sheep industry in Colorado has also declined from a high in 1970 of 3,000 operations representing 1,303,000 head to 1,600 operations in 2005 representing 365,000 head.

The hog industry in Colorado has had a variable history in the state. In 1970, there were a total of 5,300 operations, representing 339,000 hogs. By 2005 there were 700 hog operations representing 840,000 hogs. The industry doubled its inventory of 410,000 hogs in 1991, to a high of 910,000 hogs in 1999. The hog industry in the state has declined since 1999 due in part to the closure of National Hog Farms to 850,000 head.⁶

The reductions in the number of livestock operations in the state reflect the changing face of agriculture nation-wide. The movement to consolidate livestock operations over the last 35 years is believed to be a function of increasing demand in domestic and international markets for U.S. products and increased production efficiencies put into practice to meet the growing demand.

b. Crop Production Trends

The application of fertilizers to agricultural crops has changed over time. Historically, a good rule of thumb was to apply 200 pounds of available nitrogen per acre to corn during the fall or spring planting season. Corn planted on sandy soil received a split application with 100 pounds during planting and the other 100 pounds applied as a side dress application to the growing crop during June or July. The addition of manure fertilizer would change the total amount of commercial fertilizer applied by 50 to 80 pounds.⁷

More recently, it is a common practice to take soil tests on each field prior to planting in order to plan fertilizer needs based on the nitrogen available in the soil profile. Samples generally are taken up to a depth of four feet. Producers using manure as a source of fertilizer, or in addition to commercial fertilizer, also sample and test the manure for nitrogen content and availability in order to calculate the proper application rate of fertilizer based on the crops growth needs. Application of the right amount of fertilizer for the needs of the crop is known as applying at agronomic rate.

Soil and/or manure sampling provides information that is used to formulate a nitrogen recommendation for a crop and an estimate of the average yield history of the field. For example, a farmer would not apply fertilizer to a field sufficient for a 200-bushel yield goal if the history of that particular field were capable of producing only a 175-bushel yield. If a split application of fertilizer is used, soil testing can more closely balance the

⁶ It is estimated that 2% of the operations in Colorado raise approximately 93% of the hogs.

⁷ Source: Best Management Practices for Nitrogen Fertilization, CSU Bulletin #XCM-172, August 1994

remaining nutrient needs of a crop during a subsequent side dressing or water application later in the growth cycle of the crop. For instance, changes to the amount of available water, crop health or growing conditions of any particular year, can result in adjustments to the amount of fertilizer applied during the side dressing application. A poor stand, in particular, can influence a farmer's decision to apply additional fertilizer based on the cost of the fertilizer versus the market return on the investment.

Overall, the use of fertilizer, both commercial or manure, has trended toward increased efficiency driven by advances in application techniques and BMPs developed in response to both environmental and economic pressures.

Another important trend associated with commercial fertilizer is with the form of nitrogen used in fertilizers. Due to the reduced domestic production of nitrate nitrogen (a commonly used lawn and agricultural fertilizer) and the increased costs of sourcing fertilizers, minimal amounts of nitrate nitrogen are currently used in agricultural production practices. A similar downward trend in usage is found with the product anhydrous ammonia. Recent regulation of hazardous materials by Homeland Security, including anhydrous ammonia, has made the storage and distribution of this product difficult and costly. Another factor impacting the use of anhydrous ammonia is the illegal production of methamphetamine production in Colorado. Early in this illicit production of this drug, anhydrous ammonia was stolen from agricultural operations such as fertilizer dealers or directly from tanks located on farms. Given the unique financial, liability and regulatory burdens of storing anhydrous ammonia, many of Colorado's fertilizer dealers have discontinued offering this product.

7. Current Practices

Ammonia is the most prominent gaseous species emitted from livestock operations and is heavily discussed in the literature from a management and air quality perspective. Ammonia is produced on livestock operations when urea nitrogen in urine combines with the urease enzyme in feces and rapidly hydrolyzes to form ammonia gas. The reaction is quick, taking anywhere from 2-10 hours for ammonia volatilization to peak after urine and feces get mixed together (Muck, 1981; James et al., 1999). The quantity and rate of ammonia volatilization depends on a variety of factors such as the amount of crude protein in feed rations, manure management strategies, pH, and climate effects (temperature, relative humidity, etc.), to name a few. Since there is such a large reservoir of ammonia sources (i.e. manure) on livestock operations, there can be a number of areas from which ammonia can be volatilized.

