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Colorado Nutrient Management Practices: A Summary of Adoption Rates and Costs

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INTRODUCTION

According to a 2012 U.S. Census Bureau report, the Earth's estimated human population has surpassed seven billion and continues to grow. One thing holds true now and into the future. All of these people require food and clean water for survival.

Appropriate nutrient use in agriculture, especially nitrogen (N) and phosphorus (P) and potassium (K), is closely tied to meeting both of these basic needs. Replenishment of nutrients to the soil system to compensate for crop removal is not only necessary for productive crops; it is also essential to ensure the sustainability of the soil resource. However, the use of nutrients in agricultural production may impact water quality. Surface and groundwater contamination from excessive N and P application have been well documented and researched for many environments and cropping systems (Dubrovsky et al., 2010; Puckett et al., 2011; Ribaudo et al., 2011). There is current and future potential for agricultural production to impair water resources, especially with regards to nitrate (NO_3-N) groundwater contamination (Bauder et al., 2013).

Water quality and water quantity issues are of concern to Coloradoans who live in a semi-arid climate with scarce water resources. Because a large percentage of Colorado's water supply is diverted for cropping use, agriculture is frequently asked to find ways to both conserve water quantity and protect water quality. Practices that aim to protect water through improvements in irrigation, pesticide and nutrient management are commonly known as BMPs or Best Management Practices. Colorado farm operators have been encouraged to voluntarily adopt BMPs without facing state or federal mandates to do so.

Voluntary BMP adoption programs consist of conservation practices designed to prevent the decline of water quality. Successful voluntary compliance programs have the potential to yield numerous benefits. As this report shows, farmers shoulder additional costs to implement nutrient management practices, although the costs would arguably be lower than enforcing compliance with state or federal mandates. Some nutrient management practices are cost-neutral. Other voluntary nutrient management practices like soil testing or developing a nutrient management plan can also simultaneously increase crop yield while reducing nutrient losses (Bauder and Waskom, 2011).

BMP adoption programs have been implemented across the country with mixed success. In a recent USDA Economic Research Report, Ribaudo et al. (2011) document that in 2006, only 35% of U.S. field crops fertilized with nitrogen met nutrient management BMPs for rate, timing, and method of application. The Ribaudo et al. report finds that Mid-Western corn producers have the greatest amount of non-adoption with N BMPs. In contrast, states in the Mountain region (including all of Colorado) have one of the highest regional rates of nutrient BMP adoption. The lowest rates of BMP adoption in the Mountain region were predominately related to time of method of application. This suggests that Colorado producers are implementing BMPs, but that cropping systems in Colorado may require additional implementation methods.

This report provides a straightforward, basic summary of BMP nutrient management adoption rates and costs for Colorado agricultural producers. The study is based upon results from a 2011 survey querying Colorado farmers about fertilizer and manure application practices that may potentially improve water quality. The preliminary technical report and summary include a literature review of nutrient BMP costs (Keske, Bauder, and Irrer, 2011). The current report expands upon the results of the prior summary by providing greater detail about the survey development, methods, and results. The present report is part of a series of publications that document Colorado producer nutrient BMP adoption during the past 15 years. The last effort was published in Survey of Irrigation, Nutrient and Pesticide Management Practices in Colorado

(Bauder et al. 2005). Like the prior studies in this series, more sophisticated analysis and analytical work are planned for submission to the peer-reviewed, scientific literature. Additional questions about the project can be directed to Troy Bauder (troy.bauder@colostate.edu), the report's primary author.

EXECUTIVE SUMMARY

This purpose of this publication is to summarize Colorado nutrient management adoption rates and costs. Information from the report can be used to develop policies and incentives that may prevent water source impairment from agricultural nonpoint source (NPS) nutrients. Results can also be used to direct future education, outreach, and research efforts. The following is an Executive Summary of the 2011 survey instrument, study parameters, and findings.

The 2011 study consisted of a sample of 2,000 Colorado producers from six agricultural regions. This survey followed similar methodology of prior surveys conducted in 1997 and 2002 (Frasier, et al. 1999; Bauder and Waskom, 2005). In Spring 2011, surveys were mailed to 2,000 producers identified through the Colorado Agricultural Statistics annual crop production survey as likely engaging in irrigated agricultural production (NASS, 2009). Approximately three weeks after the original surveys were mailed, non-respondents were mailed a second survey. Three weeks after the follow-up survey, phone calls were made to non-respondents in order to gain a representative sample. The overall response rate was 55.3%, but this included individuals who concluded during the follow-up phone interview that they were not appropriate candidates to participate in the survey (e.g.. The respondents left agriculture, or no longer irrigated their crops.). The response rate for completed surveys was 44.5%; however, this data included 128 individuals who had no irrigated land. Once responses from non-irrigating agricultural producers were removed the final usable response rate was 37%. Responses were categorized by county into six regions that have similar water and cropping system characteristics. The final sample was representative of NASS demographic data for the agricultural producer population in the six agricultural regions (NASS, 2007).

The 38-question survey instrument was divided into five sections. These included General Farm/Ranch Information, Nutrient Management Experience, Technology and Nutrient Management, Costs of Nutrient Management, and Demographics. A copy of the survey is included in Appendix A.

Producer demographic information was consistent with national data (NASS 2009). The average age of survey respondents was 57 years. Producers had an average of 37 years of experience and operated their current operation for an average of 33 years. Ninety-five percent of the respondents were male and well educated, and almost two-thirds indicated having some level of post-high school education. The majority of respondents (68%) reported annual gross farm sales of greater than $100,000. Approximately 50% of respondents supplemented their family's farm income with off-farm employment. In these cases, slightly less than 50% of their income came from the actual farm operation. The average whole-farm size for the sample ranged from 1,411 acres in the San Luis Valley to 4,369 acres in the Eastern Plains. The irrigated acreage sample represented approximately 430,000 (or 15%) of the state's 2,867,957 acres (NASS, 2009).

As expected, water sources varied dramatically by region. Surface water accounted for slightly over 70% of the irrigation water used. The balance came from groundwater. Many respondents reported relying on water from both surface and aquifer sources. As might be expected, there was also regional variability in the types of crops grown. Alfalfa and corn, respectively, were the most and second-most frequently irrigated crops statewide. The majority of the respondents (63%) owned some type of livestock, but only 20% had herds of greater than 250 head. Beef cattle comprised the dominant livestock type.

The irrigation systems also varied by region and size of operation. More producers used surface irrigation (flood or furrow) systems, but larger farms tended towards sprinkler irrigation. A breakdown showed that 56% of the acres were irrigated with sprinklers, 42% with furrow/flood, 1.7% with other irrigation systems, and only 0.3% used drip irrigation.

The Nutrient Management Experience section queried producers about rate and timing of nutrient applications, placement methods, and nutrient sources. Rate and type of nutrient management practices varied considerably by region. This reflected differences in cropping systems, water sources, climate, and altitude. Regions with the highest adoption rates had more intensive cropping systems and tended to use the most nutrients for crop production. This is consistent with well-established agricultural production patterns; higher value crops generally require higher levels of nutrient management. The Eastern Plains region had the highest overall adoption rates for many of the practices followed by the San Luis Valley and the South Platte. These regions also had more respondents who indicated that they attended workshops or training on nutrient/fertility management.

Colorado producers reported taking advantage of the manure produced by the state's prevalent livestock industry. More than half of the respondents indicated that they utilized manure or compost as a nutrient source. BMP adoption for determining manure application rates was lower than fertilizer application BMPs. This was likely due to the comparatively higher commercial fertilizer costs. Producers may devote comparatively more attention to commercial fertilizer use so as to not squander their financial investment. Only a small percentage of the respondents indicated that they did not apply either manure or fertilizer.

Many BMPs are designed to prevent off-field nutrient transport and/or prevent erosion. These BMPs include a variety of physical modifications or management practices that reduce runoff and/or leaching of nutrients at the field scale. Transport and erosion mitigation BMPs are very site specific. In a manner similar to other nutrient practices, the survey showed that adoption of these practices varied considerably by region. Conservation tillage was the most popular practice within this group of BMPs, and filter or buffer strips were the least commonly implemented.

Precision farming technologies that allow for more precise and varied fertilizer rates at the subfield scale had relatively low adoption rates. This was not surprising given the somewhat recent release and novelty of some of these technologies. Guidance and auto steering had the highest adoption rates although these technologies were implemented more often to improve productivity rather than nutrient management. A minority of respondents, mostly from larger farms on the Eastern Plains, reported that they utilized yield monitoring, crop or soil sensing, or targeted soil sampling to adjust for variability between fields.

Costs associated with fertilizer and nutrient management varied from approximately $20 per acre on the Eastern Plains to approximately $2 per acre in the Mountains. The wide regional variation could be explained by the more common use of fertilizer for high value crop production in the Eastern Plains. Fertilizer price proved to be a relatively inelastic input. Few producers reported that they would change their use of fertilizer given a 15% annual price increase. Commitment to nutrient management also did not decline when producers were asked to consider a ten percent increase in total operational costs.

An experimental section of the survey was designed to learn about producers' willingness to accept and willingness to pay for varying nutrient management plans. This section had a considerably lower response rate than most of the other sections. However, the results showed that many producers were willing to accept a basic or moderate level of nutrient management with little or no cost share, perhaps indicating an ethic of stewardship or a perceived benefit from basic nutrient management practices. The highest level of nutrient management, which included elements of precision agriculture, required the greatest level of cost share ($25/acre) for adoption. Precision agriculture questions also had the highest level of nonresponse indicating that these respondents may not be willing to manage nutrients with this high level of precision for any amount of cost share, or they may be unfamiliar with the technologies.

Supplemental nutrients, particularly nitrogen and phosphorus, are critical components of highly productive irrigated agriculture. The vast majority of the respondents reported that they obtained the supplemental nutrients from either commercial fertilizer or from organic sources like manure or compost. This study found that most respondents implement at least some form of nutrient management in order to enhance nutrient use efficiency and to prevent losses from irrigated fields.

In summary, this study showed that the rate of adoption and type of BMP practices used varied considerably across the state. The regional variability is commensurate with a large state like Colorado that has diversified topography and agricultural production. Irrespective of location, the BMPs that are most likely to be adopted tend to be those with lower costs or are cost neutral to the producer. BMPs that require agricultural producers to incur both start-up and operating costs, in order to attain environmental targets may require additional incentives.

METHODOLOGY

Primary data for this report were collected from a sample of 2,000 agricultural producers. The sample was identified through the Colorado Agricultural Statistics annual crop production survey as likely engaging in irrigated agricultural production (NASS, 2009). In spring 2011, surveys were mailed to 2,000 producers, a sample that was stratified by six agricultural regions. Respondents were queried about nutrient BMP adoption rates and costs for the 2010 growing season and calendar year. Survey questions and data collected in spring 2011 paralleled CSU best management studies conducted in 1997 and 2002 (Bauder, Waskom, and Frasier, 2003; Bauder and Waskom, 2005). The overall response rate was 55.3%, but observations were omitted from analysis when it was learned that these respondents did not use irrigation.