The emission of ammonia from livestock operations has many secondary effects such as ammonium salt formation (PM_{2.5}), wet and dry nitrogen deposition in surrounding areas, soil acidification, water eutrophication, and ecosystem changes (Vitousek et al., 1997). As with many processes, there is a trade-off to reducing ammonia emissions. For instance, by retaining ammonia in one area of the operation, it becomes more susceptible to emission later in the system. If nitrogen is retained in manure, the possibility of nitrate leaching and runoff into ground and surface waters, respectively, increases. Additionally, some management practices that reduce ammonia emissions, such as decreasing pH or encouraging aerobic conditions in manure, can lead to an increase in hydrogen sulfide, odor, or nitrous oxide emissions. To truly eliminate ammonia emission, the source of

nitrogen input into the system must be targeted, or a way found to bind or permanently change the form of ammonia-nitrogen that is emitted in manure.

a. Best Management Practices

Two different strategies can be used to limit the amount of ammonia that is released from crop and livestock production activities. One approach is to reduce the amount of ammonia that is generated in the first place. The second approach is to reduce the transfer of ammonia that is produced by agricultural operations. Proceeding with either or both strategies requires using the right practices, at the right time, under the right conditions. Throughout the agricultural industry, these practices are referred to as best management practices (BMPs).

BMPs are recommended methods, structures or practices designed to prevent or reduce environmental impacts to water, air or land. BMPs are inherently voluntary, site-specific and applied at the local level with or without input from agricultural experts such as the National Resource Conservation Service (NRCS) or Colorado State University (CSU) Cooperative Extension. Many BMPs are considered standard industry practice and often provide both environmental and economic benefits to agricultural operators.

b. The Nitrogen Cycle

The nitrogen cycle is a set of transformations that affect nitrogen in the atmosphere. Through a series of microbial reactions in the soil, nitrogen is made available to growing plants and crops. Thus, knowledge of the nitrogen cycle helps to explain how nitrogen passes from air to soil to organisms and back to air, and how the components of the cycle are affected by human activities. This cycle is important to understand in order to design effective strategies for decreasing losses of nitrogen from agricultural production to the environment.

Nitrogen in soils is commonly found in the form of organic nitrogen in soil hummus, ammonium (NH_4), nitrate (NO_3) or in a gaseous form. Nitrogen in organic soil hummus may be converted to ammonium through a biological process call mineralization. Ammonium is converted to nitrate through another biological process called nitrification. Nitrogen fertilizer, whether organic or inorganic, is biologically transformed to nitrate. The rate of this transformation is influenced by soil temperature, moisture and draining abilities of the soil. Thus, matching nitrogen applications to crop uptake minimizes nitrate leaching and maximizes efficiency.⁸

c. Livestock Production Practices

Currently, the manure management strategies practiced by Colorado cattle feeders are directed at protecting surface and ground water quality; dust and odor reduction and animal comfort. The major federal environmental law affecting animal operations is the Clean Water Act (CWA). Animal Feeding Operations (AFOs), depending upon size and proximity to surface water, were deemed under the CWA to be “point sources” of pollution and can be required to obtain a National Pollution Discharge Elimination

⁸ Source: Best Management Practices for Nitrogen Fertilization, CSU, Bulletin #XCM-172, August 1994

(NPDES) permit if they are at risk of discharging to surface waters. In Colorado, in addition to the federal requirements there are groundwater protection seepage rate requirements that apply to the construction and management of process wastewater impoundments in an animal feeding operations production area.

Typically, manure is stockpiled and then made available for land application on acreage owned by the AFO or on lands owned by cooperating farmers who use the manure for fertilizer. The manure is tested for nitrogen and other constituents before being applied. Producers document the manure's profile, rate of application (for own use) and third-party destination, if applicable. Manure is land applied at agronomic rates using the guidelines developed by technical resources such as Colorado State University and/or the USDA Natural Resource Conservation Service.

Production area practices to control dust and odor are part of an operation's "good neighbor" policy and also provide for animal comfort.

d. Crop Production Practices

Fertilizer use efficiency is at, or near, an all-time high in U.S. agriculture. Total fertilizer use has remained relatively level since the mid 1980s, while crop yields continue to increase. While a certain amount of nitrogen loss is unavoidable, it is to a producer's economic and environmental advantage to minimize nitrogen losses and maximize crop uptake.

Planning fertilizer usage based on agronomic rate is a significant part of the overall nitrogen management strategy used by agricultural producers. Producers use this management practice, advance application techniques and BMPs to formulate an overall nitrogen management plan. In addition, there are other practices that producers can use to enhance sustainable fertilizer practices.

Placement practices, for example, further improve nitrogen efficacy by placing low salt products with or very close to the seed during planting. Another emerging technology is foliar feeding these products during cultivation or spraying to reduce the amount of additional nitrogen need. With the recent drought conditions, minimum or reduced tillage has significantly increased in an attempt to conserve available soil moisture. Using foliar feeding practices, fertilizer is shanked into the root zone of the intended crop and nitrogen from the crop residue is calculated into the total nitrogen requirement of the crop.

Another fairly new fertilizer management technique is the use of precision agriculture during land application. Precision agriculture provides for site-specific application of fertilizer that can be customized to the exact needs of the field and crop. The technique works by splitting fields into grids ranging from 10 to 40 acres and sampling soils separately in these grids. The results are calculated per grid and provide a customized fertilizer recommendation that is programmed into a specialized piece of equipment that varies the rate of fertilizer applied to the field as it travels across the grids. The amount of nitrogen, phosphate and potash vary based on the need identified in each grid. Due to

the cost of grid sampling and application expense, precision agriculture tends to be used for higher value crops such as sugar beets and vegetable crops.

Overall, several sources of ammonia used in agriculture and that are capable of volatilizing have been significantly reduced over the past 10 years because of improved technology, use of BMPs and increased regulatory burdens. Even for those fertilizers that are more highly volatile, like urea, it is common practice within the industry to incorporate urea into the soil as soon as possible to prevent capture the valuable nutrients contained within this fertilizer versus losing the nutrients through volatilization.

Trait seed is also gaining ground in the use of pesticides. Glyphosate tolerant corn has reduced the amount of chemicals applied to corn and changed the timing of pesticide applications by a considerable degree. In the past, the only effective way to control weeds was by using a preplant treatment for specific weed varieties. Now preplants are seldom used and weed pressures are determined later when a combination of glyphosate and other post applied chemicals can be applied to control a variety of weeds present at the time. Other traits may be added for insect control, such as a corn rootworm trait that can control damage to corn root systems by the corn rootworm. Traits are currently being perfected to help make corn more drought tolerant and more effective at using nutrients present in the soil. Trait technology will help improve additional fertilizer utilization and reduce the rate and amount of fertilizer needed.

8. Identification of Gaps

a. Inventory Data

The Colorado 2002 Ammonia Emission Inventory includes source categories for livestock and fertilizer application, along with domestic sources, wild animals, native soils, point sources, mobile sources, open burning and waste disposal treatment and recovery. Associated with the ammonia inventory is a high level of uncertainty in many, if not all of the source categories. The native soils, livestock and fertilizer categories, taken together, comprise a significant portion of the inventory built from numerous assumptions and emission factors that estimate ammonia emissions from these sources.

In order to provide a representative inventory of emissions from a particular source category, emission factors must be accurate and reasonably reflective of the different variables that influence emissions from a particular source. For example, the livestock emission factors were taken from the work of Battye et. al. (2003) and Chinkin et. al. (2003)⁹. The emission factors do not differentiate between livestock on rangeland or livestock in an animal feeding environment (feedlot or barn). The type of feed these animals have access to is vastly different and will influence the amount and type of emissions range cattle versus feedlot cattle will emit. In addition, the sex and different growth cycles of animals are not taken into account in calculating the livestock emission inventory data. Furthermore, the data from which these emission factors were developed are based almost exclusively on European studies and therefore may not accurately reflect ammonia emissions from livestock produced in the US. Differences in diet, management practices, and housing between the US and European production are not

⁹ Source: Colorado 2002 Ammonia Emission Inventory, CDPHE, APCD, January 13, 2006

accounted for in the livestock emission factors. These questionable emission factors may, therefore, misrepresent the contribution from animal agricultural sources to the ammonia inventory.

In the fertilizer category, domestic fertilizer use and bagged fertilizers are not accounted for in the inventory. Given the large number of golf courses, hotels, parks and residential users of commercial fertilizer, the inventory is lacking sizable source categories. Urbanization is having a major impact on the total number of acres currently used for agricultural purposes. Over the last 10 years alone, agriculture has lost nearly two million acres of agricultural land to development and other uses¹⁰. The result is that thousands of agricultural acres have been idled and replaced with urban developments. Turf for homes, golf courses, parks and open space receive a significant amount of nitrogen annually that needs to be properly accounted for in ammonia and nitrogen inventories. These urea-based fertilizers are often applied by the lawn care industry because of the non-burning characteristics of the product when applied to leaf surfaces in a manner that allows for a considerable volatilization of the product. In addition, thousands of acres have been fallowed due to water being purchased from irrigated acres and diverted to urban use to support new developments. These two factors alone have significantly altered the total nitrogen fertilizer use, especially along the Front Range. Another contributing factor is the prolonged drought over the past five years. This climatic condition has led to further reallocation of water resources. It is likely that due to the sheer economics involved with water rights issues, agriculture will not reacquire the water that has been reallocated for nonagricultural purposes.