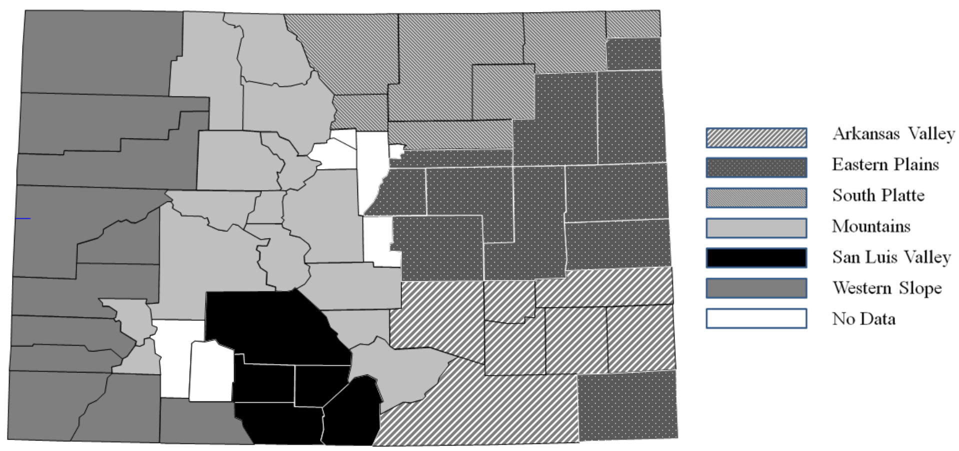

Figure 1. Regional grouping of survey responses by county.

The 2011 survey was pilot tested with 16 individuals. Modifications were made based upon reviewer input. Reviewers reflected a mix of agricultural producers, extension specialists, agency personnel, and university faculty. A copy of the final cover letter and survey are presented in Appendix A.

The 2011 sample was drawn from farm operators with at least 100 acres of irrigated agricultural land. The National Agricultural Statistics Service (NASS) stratified the sample of Colorado irrigators by county, using the same general criteria used in the 2007 Agricultural Census (NASS 2009). In order to protect producer identity and confidentiality, surveys were mailed directly to producers by NASS. Study participants remained anonymous to researchers at all times. Refinements were made throughout the data collection process to ensure that the sample represented a county-level distribution of NASS Agricultural Census agricultural producers. Nine counties were not included in the survey because they were urban and/or mountainous with few or no farmers meeting the criteria for the sample draw.

In order to ensure a successful response rate, the survey design methodologies were a modification of the Dillman Total Design Method (Dillman, Smyth, and Christian, 2008; Dillman, 1991). The mailing consisted of a cover letter highlighting the purpose and parameters of the study, a survey booklet, and a self-addressed, stamped reply envelope. The first flight of surveys was sent on February 18, 2011 to agricultural producers. On March 3, 2011 a second mailing was sent out to those who did not respond to the first mailing. In a final effort to increase the survey response rate, producers who did not complete and return the second mailing were contacted by the NASS call center located in Cheyenne, Wyoming during one of six separate occasions.

When the results of the survey were analyzed it became apparent that 128 of the respondents who completed the survey indicated that they irrigated less than 100 acres of land. In some cases, respondents stated that they did not use irrigation at all. It can therefore be assumed that some of the other individuals who either did not respond to the survey or refused to respond were also non-irrigators.

Survey responses were entered into an Access database for ease of data entry and quality control, and then exported into an Excel spreadsheet format to build tables and to conduct analyses. In order to control for the diversity of cropping practices in Colorado, survey responses were grouped into six geographic regions, based upon county (Figure 1). The regions were, in alphabetic order: Arkansas Valley, Eastern Plains, Mountains, South Platte, San Luis Valley, and Western Slope. This regionalization also allowed for comparison to regional data presented in previous Colorado survey reports by Frasier et al. (2001) and Bauder and Waskom (2005).

SURVEY DESIGN

The survey was divided into five sections: General Farm/Ranch Information, Nutrient Management Experience, Technology and Nutrient Management, Costs of Nutrient Management, and Demographics. The survey consisted of a total of 38 questions.

The purpose of the first section, General Farm Information, was to gain general information about the respondents' agricultural operations. These questions included total size of farm, major farm enterprises (crops and livestock), proportion of crop land irrigated, land leased or rented, origin of the producer's irrigation water, and type of irrigation system.

The second section, Nutrient Management Experience, focused on how the respondents managed their fertilizer and manure. The questions queried producers about a range of nutrient best management practices (BMPs) that any Colorado producer could potentially adopt. Questions asked producers about how they determined nutrient application rates, placement, source, and timing. A question was included about physical, structural, and management BMP adoption intended to reduce off-field transport of nutrients, sediments and pesticides. Producers were also asked about whether they had obtained information on nutrient management during the past five years at a workshop, meeting, or conference.

The third section, Technology and Nutrient Management, asked producers about the use of new and innovative practices that may improve both production efficiency and nutrient management. These practices are frequently termed 'Precision Agriculture' and are made possible the recent advances in and availability of Global Positioning Systems (GPS); mapping and modeling technologies with Geographic Information Systems (GIS); crop and remote sensing; and yield monitoring. These technologies allow for better control and management of field-level variability that may result from differences in soil type, nutrient content, and other varying factors. Whether or not a producer uses precision agriculture can be used to define the difference between advanced and basic level nutrient BMP adopters.

The fourth section, Costs of Nutrient Management, was included to obtain an understanding about the costs producers incurred to manage essential crop nutrients. Potential costs could include soil sampling, lab analyses, consulting fees, labor, or equipment. The question was deliberately written to exclude actual fertilizer costs, which were evaluated later in the survey. The section also included questions to better understand the elasticity of fertilizer price and total fertilizer application costs. Elasticity is a calculation that measures the way in which one variable changes in response to another. In this study, elasticity was used to measure how producers would change their demand for fertilizer given a hypothetical increase in fertilizer prices. The section also included two matrices of experimental questions intended to measure how producers would be willing to accept or willing to pay for three possible nutrient management scenarios. The scenarios included basic to advanced levels of nutrient management at three cost levels. For each of the given nutrient management plans, the producer had the option of selecting a single per acre amount that they would be willing to pay for the plan, based on a fixed interval of $0, $5, $15 or $25 dollars. This interval was selected to reflect actual payment values given to producers who voluntary participate in the USDA/NRCS Environmental Quality Incentive Program (EQIP).

The final section, Demographics, requested that the respondents provide basic demographic information about themselves. This included years of farming experience, farm location by county, gender, age, education level, annual gross farm sales and whether or not the respondent or spouse has another job off the farm.

SURVEY RESPONSE

Survey responses were obtained from 636 hard copies of surveys returned in the mail and from 261 responses obtained over the phone from the NASS regional call center. The overall gross response rate was 55.3%, including 209 respondents who were contacted by the NASS call center but declined to participate in the survey. These individuals either expressed concern that the survey did not apply to them, reportedly left agriculture, stated that they had less than 100 acres of irrigated agriculture, or simply did not irrigate at all. The response rate for completed surveys was 44.5%, however; this data included 128 individuals who reported no irrigated land. The NASS draw was intended to survey only irrigating farmers. The draw was based upon a pattern of answers to NASS's 2007 Ag Census data, but NASS also surveyed an unknown number of famers who do not currently irrigate. 128 of those producers returned the survey. Eliminating this group provided a net usable response rate of 37% (738 surveys out of 2,000 mailed) on which BMP adoption rates were calculated. A complete listing of surveys mailed and returned by county is provided in Table B3 of Appendix B. A complete table of response by county and region is provided in Appendix B.

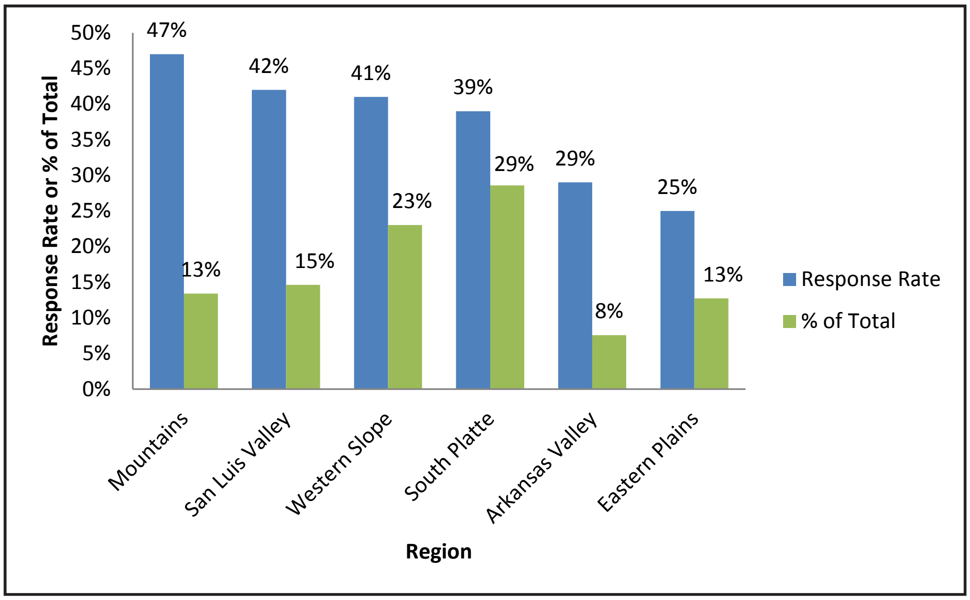

Figure 2: Usable survey response rates by region and percent of total responses within each region.

The percentage of usable surveys, by region, is presented in Figure 2. Survey response rates varied significantly by region. The region with the highest response, the Mountains, also had the lowest rate of fertilizer nutrient use. The low response rate in the Eastern Plains can be partially explained because the 128 returned surveys excluded from the analyses were disproportionately skewed towards the Eastern Plains.

SURVEY RESULTS

This section presents the word-for-word questions and a basic summary of results from the 2011 survey. Individual survey questions and corresponding responses are provided either in the text, or in an appendix, as noted. When applicable, results are compared to those of previous surveys, or government reports.

Most of the results are presented as the average percent of respondents using a particular practice or having a specific characteristic. These averages are the simple arithmetic mean of the percentage and are not weighted by the size of the group categorized. In general, if a question does not have a sufficient number of respondents (typically < 5) for accurate comparison, the calculation is not made and a footnote is provided to indicate as such. Totals sometimes do not sum to 100% because not every respondent answered each question or they provided more than one response for the question.

Respondent Characteristics

Demographic data indicates consistency with the 2007 NASS Census data, supporting the premise that a representative sample was obtained. Although demographic questions were posed at the end of the survey, the results are presented at the beginning of this report in order to provide better context for BMP adoption rates and cost information.

Agricultural producers were queried about age, number of years of farming experience, and number of years as primary owner/operator. The average age of the respondents was 57, with a small regional difference in age range, from 55 years on the Eastern Plains to 59 years in the Mountains. This is consistent with the 2007 Census of Agriculture (USDA/NASS, 2010) that also found the average age of the Colorado farmer to be 57 years.

Survey Question

Age? _____Years

While respondent age is important, producers who started farming later in life have a different experience level compared to those who started farming in their youth. For this sample, the average years of experience was 37.4 years, with the most experienced farmers in the Mountains regions and the least on the Eastern Plains.

Survey Question

How many years have you been involved in farming or ranching?
____________________Years

Producers were also asked how many years they were the primary operator of their current property. There was an average gap of approximately 12 years between years of actual farming experience and number of years as primary operator of the current farm. Table 1 summarizes the differences between the number of years involved in farming and the number of years serving as primary operator of the current property.