Another potential gap in inventory data identified by the RMNP Agriculture Team is related to the large numbers of impoundments located at sewage and drinking water treatment plants throughout the state. Due to federal Clean Water Act and state regulatory requirements these facilities must implement water quality control measures (i.e., denitrification) in the treatment of wastewater. A recent tightening of the water quality standards requires these facilities to retrofit treatment systems based on technology that uses a denitrification stripping process to treat wastewater, thus increasing nitrogen emissions to the air. Given the significant number of these facilities, this could be a source category that is not accurately reflected in the 2002 Colorado Ammonia Inventory. New water quality ammonia standards could also have a significant impact on future ammonia emissions.

Emissions from landfills and other garbage dumps are another source category that the Agricultural Team is concerned are not adequately considered in the inventory.

As water resources continue to shift from agriculture to municipalities, there will be a correlated shift from rural to urban sources. The result could be a drop in the number of agricultural operations in Colorado – a number that could influence the future inventory numbers downward in the livestock and fertilizer categories. This conversion of

¹⁰ Source: USDA National Agricultural Statistics Service

agriculture land along the Front Range is changing and the Agriculture Team suggests that this should be considered in forecasted inventories. In addition, animal agriculture is expected to decline. Calculating numbers based on gallons of water per person can help improve inventory data. In addition, the Division of Water Resources has numbers on water use ranging from agriculture to domestic uses that may be helpful in increasing the accuracy of inventory data.

b. Air Quality Modeling

Air quality models are used to predict the transport of pollutant emissions from their source to a given downwind location. Air quality models use mathematical representations of physical processes such as ammonia volatilization and transport. Model inaccuracies occur because of inaccurate or over-simplified mathematical representations of the physical processes involved in pollutant dispersion and/or inaccurate and imprecise inputs (i.e. air quality models are only as good as the data put into the model.) A general rule-of-thumb used by modelers to estimate the accuracy of a given model is the "factor-of-two" rule. This means that an acceptable dispersion model may predict downwind concentrations from a source emitting a known concentration of pollutant of 50 to 200 percent of the actual concentration. The implications of these inherent and acknowledged inaccuracies are that the contribution of a particular source to the nitrogen deposition problem in RMNP may be grossly misrepresented.

The magnitude of model inaccuracies are likely to increase as the modeling domain increases in size and becomes more heterogeneous. Furthermore, complex terrain features such as those found on the Front Range may compound problems with modeling results as the mathematical representations of pollutant emission, reaction, transport, and deposition become more complex and require additional assumptions.

Uncertainty in modeling results can compound potential errors from model inaccuracies. Uncertainty results from the use of unknown conditions in a model such as mixing height and turbulent velocity for filling in gaps within measured data. In their "Guideline on Air Quality Modeling"¹¹, the US Environmental Protection Agency (EPA) divides the uncertainty in modeling into "inherent" uncertainty and "reducible" uncertainty. Inherent uncertainty is that which results from unknown parameters such as those mentioned previously. "Available evidence suggests that this source of uncertainty alone may be responsible for a typical range of variation in concentrations of as much as ± 50 percent" (CFR, 2003). Reducible uncertainty is that which results from imperfect input data, such as emission characteristics and meteorological data, and may be reduced by more accurate and more representative measurements.

For a domain as expansive and complex as the Front Range, reducing uncertainty in modeling results will require high resolution meteorological measurements, accurate and

¹¹ *Code of Federal Regulations (CFR)*. 2003. *Guideline on Air Quality Models*. 40 CFR Part 51. Office of the Federal Register, National Archives and Records Administration. Washington, DC: U.S. Government Printing Office.

representative emission factors, and analysis of all imbedded model assumptions. All modeling results used in the subsequent work should also be accompanied by an estimate of the uncertainty associated with the estimate.

c. Scientific Data

The Rocky Mountain Atmospheric Nitrogen and Sulfur Study (RoMANS) currently underway, holds great promise in helping to provide additional information on the overall mix of sulfur and nitrogen in the air on both the east and west sides of RMNP. The height of the monitors, at two meters, raises concern from the Agriculture Team that atmospheric transport from other states cannot be accurately measured at this height.

d. Research

There are a number of best management practices (BMPs) that have been demonstrated in the laboratory to be effective at reducing ammonia emissions at livestock facilities. Wide scale field-testing is needed to compare laboratory-based results with real world results. For example, oscillating protein in the diet has been shown to be an effective means of reducing total nitrogen output in ruminants. Oscillating protein works by changing the animal's protein intake amount from a low to a high amount every three days. Cole (1999) found that by oscillating the protein in lamb diets, animals were able to retain more nitrogen and excrete less. The oscillating protein diet is a new method of feeding and needs further research, but the potential benefits in reducing ammonia appear promising.

Additional research is also being carried out to develop emission factors for a number of confined animal feeding operations in the United States. Work is being done at Texas A&M University to develop process-based ammonia emission factors from dairies (see Mutlu et al (2003)¹² for preliminary work) and to analyze emissions of VOCs from feedlots and dairies in Texas.

9. Regulatory Concerns

a. Cross Media Issues

Agriculture, by its very nature, is a biological system that is inherently connected. The nitrogen cycle, for example, demonstrates how nitrogen moves from air to soil to organisms and back to air. Depending on the activities that occur during the cycle, additional changes can occur as nitrogen passes through each cycle or can simultaneously affect more than one environmental media (air, water, waste). The biological connection is also inherently cross media in nature. This nexus is leading the U.S. EPA and many

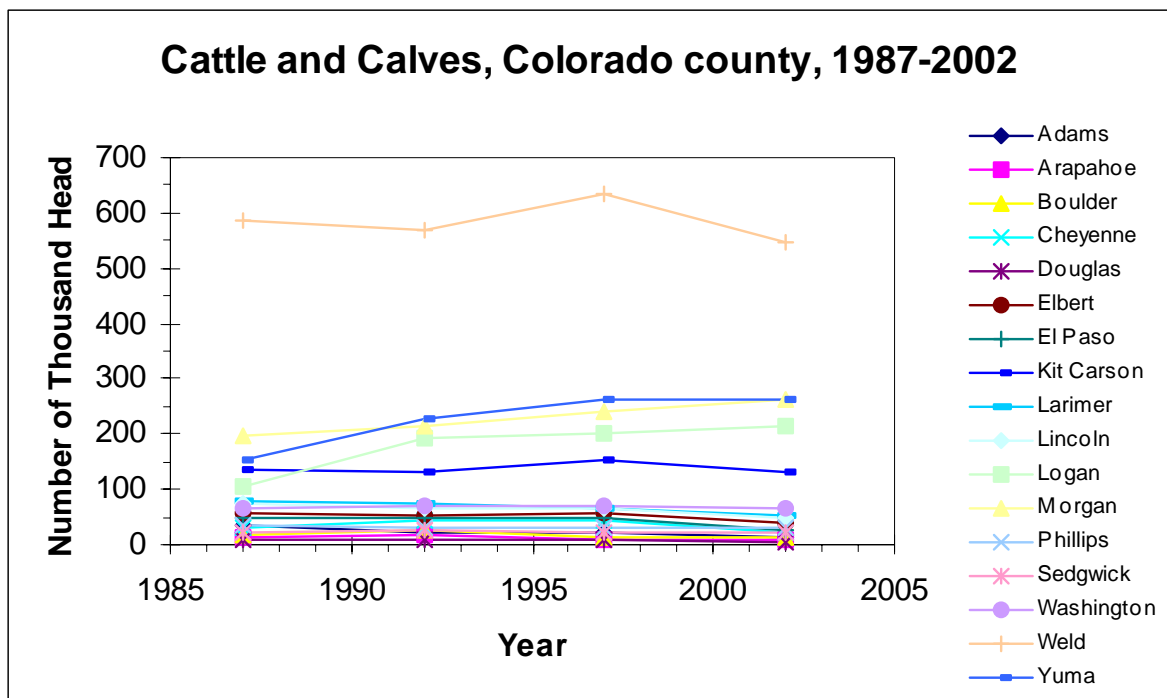
¹² Reference: Mutlu, A., S. Mukhtar, S.C. Capareda, C.N. Boriack., C.B. Parnell, Jr., R.E. Lacey and B.W. Shaw. 2004. A Process-Based Approach for Ammonia Emission Measurements at a Freestall Dairy. Paper presented at the 2004 ASAE/CSAE Annual International Meeting held from August 1-4, 2004 at Ottawa, Ontario, Canada. Paper No. 044110.