Survey Question

For how many years have you been the primary operator of your current property?

____________________Years

A complete table of county-level response data is provided in Appendix B. As previously stated, county level data was combined into the six regions. This aggregation accounts for the heterogeneity in water sources, cropping systems, livestock, soils, hydrology and climate that exist throughout Colorado. Most of the results provided in this report are reported by region.

Table 1: Average years primary farm operator

Region	Average # of years primary operator	Average # of years farming
Ark	24.8	37.3
E. Plains	27.7	37.1
Mts	22.3	39.9
S. Platte	24.9	36.9
SLV	24.6	35.4
W. Slope	25.7	38.2
Colorado	25.1	37.4

Survey Question

In what county is the majority of your farm located? _______________ County

The respondents for this survey were predominately male (95%). At first glance, this conflicts with the USDA/NASS 2007 Ag Census study that reports females as the principal operator of approximately 19% of agricultural operations. However, it should be noted that the majority of female owned operations in the 2007 Ag Census are smaller than 100 acres. In large operations, many females also report being co-operators with male partners. Hence, the high male response rate in the presenting study is not inconsistent with the actual gender distribution for operators of large farms using irrigated agriculture.

Survey Question

Are you? _____Male _____Female

Slightly more than half (50.3%) of the respondents or their spouse had an off farm job. On the Eastern Plains, respondents were more likely to obtain all of their income from the farm. The Arkansas Valley had the highest number (61%) of respondents working off farm, compared to a low of 42% on the Eastern Plains. Likewise, respondents reported having slightly less than 50% of their total combined income from the farm, with a high of 64% in the Eastern Plains and a low of 42% in the Mountains and Western Slope. Regional differences are shown in Figure 3.

Survey Question

Do you or a spouse have an off farm job?

_____No _____Yes

If yes, what percentage of your combined income is from farming? _______%

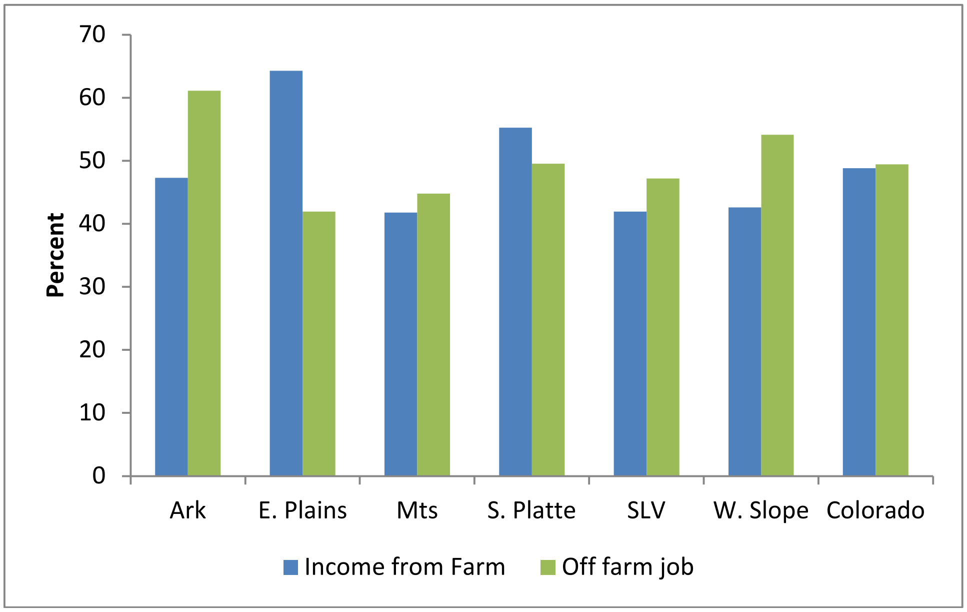

Figure 3: Income distribution from on and off farm sources.

The respondents in this survey were well educated, with almost two-thirds having some college or graduate school. Only a small minority did not finish high school.

Survey Question
Your highest level of formal education? (Please circle one)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20+
(Elementary) (Middle) (High School) (College) (Graduate Degree)

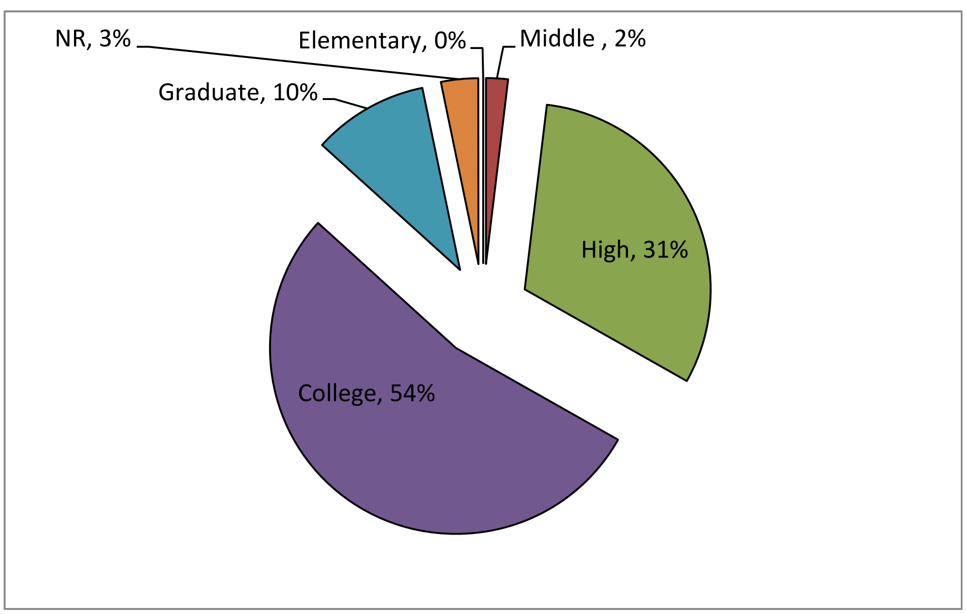

Figure 4: Education level of respondents.

Survey Question
Your estimated annual gross farm sales:
_____ under $50,000 _____ $100,000 - $249,999 _____ $500,000 - $1,000,000
_____ $50,000- $99,999 _____ $250,000 - $499,999 _____ over $1,000,000

The largest fraction of respondents reported gross farm sales of between $100,000 and $250,000 (Figure 5). Thirty-three percent had gross incomes greater than $250,000 and 44% had less than $100,000.

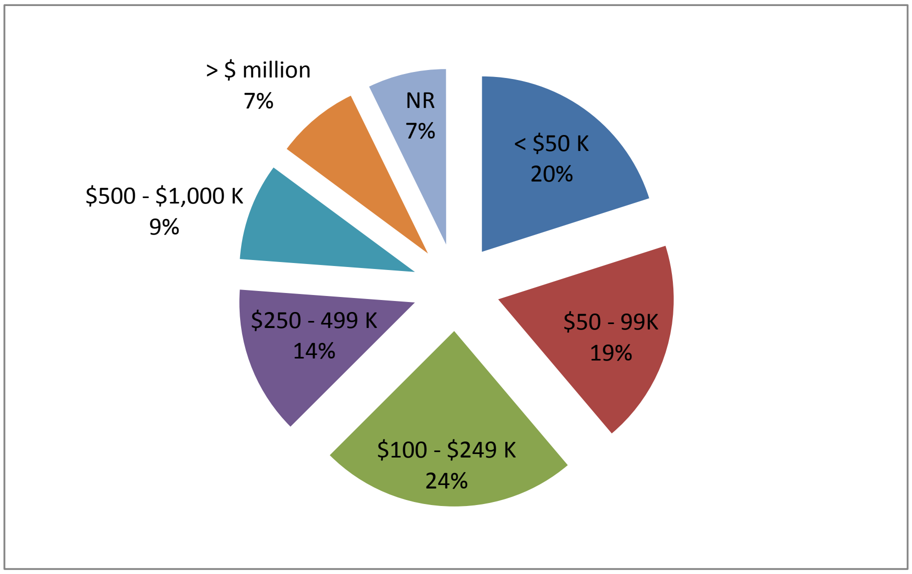

Figure 5: Gross farm sales of respondents

***Farm Characteristics** - Land*

Average farm size ranged from 1,411 acres in the San Luis Valley to 4,369 acres in the Eastern Plains.

Survey Question
What is the total* size of your farm of ranch? ___________ acres
*total number of irrigated and dryland acres

Table 2. Farm characteristics by identified region.

	Regional Farm Characteristics					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
Farm Size			(acres)			
Total Farm	172,075	410,716	300,562	315,236	152,338	293,705
Average Total	3,073	4,369	3,036	1,494	1,411	1,728
Median	1,025	2,000	1,200	600	700	377
Total Cropland*	53,984	201,722	55,249	179,088	79,100	86,003
Average Cropland	964	2,146	588	849	732	506
Median Cropland	382	1,138	250	445	445	220
Irrigated Area			(acres)			
Total	43,868	89,680	40,965	125,075	72,647	54,284
Average	783	954	414	593	673	319
Median	350	558	238	356	400	200
Water Source			(acres) %			
Groundwater	8	92	4	27	39	0
Surface Water	92	7	95	72	61	98

*Includes pasture and hay

The most recent Agricultural Census report (USDA/NASS, 2007) reported that total cropland in Colorado consisted of 11,483,936 acres on 37,054 farms. NASS reported that there were 15,774 irrigating farms with 2,867,957 acres under irrigation in the state. However, only 5,398 of these farms had greater than 100 acres with irrigation, the targeted audience for this survey. The 742 respondents to this survey reported farming a total of 656,819 acres, with 428,022 of these acres being irrigated (Table 1). Thus, the sample reflected approximately 14 percent of all irrigating agricultural producers and 15 percent of irrigated acreage of Colorado. Since NASS mailed surveys to an unknown number of producers that NASS thought were engaged in irrigated agricultural production (but who were not, as it turns out), the survey actually reached a larger percentage of the total number of NASS Census irrigated farms and irrigated acreage.

Regional differences in farm size and irrigated areas reflect the heterogeneous farming systems observed within the state. For example, the largest difference between total cropland and irrigated cropland was in the Eastern Plains region where many farms have significant dryland (non-irrigated) fields. Average farm size in this survey was slightly higher than NASS data, since the intention was to only survey farms with more than 100 acres of irrigation.

Farm water sources were divided between surface and groundwater. Groundwater was most commonly used in the Eastern Plains, the San Luis Valley and the South Platte, respectively. The division of surface versus groundwater use was similar, within 5%, to the 2002 survey (Bauder and Waskom, 2005) in all regions with in exception the Arkansas Valley, where in 2002, groundwater represented 16% of water use.

Survey Question

Please list your **major** farm enterprises in Colorado

Crop	Total Crop Acres*	Approximate Number of Irrigated Acres	Livestock Type	Peak # of Head in Past Three Years

*Total number of dryland and irrigated acres

Survey Question

Approximately what percentage of irrigation water used on your farm comes from the following sources? (allocations should total 100 percent)

Groundwater well _________ %   Surface water _________ %

Crops and Livestock

Alfalfa hay, corn, and wheat were the top three crops grown by respondents, in terms of total acres and number of respondents growing the crops. These crops also reflected the most acreage grown in Colorado for 2010, according to the Colorado Agricultural Statistics annual report (USDA/NASS, 2011). The crop mix was very similar to the 2002 BMP survey, with slightly more corn in grown in 2011. The increase in corn production was likely the result of higher prices in 2010.