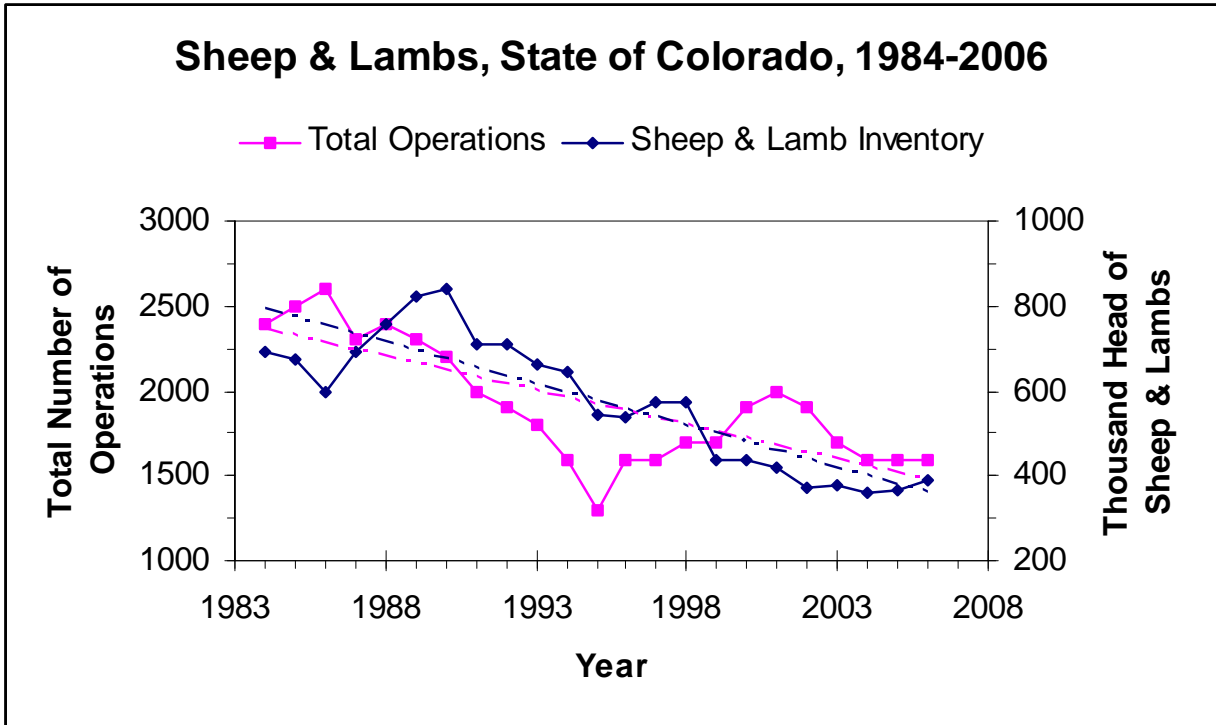
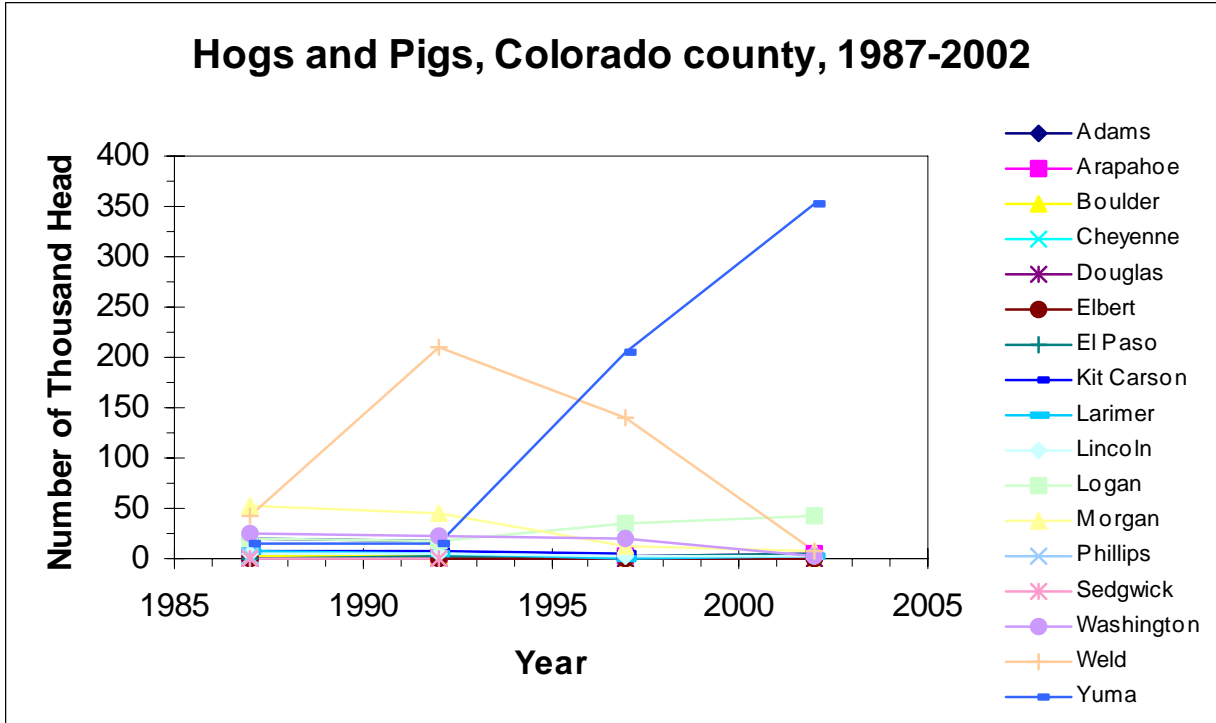
regulatory states, including the Colorado Department of Public Health and Environment, to recognize the need to coordinate both air and water quality goals when working with agriculture. For example, to meet a water quality protection goal, a farmer will most likely use a BMP that increases ammonia emissions to the air through volatilization. On the other hand, to protect air quality, a farmer would increase nitrogen application to fields, increasing losses from fields to surface and ground water. Anticipating the different forms and pathways that nitrogen can take, can keep air quality and water quality policies from working at cross-purposes. Additionally, an uncoordinated approach to environmental protection can have costly implications to agricultural producers.