Figure 6. shows the top seven major crops that were grown by at least five percent of the respondents. Irrigated corn and wheat require relatively higher nutrient rates as compared to alfalfa, so it is appropriate that we captured these acres in this survey. The 'Other low' and 'Other high' categories were created to capture the minor crops that are important locally, but that did not contain enough responses to report at the state level. 'Other low' value crops are generally crops that have a lower sales value and generally lower levels of inputs such as proso millet. 'Other high' value crops reflect crops like potatoes and other vegetables that usually produce a higher value and also require higher crop inputs to produce. Appendix Table B6 provides a list of actual crop and livestock types reported and the categorization used for 'Other high' and 'Other low'.

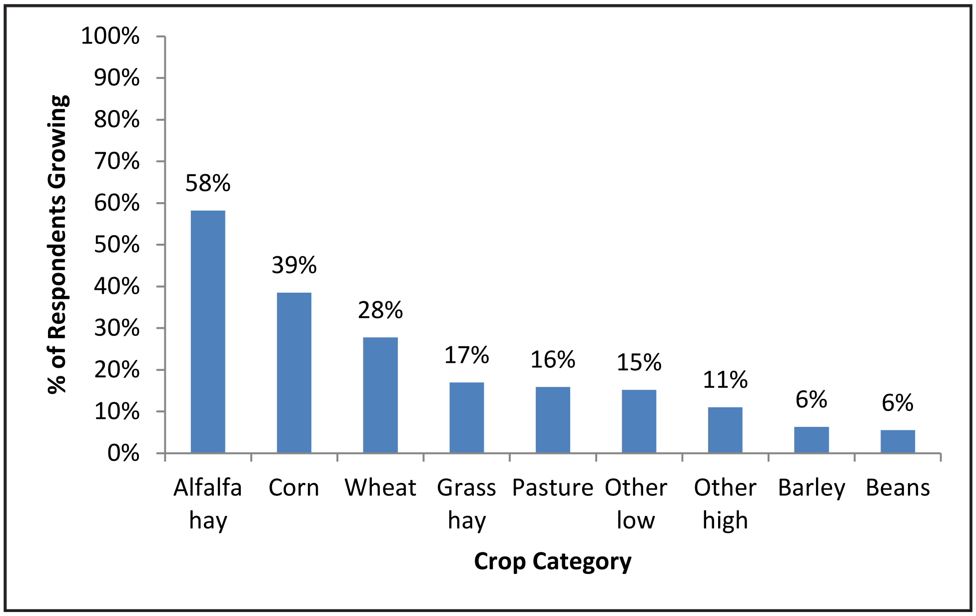

Figure 6: Percentage of respondents that report growing common Colorado crops

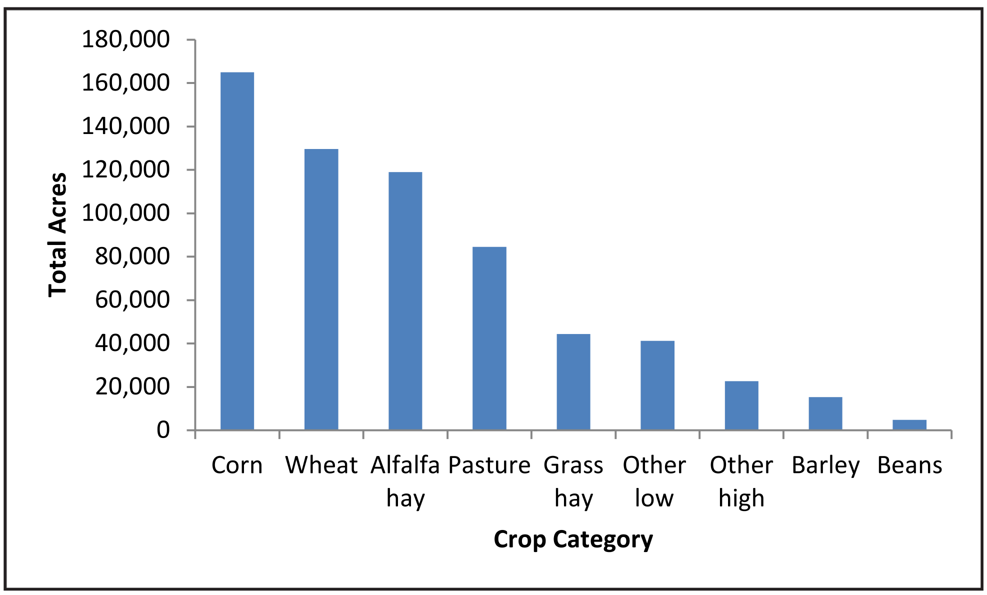

Figure 7: Total acres of common Colorado crops grown by respondents

The majority of respondents (63% statewide) owned at least one type of livestock (Table 3). However, 50% of the respondents reported that they owned less than 50 head and 80% had less than 250 head.

Beef cattle dominated the type and number of livestock raised (Figure 8). With the exception of horses, all other types of livestock were owned by less than five percent of respondents. Medium sized herds consisting of 51 – 250 head, were owned by 30% of the respondents and only 5% of respondents had >1,000 head of livestock.

Table 3. Respondents owning livestock by herd size

	Region						
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope	Colorado
# Head	% of Respondents						
0	36	47	18	52	46	21	37
< 50	11	11	12	14	11	15	13
50 - 250	34	21	40	19	30	42	30
251 - 1000	18	11	22	12	11	19	15
> 1000	2	11	7	4	2	4	5

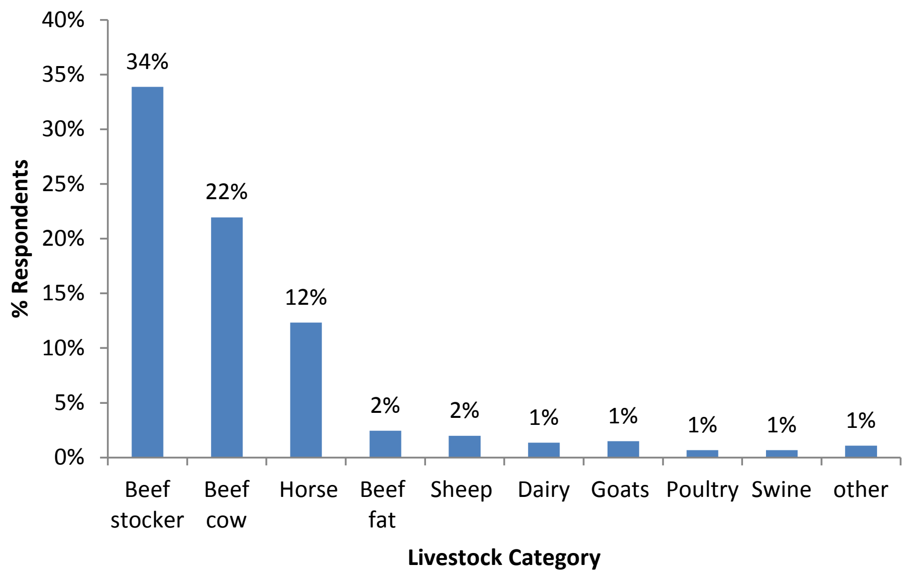

Figure 8: Percentage of respondents that report having livestock

Survey Question

What portion of your acres are rented or leased from someone else?

__________ % or __________ acres

Results for the rented/leased acre question were not compiled. Due to the ambiguity of the wording, it became apparent from the data that respondents did not answer the question with consistency. Some reported cropped acres leased, some reported irrigated acres, and others reported total acres, including potential grazing leases. In retrospect, the question should have been specific to the cropped or total acres to get meaningful results.

Survey Question

Approximately what percentage of your irrigated acreage is served by the following systems? (allocations should total 100 percent)

% Flood or furrow ______ % Sprinkler ______ % Drip ______ % Other ______

The type of irrigation system used was most highly influenced by the region and farm size. As farms grow larger, a greater percentage of irrigated acres are serviced by sprinkler irrigation (more often center pivot). In contrast, drip irrigation systems are more often utilized on smaller farms (Table 4). The differences in labor requirements between surface (flood and furrow) and sprinkler irrigation systems (particularly for center pivot irrigation) and available capital explain why larger farms tend to utilize sprinkler over surface irrigation systems in Colorado. Other drivers for irrigation system selection include water source and availability, potential for conservation, and pumping costs. Irrigation application efficiency, from lowest to highest, is ranked as follows: flood < furrow < sprinkler < drip. Higher efficiency systems require less overall gross water application and less pumping. This also increases nutrient use efficiency with fewer losses to runoff and leaching.

Table 4: Respondents using irrigation systems by farm size classification

	Farm Size Classification (acres)		
	100 to 999	1,000 to 2,999	> 3,000 acres
	% of respondents		
Flood or Furrow	51%	43%	33%
Sprinkler	44%	54%	63%
Drip	0.6%	0.3%	0%
Other Irrigation	3%	2%	0.6%
Non Response	0.9%	0.4%	3%
n	407	193	130

Statewide, a higher percent of the acres (56%) were covered by sprinkler irrigation than furrow/flood (42%), other (1.7%) and drip (0.3%). This compares to USDA/NASS data (NASS, 2007) showing 54% of acres under sprinkler, 49% covering furrow/flood, and 0.8% covering drip. The fairly close agreement is additional evidence that the 2011 survey obtained a representative sample. The amount of acreage covered by sprinkler irrigation increased by 14% compared to the 2002 survey (Bauder and Waskom, 2005), likely because producers recognized water savings and labor efficiency with this improved system. As the proportion of ground water sources increase, the proportion of acres covered by sprinkler irrigation vs. surface (furrow/flood) within a region also increases (Table 2).

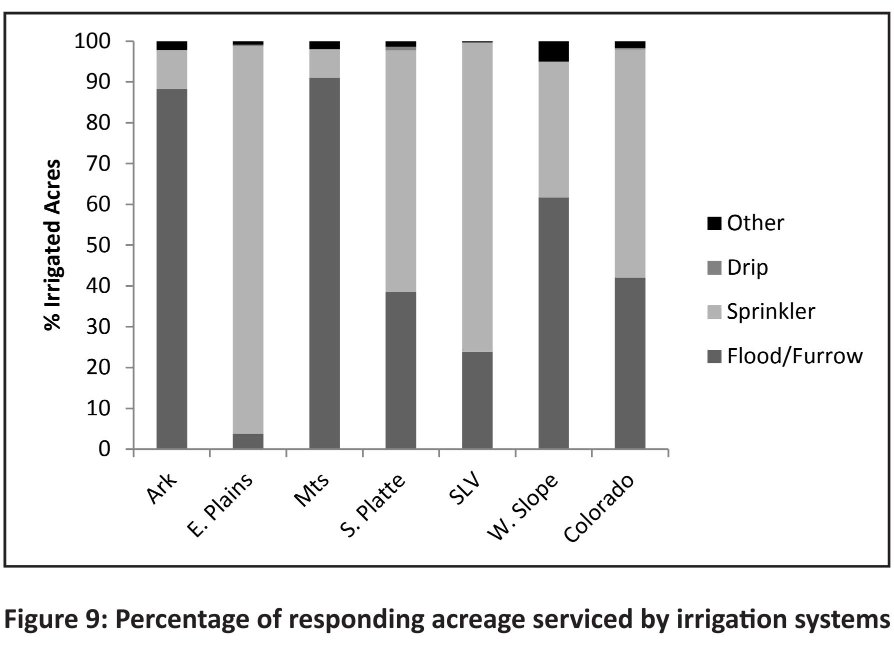

Figure 9: Percentage of responding acreage serviced by irrigation systems

Nutrient Management

Survey Question

With respect to your nutrient management do you?