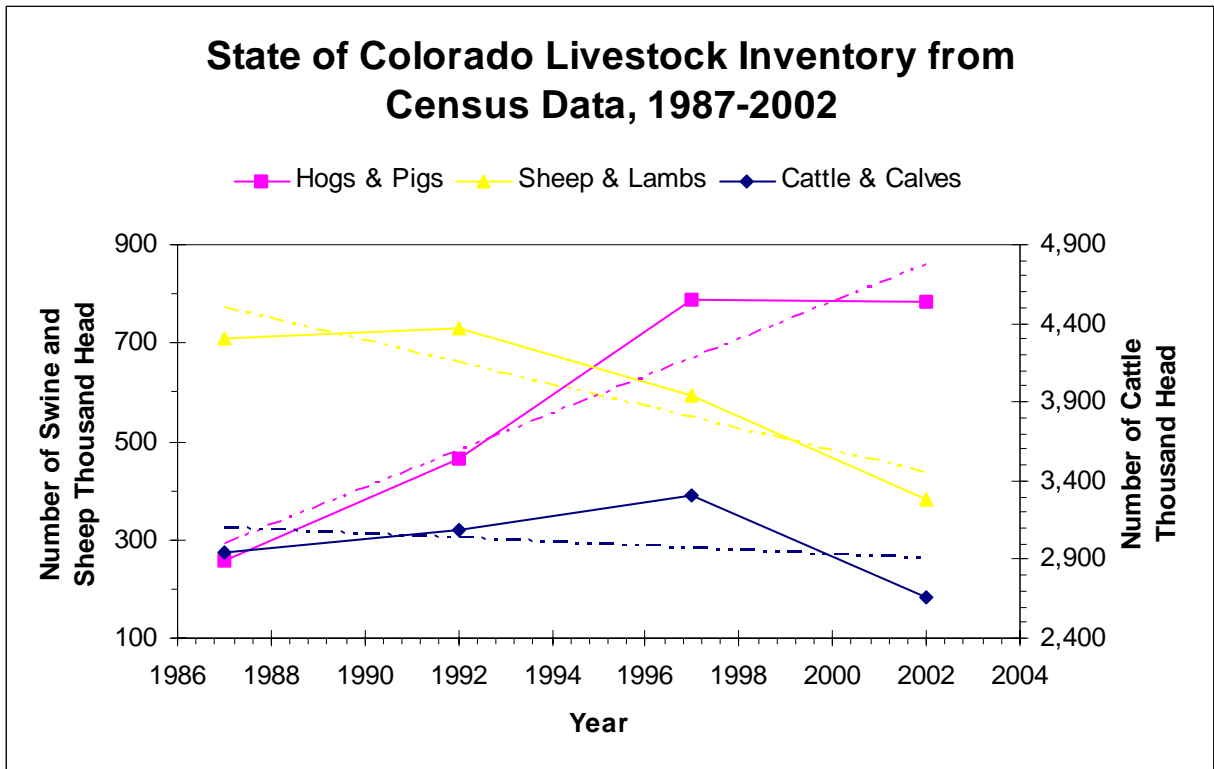
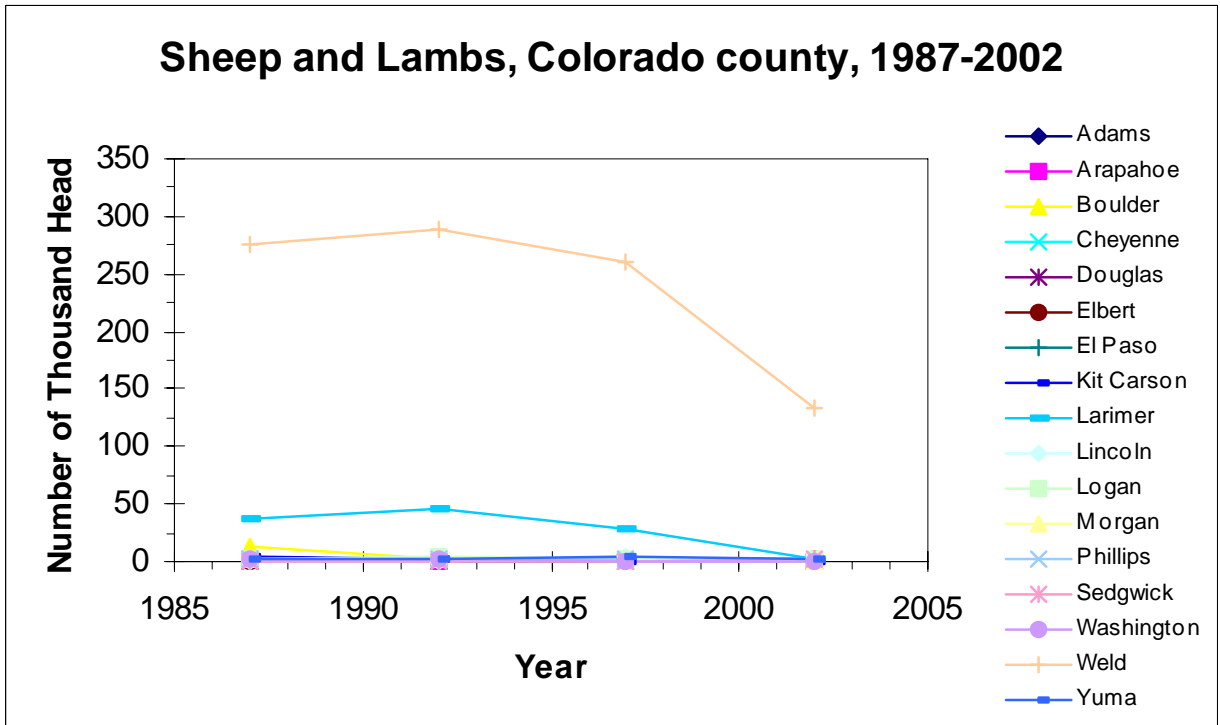
10. Measurement