Please check all that apply:

□ Keep written records □ Establish crop yield goals

□ Take plant tissues samples □ Use a paid crop consultant

□ Use soil test analysis to determine fertilizer rate □ Deep (subsoil) soil test

□ Use dealer rep for fertilizer recommendation □ None of these used.

□ Other ______________________________

One of the most obvious factors affecting the adoption of nutrient BMPs was the region of the state where the respondent farmed. For example, Table 5 shows very high adoption rates for soil testing in the Eastern Plains and South Platte regions. Results indicate that this basic BMP is well accepted by irrigating producers in these areas to help determine the correct amount and type of nutrient required to achieve high crop yields. In contrast, deep soil testing is much less accepted across all regions. While striking, the 0% adoption rate for deep soil testing for the Mountain region is appropriate as the soils there are typically shallow. Record keeping, which is required to qualify in the EQIP cost-sharing program, has been adopted at a rate of less than 50% in four of six regions. Record keeping was highest in regions with more respondents with sole income from farms. However, this was still a higher rate than reported in the 2002 survey (Bauder and Waskom, 2005). The percent of producers using paid crop consultants to determine fertilizer rates is highest in areas of higher value crops, and where crop consultants are active. The adoption of the 'Establish Yield Goals' BMP is not as high as expected based upon previous studies. It is possible that growers did not understand the concept, or that other factors (water) already limit yields enough so that the BMP would be considered ineffective. Plant tissue testing was also not widely used across the state, but was reported by roughly one out of five respondents in the Eastern Plains and San Luis Valley. These areas grow more acres of crops such as potatoes where tissue testing is much more common.

Table 5: Nutrient management methods used by respondents

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents using					
Keep Written Records	32%	67%	26%	52%	49%	31%
Establish Yield Goals	30%	51%	14%	41%	31%	16%
Plant Tissue Samples	5%	22%	4%	12%	20%	5%
Paid Crop Consultants	14%	48%	1%	22%	23%	1%
Deep Soil Test	13%	36%	0%	27%	19%	6%
Soil Test Analysis	41%	86%	21%	75%	50%	45%
Dealer Representative	27%	45%	18%	59%	28%	30%
Other	7%	2%	3%	6%	4%	5%
None	23%	6%	42%	12%	28%	36%

Survey Question

If you soil test, approximately what percent of your irrigated acreage was soil sampled in:

2010? ___________ The last three years? ___________

Some crop rotations and situations require annual soil testing for a high level of nutrient management. Continuous corn is an example of a rotation where annual soil testing would be beneficial from an agronomic and environmental perspective, as compared to a rotation with a high amount of alfalfa hay. Other rotations only need soil tested before certain crops with high nutrient requirements or after manure application. These regional differences are reflected in Figure 10 where respondents in the Eastern Plains, San Luis Valley, and the South Platte soil tested greater than 50% of their acres annually, compared to less than 50% in the West Slope, Arkansas and Mountain regions.

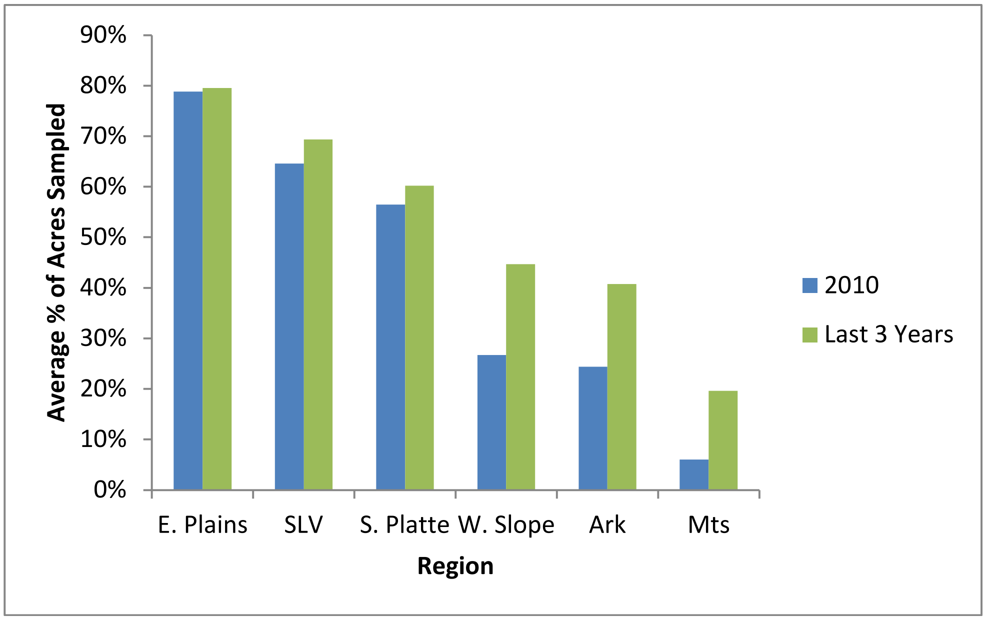

Figure 10. Soil testing frequency among producers who reported soil testing.

Survey Question

Do you use livestock manure, compost, or effluent for fertilizer?

□Yes □No

As demonstrated in Table 6, more than half of the producers reported applying manure. The widespread manure use implies that manure management BMPs should also be common. However, as indicated in Table 7 below, use of basic nutrient BMPs (such as soil testing) is lower for manure than fertilizer. The most likely explanation for this is that costs associated with manure over-application are relatively lower than costs for fertilizer nutrients. Another explanation is that some respondents likely apply a relatively small amount of manure, and thus not worth the time and effort to use soil testing or other BMPs to determine rate of application. The fact that many of the respondents own a relatively small number of livestock supports this supposition. Finally, some respondents may view manure application as disposal rather than a nutrient source.

Table 6: Percentage of respondents using manure

	Region						
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope	Colorado
	% of respondents applying						
Manure	55%	46%	64%	68%	56%	48%	57%

Survey Question

How do you determine your application rate?

Check all that apply.

□ Soil test analysis □ Manure analysis □Manure nutrient table values

□ Spreader capacity □ Paid crop consultant □ Same amount each time

□ None of these are used □ Other _______________

The Eastern Plains and South Platte regions had the highest number of respondents who reported using basic manure application BMPs. As shown in Table 4, these areas also have the highest number of confined livestock. In contrast, livestock operations in the Mountains and the West Slope tend to be more grazing oriented. Manure application is often deposited from grazing livestock, which explains the lower adoption rates in these regions. While 55.6% of respondents in the San Luis Valley reported applying manure, according to NASS, the number of livestock in this region and the number of acres applied are both low. This suggests that the actual amount of manure applied per farm is typically small in this region. High adoption rates for manure BMPs would not be expected.

Table 7: Nutrient management methods used by manure users

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents using					
Soil Test Analysis	23%	49%	5%	46%	22%	12%
Manure Analysis	19%	35%	0%	33%	10%	4%
Spreader Capacity	23%	28%	24%	34%	20%	26%
Manure Nutrient Table Values	19%	19%	0%	15%	2%	2%
Same Amount Each Time	19%	13%	11%	11%	15%	7%
Use All Manure From Pens	0%	0%	0%	0%	0%	0%
Use Paid Consultant	10%	30%	0%	19%	13%	0%
None	16%	12%	48%	8%	20%	30%
Other	13%	9%	19%	13%	28%	28%

Survey Question

During what season(s) are you most likely to apply manure?

Please check all that apply:

□ January/February □ March/April □May to September

□ October to December □ Varies

Table 8: Season in which manure is applied among those who use manure.

	Region					
	Ark	E. Plains	Mts.	S. Platte	SLV	W. Slope
% of respondents						
January/February	39%	28%	24%	28%	12%	20%
March/April	32%	51%	59%	38%	40%	43%
May/September	3%	5%	14%	8%	8%	12%
October/December	23%	21%	29%	39%	25%	26%
Season Varies	19%	12%	16%	21%	20%	27%

Questions regarding time of application and incorporation were included to better understand off-season run-off and risk of nutrient movement through ammonia volatility. Statewide, respondents were most likely to apply manure during March and April. The least amount of manure is applied during the summer growing season. There was also less manure applied during the winter months in Mountains and the San Luis Valley. However, manure was more commonly applied in mid-winter in the Arkansas Valley where it is warmer. In the South Platte, manure application was evenly split between the spring and late fall.

Survey Question

Manure is typically incorporated after application within:

□ Two days □ One week □ One month

□ After one month □ Not incorporated □ Other________________

Manure incorporation is used to preserve the ammonia portion of the nitrogen content for later use by crops and to prevent runoff in vulnerable environments. Other times, manure is left on the surface to prevent wind erosion or because the cropping system is not tilled. Liquid manure or effluent can also be applied by sprinkler during the growing season and not incorporated by tillage. Respondents from the Arkansas Valley were most likely to incorporate their manure within one week. Manure spread in the Mountains, San Luis Valley and West Slope regions is the least likely to be incorporated (Table 9). Given the crop mixes in those regions it is likely that a significant portion of the manure is spread and/or deposited by animals on pastures and hay crops, which are not tilled. Thus, it is reasonable that a sizeable number of respondents would not incorporate the manure. The broad range of timing suggests that manure incorporation as a standard practice is not common.

Table 9: Time until incorporation among manure users

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents using					
Two Days	23%	12%	5%	28%	15%	5%
One Week	45%	19%	11%	28%	10%	11%
One Month	10%	19%	8%	16%	8%	12%
After One Month	10%	16%	3%	10%	7%	10%
Not Incorporated	6%	21%	44%	13%	30%	27%
Other Time Incorporated	6%	16%	10%	15%	23%	31%

Survey Question

Do you reduce your fertilizer or manure rate to account for nutrients from any of the following?

Check all that apply

□ Previous manure application □ Previous legume crop

□ Irrigation water nitrate □ No

□ Determined by crop consultant Other______________

In many cases, determining the correct nutrient application rate for fertilizer or manure requires subtracting other nutrients available (applying credits) that can help meet crop nutrient demand. In Colorado, the most important potential credits involve previous manure applications, legume crops (alfalfa or beans), and irrigation water nitrate. Unlike a basic BMP such as soil testing, nutrient crediting is less likely to be adopted by Colorado producers although this varied considerably by region (Table 10). In some regions, producers often rely on crop consultants to determine nutrient credits. The irrigation water nitrate credit is most appropriate for groundwater users since surface water generally does not have sufficient nitrate to credit. It is interesting to note that the regions with the highest adoption of irrigation water nitrate crediting also have more wells with elevated nitrate levels (Bauder et al, 2013). This result was also observed in the previous survey (Bauder and Waskom, 2002). The variation in legume crediting may be due to subsequent crops in the rotation and stand quality when an alfalfa field is terminated. On the whole, the lower nutrient credit adoption rates suggest that producers may not have confidence in nutrient availability from sources besides fertilizer or current manure applications. The availability of nutrients from previous manure applications and legume crops can vary due to a variety of factors, including weather and other field conditions.

Table 10: Reduction in fertilizer or manure rate to account for other sources of nutrients

Credit	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents using					
Previous Manure†	39%	40%	13%	42%	17%	27%
Previous Legume Crop‡	32%	77%	2%	31%	23%	26%
Irrigation Water Nitrate₴	20%	7%	**	24%	21%	**
Determined By Crop Consultant	20%	39%	1%	29%	26%	5%
None	43%	27%	69%	27%	43%	55%
Other credit	5%	5%	5%	8%	4%	5%

**Fewer than five respondents

†Percent of respondents using manure

‡Percent of respondents growing alfalfa or beans

₴Percent of respondents using some or all groundwater

Survey Question

Check all the methods that you use to apply fertilizer.

□Broadcast □ Sidedress □ Do not apply commercial N or P fertilizer

□Injection □ Fertigation □ None of these application methods

□Subsurface band □ Topdress □ Other ________________________

□Foliar □Dribble

Applying nutrients directly into the root zone enhances nutrient uptake and prevents movement to surface water. It is thus defined as a BMP. However, in order to be effective, these methods should be appropriate for the cropping system. There is correlation between the fertilizer application methods in Table 11 and crop type and irrigation system. For example, a higher percentage of center pivot irrigation systems in the Eastern Plains allows for fertilizer to be efficiently applied during the growing season. This explains why 48.4% of respondents in that region utilize fertigation. In contrast, fertigation application is not a recommended BMP for most surface irrigation systems. As a result it is not common in the Mountain or Western Slope regions that have a higher percentage of hay and pasture crops. In general, the most practical application method for these systems is broadcast. Table 11 also shows that respondents are least likely to apply any commercial fertilizer in the Mountains and the San Luis Valley.

Table 11: Methods used to apply commerical fertilizer

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents using					
Broadcast	70%	53%	55%	79%	69%	78%
Injection	19%	49%	1%	19%	35%	11%
Subsurface Band	13%	36%	0%	12%	14%	5%
Foliar	9%	26%	0%	12%	24%	6%
Sidedress	33%	22%	0%	30%	14%	12%
Fertigation	11%	48%	0%	22%	19%	5%
Topdress	26%	45%	10%	23%	29%	16%
Dribble	11%	9%	3%	7%	2%	0.7%
None of These Application Methods	7%	1%	20%	3%	13%	9%
Other Application Method	4%	10%	11%	6%	8%	7%
Do Not Apply Commercial N Fertilizer	9%	4%	20%	5%	12%	14%

Survey Question

Check all the times when you apply fertilizer

□ Fall pre-plan □ Planting (starter) □ Do not apply commercial N or P fertilizer

□ Spring pre-plant □ In-season □ None of these application methods

□ Other ________________________________

Timing and placement both strongly influence efficient crop uptake and potential for movement (Bauder and Waskom, 2003; Bauder and Waskom, 2010). Table 12 reports the season when respondents applied crop nutrients. In-season partial nitrogen applications are typically considered a BMP. Fall pre-plant is discouraged in some systems, particularly spring crops. An exception is winter wheat and perennial pasture grasses and alfalfa. As with method of application, timing of application is closely related to the cropping system. Applying nutrients, particularly nitrogen in smaller increments or split application, is particularly recommended to improve efficient utilization. These BMPs are most likely to be adopted by producers in the Eastern Plains, Arkansas, and South Platte regions.

Table 12: Time in which fertilizer has been applied

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents					
Fall pre-plant	20%	33%	5%	28%	9%	14%
Spring pre-plant	59%	75%	30%	67%	60%	60%
Planting (starter)	22%	71%	0%	26%	28%	13%
In season	50%	59%	15%	49%	39%	24%
None	9%	2%	30%	2%	14%	9%
Other	4%	3%	14%	6%	8%	14%
Split Apply N	46%	73%	3%	43%	39%	22%

Survey Question

Do you utilize any of the following fertilization products?

Please check all that apply:

□ Urease inhibitors (e.g. Agrotain) □ Nitrification inhibitors (e.g. N-Serve)

□ Slow release or coated fertilizers □ Other ________________________

□ None

Fertilizer stabilization, uptake enhancements, and slow release products reflect a nutrient BMP suite that is less commonly utilized by Colorado growers. These products include urease inhibitors, that are utilized to prevent losses from ammonia volatilization from fertilizer products such as urea and urea-ammonia nitrate (UAN). These losses do not directly impact water quality, but they do indirectly if the volatilized ammonia later reaches water bodies through atmospheric deposition. In contrast, nitrification inhibitors slow the conversion of ammonium to nitrate in the soil. Ammonium is a positively charged ion and is much less likely to leach through the soil profile than nitrate. Nitrification inhibitors are most appropriate in areas with sandy soils and shallow ground water.

Slow release or coated fertilizers delay the availability of nitrate and ammonium from fertilizer products. The products are intended to allow fertilizer to be applied prior to the optimum time for efficient crop uptake. The release occurs later in the season and is better timed to crop need. Higher costs associated with all these products make them more appropriate for higher value crops with shallow root zones and environments vulnerable to leaching. The majority of respondents did not report utilizing advanced fertilizer products (Table 13).

Table 13: Enhanced fertilizer products used by respondents

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents Using					
Urease inhibitors	11%	7%	1%	9%	0%	5%
Slow release or coated fertilizers	22%	36%	6%	24%	19%	29%
Nitrification inhibitors	6%	10%	3%	10%	1%	3%
None	59%	51%	89%	48%	70%	62%
Other	4%	7%	5%	7%	10%	8%

Survey Question

Do you utilize any of the following practices on your farm?

Please check all that apply:

□ Filter or buffer strips □ Cover Crops

□ Linear Polyacrylamide (PAM) □ Conservation tillage (mulch till, strip-till, etc.)

□ Rotate between shallow and deep rooted crops

□ Convert from flood or surface irrigation to sprinkler or drip to reduce runoff

□ None used

□ Grassed Waterways

□ Other _________________________

Nutrient losses can also be mitigated by transport BMPs. Transport BMPs include a variety of physical and management practices, such as those shown in the previous question box, that reduce runoff and/or leaching of nutrients at the field scale. Adoption rates for transport management practices vary from very low to high depending upon the BMP and region (Table 14). Some BMPs are not appropriate or applicable to certain regions of the state. For example, cover crops are typically utilized for reducing erosion following crops like sugar beets, potatoes and onions. Cover crops are appropriate following these crops because they leave little residue and/or their harvest requires a significant soil disturbance. Cover crops also can be used to protect young plants such as alfalfa or small vegetables during seeding. These cropping systems are more prevalent in the eastern slope river basins and the San Luis Valley, but not in areas with mostly perennial hay and pasture crops such as the Mountain region.

It is likely that many growers are utilizing BMPs such as rotating between shallow and deep-rooted crops and conservation tillage more for erosion prevention or other benefits, rather than nutrient management. Irrespective of the intention, there may be resulting water quality benefits from doing so. Like many of the other nutrient management practices, transport BMPs varied widely by region. For example, conservation tillage has highest adoption rate in Eastern Plains, which likely reflects the higher amounts of dryland acreage and center pivot irrigation in that region. Linear polyacrylamide has the highest adoption rate in Arkansas Valley where it has been promoted most heavily by NRCS and Extension for surface irrigated systems.

Table 14: Use of structural management practices by respondents in regions

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents using					
Filter or buffer strips	5%	9%	3%	17%	4%	5%
Linear Polyacrylamide (PAM)	21%	1%	4%	11%	0%	5%
Convert from flood or surface to sprinkler or drip	7%	22%	4%	29%	19%	21%
Rotate between shallow and deep rooted crops	38%	32%	4%	37%	34%	16%
Cover crops	27%	31%	3%	27%	24%	26%
Conservation tillage (mulch till, strip till, etc.)	23%	66%	1%	37%	25%	10%
Grassed Waterways	5%	13%	6%	12%	4%	14%
None	25%	13%	61%	22%	35%	30%
Other	0%	3%	4%	3%	2%	2%

Survey Question

Have you attended workshops/meetings/conferences where you have received information related to nutrient management and fertilization practices during the past five years?

□ Yes □ No

Keeping up on the latest nutrient management and fertilization practices can help farmers make informed nutrient management decisions. Fertilizer dealers, CO-OPs, Extension, USDA/NRCS, and other entities often sponsor meetings and workshops. While the subject matter of these workshops may not always reflect a 'BMP' approach to nutrient management, the workshops often present information on new fertilizer products and application techniques. Results suggest that respondents in the Eastern Plains either have more of these opportunities and/or attend these types of workshops more frequently.

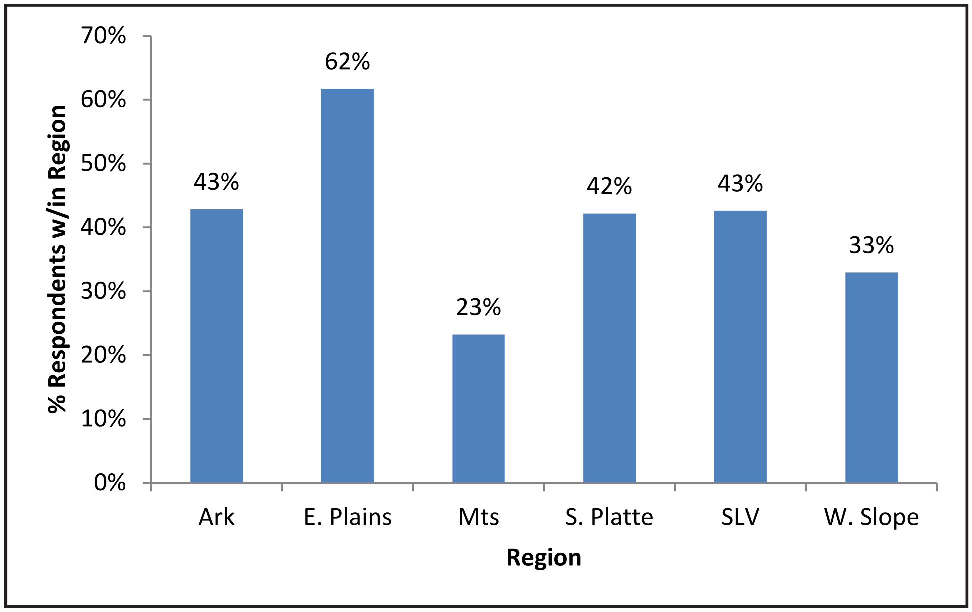

Figure 11: Respondents attending workshops on nutrient management

Technology and Nutrient Management

Survey Question

Have you employed any of the following technologies on your farm?