Quantifying actual emission reductions from the agricultural sector will be challenging due to the lack of methods available to conduct this type of analysis. Results from the survey instrument will provide data on the number and type of BMPs currently being used by Colorado producers. The use of subsequent surveys can gauge the success of outreach programs based on the number of new BMPs put into place after the initial survey and outreach efforts.

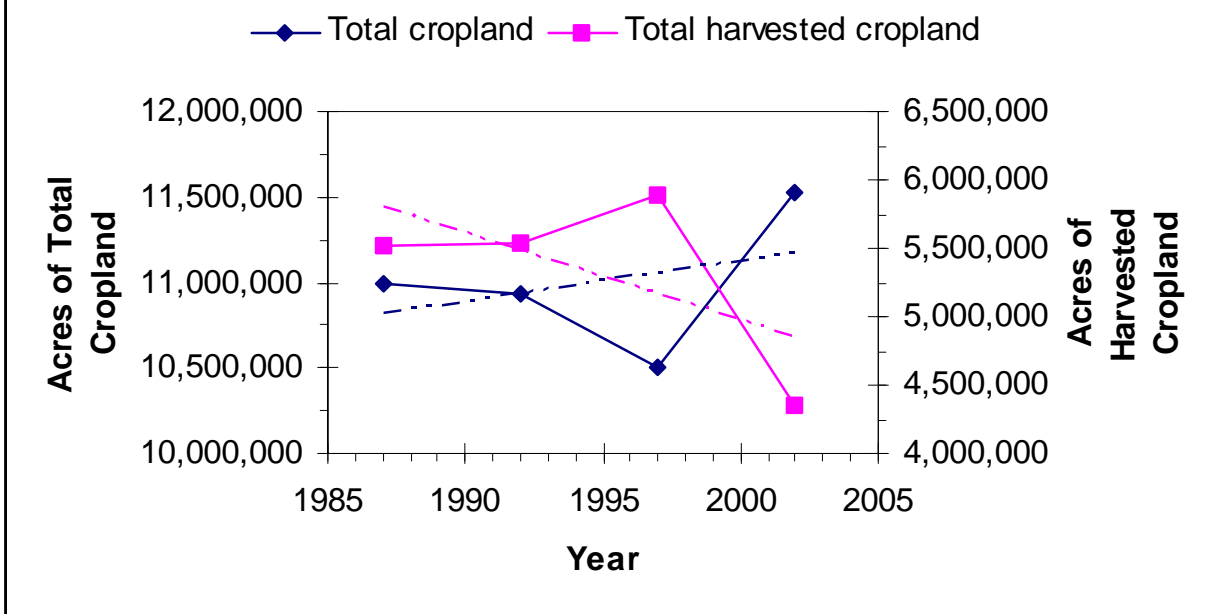
The number of successful incentives and an increase in the number of states addressing nitrogen deposition issues are additional measures that can be used.







Cropland, State of Colorado, 1987-2002



Total Cropland, Colorado county, 1987-2002