Please check all that apply:

□ Light bar guidance system □ Auto steering □ Grid Soil Sampling

□ Management Zones □ Crop Sensing □ Field mapping

□ Yield monitoring/mapping □ None used

□ Variable rate fertilizer application

□ Other ________________________

Advances in Global Positioning Systems (GPS) and differentially corrected GPS signals have improved field-level nutrient management. For example, light bar guidance systems and auto steering can help farmers reduce overlap and skips when applying broadcast fertilizer. Although these technologies may help with nutrient management, they are likely adopted for other reasons. For example, light bar guidance systems and auto steering allow producers to reduce spray and fertilizer overlap, but they also reduce driver fatigue, increase fuel efficiency during tillage operations and cover more acres. Precision technologies like yield monitors are appropriate for row crops and small grain cropping systems, but not for hay crops. The highest adoption rates are in the Eastern Plains and South Platte where larger farms with grain crops can better take advantage of these technologies.

Table 15 : Precision farming technologies used by Colorado respondents within a region.

Technology	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents using					
Light bar guidance system	13%	35%	0%	21%	10%	5%
Management Zones	2%	12%	2%	7%	7%	4%
Yield Monitor/Mapping	9%	47%	5%	16%	13%	7%
Variable Rate Fertilizer Application	5%	26%	3%	14%	7%	8%
Auto Steering	16%	64%	1%	28%	22%	2%
Crop Sensing	0%	12%	0%	2%	2%	1%
Grid Soil Sampling	4%	16%	2%	10%	14%	4%
Field Mapping	18%	32%	5%	24%	19%	4%
None	59%	17%	70%	38%	47%	67%
Other	2%	3%	3%	4%	1%	2%

Survey Question

Have you ever used the information provided by your yield monitoring system to make fertilizer management decisions?

□Yes □ No □I do not use a yield monitor

A yield monitor on a combine or other harvesting equipment provides real-time yield information. Yield mapping and electronically stored yield records enhance these capabilities. This information can be used to alter nutrient application decisions on the whole or partial field basis. The information in Table 16 only utilized results from respondents growing grain crops (not forage), because yield monitors are most widely available for grain combines. Among farmers utilizing a yield monitor, only a minority uses the information to make fertilizer management decisions for grain crops. This is likely due to the fact that few decision support systems are currently available to translate yield monitor information into usable outputs, like fertilizer recommendations, or transfer maps into management zones.

Table 16 : Yield monitor used to make fertilizer management decisions among respondents growing a grain crop.

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents					
Yield monitor is used to make fertilizer decisions	7%	38%	**	14%	21%	7%
Yield monitor is not used to make fertilizer decisions	32%	41%	**	37%	31%	21%
Do not use a yield monitor	61%	20%	**	47%	43%	65%

**Fewer than five respondents

Survey Question

Do you currently use any soil or crop sensing technology to test for fertility? (e.g. soil EC, soil color, crop (canopy) sensors)

□ Yes □ No

Crop sensing is an experimental technology that has been used primarily on wheat and corn in Colorado. The process can be performed either by on-the-go sensors installed on fertilizer application equipment or remotely by airplane or satellite imagery. While crop sensors are commercially available for purchase, recommendations for adjusting fertilizer are not currently available from CSU Extension. Thus, only a very small number of the respondents reported using this technology for fertility testing at the time of this survey. Soil EC (electrical conductivity) mapping is a technology that can be utilized to develop yield management zones that may be used to vary fertility rates within a field. While these technologies were grouped into one question, it is clear that adoption of soil and crop sensing is still low in Colorado.

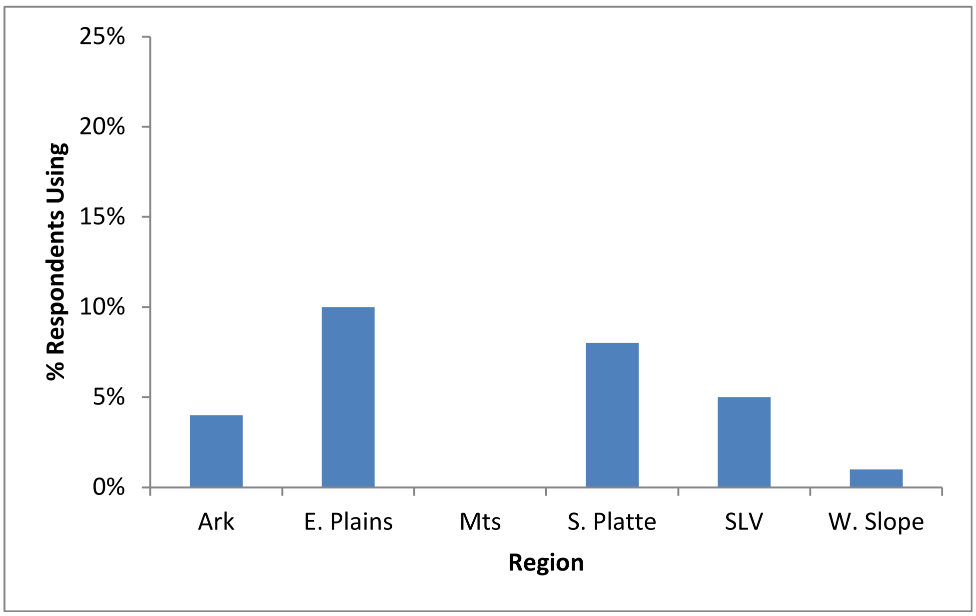

Figure 12: Respondents using crop sensing technology to test for soil fertility

Survey Question

Do you take separate soil samples to account for variability within a field?

□ Yes □ No (I take one composite sample) □ I do not soil sample

Survey Question

If yes check all that apply:

□ I collected the sample □ A consultant collected the sample

□ Used GPS to sample in grids or zones □ I don't know if GPS was used to sample

Because nutrient content can vary significantly within a field (Mzuku et al., 2005; Inman et al., 2005), multiple soil samples can be taken within a field to account for soil nutrient availability. This is known as precision sampling. This study showed that the frequency by which producers conduct precision sampling was largely determined by the primary crops grown in the region where they farmed. The Eastern Plains and South Platte tend to separate samples more than other regions. This reflects the trend of larger fields, field variability, and the use of paid crop consultants. Curiously, the number of producers who reported 'I do not soil sample' was lower than the soil sampling non-response in Table 5. This could reflect respondent confusion, or it could reflect the fact that soil samples are not necessarily taken for nutrient management, but rather for another purpose such as sampling for pests or soil moisture content.

Table 17. Separate soil samples are taken to account for field variability

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	% of respondents					
Separate samples are taken	29%	76%	23%	58%	39%	31%
I take one composite sample	25%	14%	15%	20%	22%	20%
I do not sample	41%	6%	52%	18%	29%	41%

Of the respondents who reported taking separate soil samples to account for variability, very few indicated that GPS was used to sample in grids or zones (Table 18). Consultants were more likely to take separate samples in the Eastern Plains, South Platte, and the San Luis Valley. Respondents in the other regions reported taking the sample themselves. Overall, only a few respondents in this survey reported that they conducted precision sampling.

Table 18. Methods to collect soil samples by respondents who sampled to take account for field variability.

	Region						
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope	CO
	% of Respondents that Collected Separate Samples						
Self collect sample	56%	15%	48%	16%	24%	79%	31%
Use GPS to sample	**	14%	**	8%	**	**	9%
Consultant sampled	38%	76%	35%	83%	74%	27%	66%
Don't know if GPS used	**	7%	**	4%	**	**	4%

**Fewer than 5 respondents

Costs of Nutrient Management

One of the primary objectives of this study was to ascertain the costs of nutrient management. Nutrient management costs can be measured by the acre for practices like soil testing, or measured by total cost for purchases like a new piece of equipment.

Survey Question

I spent $_________ per acre on nutrient management in 2010, not including fertilizer.

I spent a total of $_________ during 2010 on nutrient management in 2010, not including fertilizer.

The results of the two questions about nutrient management costs were mixed in terms of the range of values that were reported, particularly for the Arkansas and San Luis Valley regions. The average reported nutrient management costs for these two areas appeared to be much higher than the level of adoption reported from the other questions. A review of the data showed that a few very high values in per acre costs caused these averages to be high. The most likely explanation for this result is that some respondents misread the question and included fertilizer costs. However, it is possible that the respondents incurred large fertilizer application equipment expenses and allocated those expenses across their cropped acreage. Costs reported for the other four regions were in line with expected values. To validate the costs, a literature review was conducted on the costs most commonly associated with the nutrient BMPs queried in this study (Keske, Bauder, and Irrer, 2011). The results of this review are provided in Table B7. As shown in Table 19, the calculated costs associated with the BMPs reported closely agree with the reported costs in every region except the Arkansas and San Luis Valleys. Calculated expenditures for BMP adoption were highest in the Eastern Plains where reported BMPs are generally higher and lowest in the Mountains. This was consistent with the cropping intensities in the respective regions.

Table 19. BMP expenditures reported and calculated by region and by average acre cost

Region	Reported Per Acre Nutrient BMP Expenditures	Calculated Per Acre Nutrient BMPs Expenditures *
Arkansas	$71.59	$14.20
E. Plains	$23.14	$20.80
Mts.	$3.20	$2.20
S. Platte	$15.86	$15.20
SLV	$56.04	$10.50
W. Slope	$5.22	$7.30
Colorado	$23.64	$11.60

*Average BMP expenditures include precision agriculture, transport, and nutrient BMPs.

Depending upon the cropping system, fertilizer prices can be up to 30% of the total crop inputs budget. To better understand how a potential increase in fertilizer costs might affect fertilizer use, the following question was included. This study uses a “point elasticity” measurement to determine how producers would change their practices in response to a specified price or cost increase. In reality, producer behavior would likely be different at various price points. For example, at a very high price level, they could stop using fertilizer altogether. Respondents were queried about a 15% change in prices, as this value represents the median inter-annual change in fertilizer prices during the past 15 years (USDA Economic Research Service, 2011).

Survey Question

As you know, farm input costs vary each year. Given a 15% increase in the price of fertilizer how much less fertilizer would you apply? Please check one:

______ 0% (not affected) ______10% less ______15% less

______25% less ______33% less ______ Other (Please specify)

Not unexpectedly, fertilizer proved to be a relatively inelastic input at 15% increased price for survey respondents. In other words, with a 15% price increase, the majority of producers would not change their use of fertilizer, or minimally decrease their use of fertilizer. Over half of the respondents in every region except the mountains indicated that a 15% price increase would not cause any reduction in their fertilizer application (Table 20). Of those who would reduce their rate, the most common reduction was 10%. Ten percent of respondents did not answer the question. Many respondents commented that they thought they were currently at the lowest application rate possible and any further reduction would cause a significant yield loss. Others felt that commodity prices have kept pace with nutrient costs. Another factor was the higher than average grain prices, particularly corn at the time of the survey, which would buffer the effect of a potential fertilizer price increase. While producers might be able to sustain cost increases during times of high commodity prices, fertilizer and nutrient management costs will erode profit margins when the crop prices fall.

Table 20. Percent* reduction in fertilizer application due to a 15% price increase

	Region						
Values	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope	CO
	% Reduction in Fertilizer Applied						
0% (not affected)	63%	67%	49%	58%	60%	53%	57%
10% less	7%	12%	12%	15%	6%	9%	11%
15% less	7%	6%	3%	5%	3%	9%	6%
25% less	7%	3%	3%	2%	4%	6%	4%
33% less	2%	0%	3%	1%	4%	3%	2%

*Results do not sum to 100% due to nonresponses for this question

Survey Question

Would you change your nutrient management practices if your total operation costs increased by 10%? □Yes □No

Please explain:

Similar to fertilizer prices, the majority of respondents indicated that they would be unlikely to modify their nutrient management practices, if total operation costs increased by 10% (Figure 12). Specifically, 62% of respondents stated that they would not change their nutrient management practices. Only 21% stated that they would change their nutrient management practices, and 16% did not respond to the question. Approximately 10% of respondents provided subjective comments on the survey. Their comments reinforced that respondents believe that higher yields are directly related to more fertilizer, and that they would continue make the investment in fertilizer, particularly in the context of high commodity prices. So long as commodity prices and profit margins are high, most producers will look to reducing other operational costs rather than reducing nutrient management costs. Putting these results in context, it appears as though participants view nutrient inputs as necessary expenses that they are not willing to forego with a price increase because many believe that they are currently applying only the nutrients needed to achieve current yield goals.

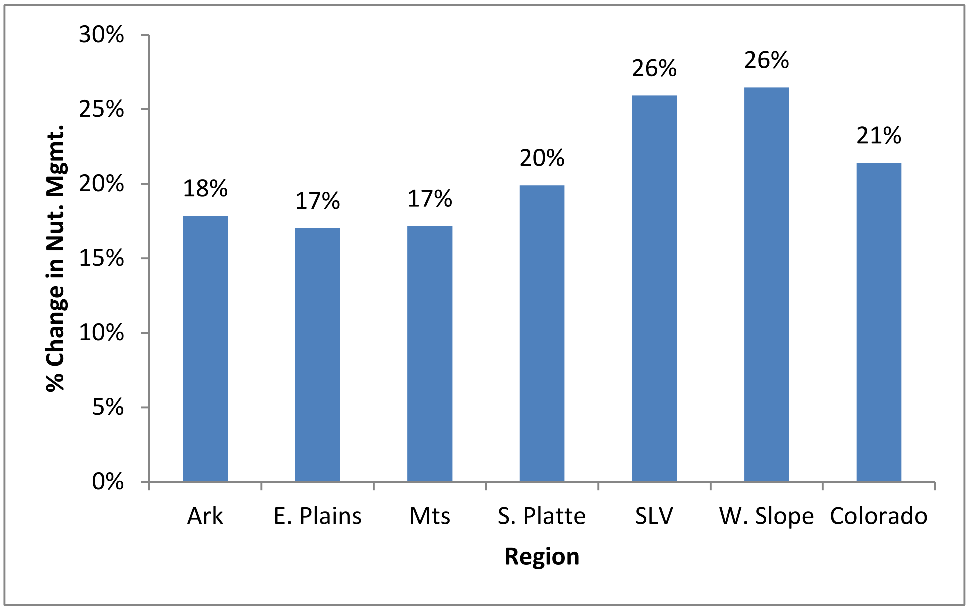

Figure 13. Percent of respondents indicating a change in nutrient management with a 10% increase in total input costs.

The final section was a "Willingness to Accept and Willingness to Pay" question matrix. The two part matrix was designed to learn how much producers would need as a cost share to increase their level of nutrient management and how much they were willing to spend on the same nutrient management practices without cost share.

The levels of nutrient management offered in this question were similar to those found by the USDA/NRCS Environmental Quality Incentives (EQIP) program. The cost share ranges of $0.00 to $25.00 per acre were based upon this EQIP payment schedule. The payment schedule at the time of the survey was $5.66, $11.67 and $21.79 for basic, moderate and adavanced nutrient management, respectively. These EQIP levels were similar to options A, B and C int his question.

The results from this section of the survey were not as complete as other sections of the survey because up to 38% of the respondents left all or part of the section blank. This could have been due to the complexity of the question, poor wording, and/or respondents' unfamiliarity and distrust with government cost share programs. It also could indicate that the respondent was not willing to accept that option of nutrient management at any level of cost share. That potential response should have been part of the matrix, but was not realized until after the study. Regardless, the results presented here should be considered with the understanding that the response rate is substantially lower than the survey as a whole, and that the matrix question was experimental in nature.

Survey Question

(a) Please consider the following three options (A, B, C) for managing plant nutrients. What level **of cost share** (e.g. reimbursement) would you need in order to use the following nutrient management options?

	Minimum cost share in $/acre			
Practice options Check one box per management option	$0.00	$5.00	$15.00	$25.00
Option A: 1. Soil test fields at least once every 3-5 years, 2. Reduce fertilizer rate to account for legume, manure and/or water nutrients <u>when appropriate</u>, and 3. Maintain record of nutrient applications, rotation, and yeilds for at least 5 years.	☐	☐	☐	☐
Option B: Use all of the practices in Option A, plus soil test fields <u>every year</u>.	☐	☐	☐	☐
Option C: Use all of the practices in Option A, and utilize GPS or other technologies that vary your fertlizer rate according to yield zones, crop sensors or soil variability.	☐	☐	☐	☐

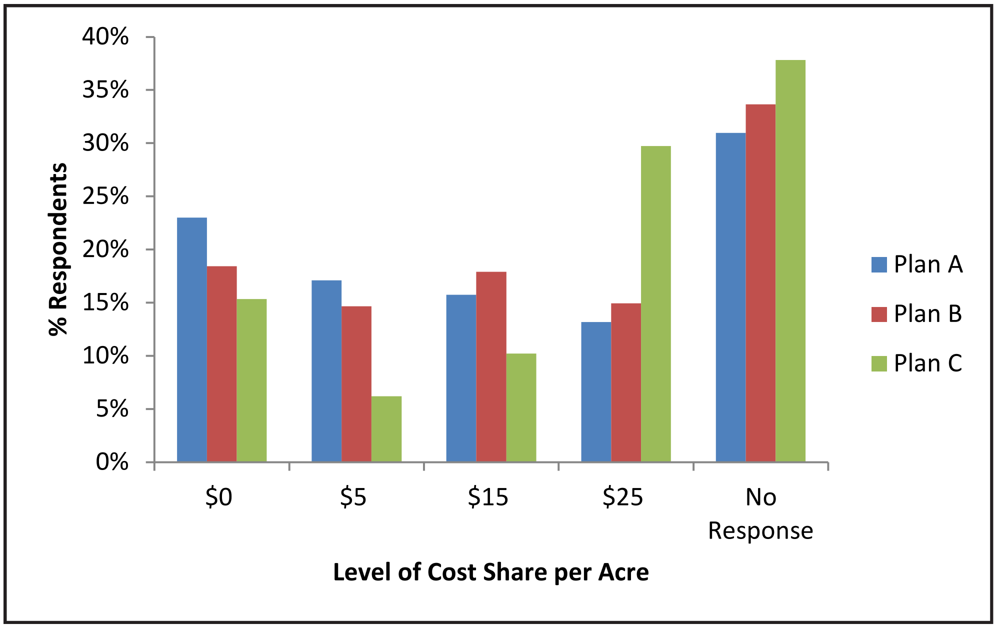

Figure 14. Levels of cost share required (willingness to accept) for three options of nutrient management.

As shown in Figure 14, respondents generally required an increased level of cost share as the complexity of the nutrient management program increased from Plan A to Plan C. This is expected given the potential costs associated with adopting that level of management. What is striking is the number of producers (23 – 15%) who indicated that they would adopt one of the plans for no cost share ($0) at all. Many of these producers are likely adopting these practices already and don't feel they need compensation because they find a return on their investment. On the other hand, some producers wanted the higher levels of compensation ($15 – 20) for the most basic plan A, which does not cost that much to implement on an annual per acre basis.

Survey Question

4(b) What is the most that you would be willing to spend for the following nutrient management practices, if you did **<u>not</u>** receive reimbursement?

	Minimum cost share in $/acre			
Practice options Check one box per management option	$0.00	$5.00	$15.00	$25.00
Option A: 1. Soil test fields at least once every 3-5 years, 2. Reduce fertilizer rate to account for legume, manure and/or water nutrients <u>when appropriate</u>, and 3. Maintain record of nutrient applications, rotation, and yeilds for at least 5 years.	☐	☐	☐	☐
Option B: Use all of the practices in Option A, plus soil test fields <u>every year</u>.	☐	☐	☐	☐
Option C: Use all of the practices in Option A, and utilize GPS or other technologies that vary your fertlizer rate according to yield zones, crop sensors or soil variability.	☐	☐	☐	☐

The responses for the willing to pay question followed patterns that would generally be expected. Less than 10% respondents were willing to spend the highest amount per acre, $25 dollars per acre, even to obtain the highest level of nutrient management in Option C (Figure 15). On the other end of the spectrum, approximately 30% of the respondents indicated that they were not willing to spend any amount ($0) for even the basic level of nutrient management with reimbursement. This group likely is divided between those who would not adopt this nutrient management plan regardless of cost and those who might be adopting this less of management on their own and don't see a reason to spend extra money for something they doing for themselves. Written comments offered in the margins of the survey support both suppositions. Both the parts of this section offer some insight into respondents' views on input costs and returns for in increasing levels of nutrient management and what level of cost share funds would be required to foster this adoption.

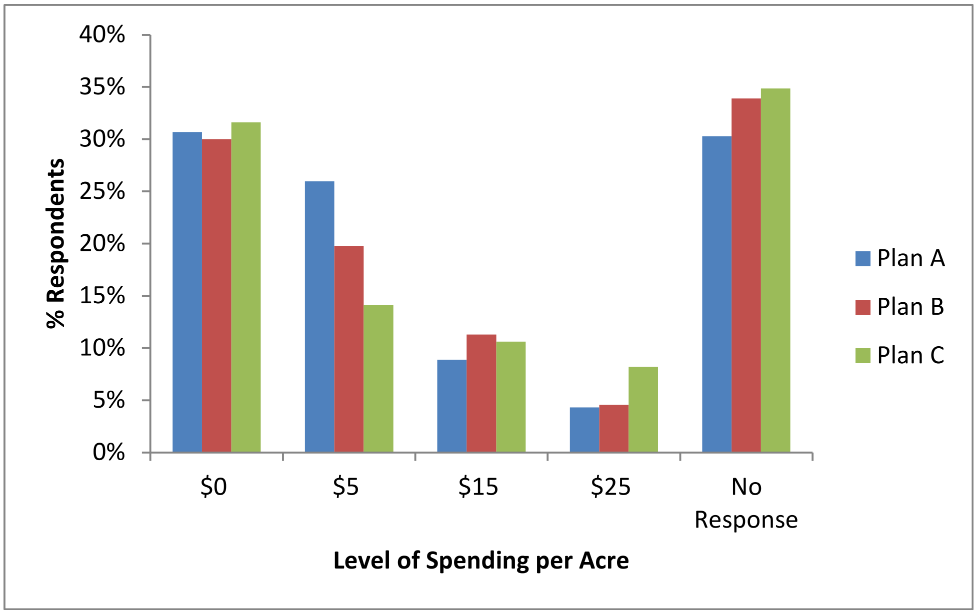

Figure 15. Willingness to spend for three options of nutrient management at four levels of cost share.

Summary

A survey of 2,000 Colorado producers was conducted to better understand their current level of nutrient management level adoption and costs they incur for this adoption. Despite a high response rate (55.4%), 37% (738 surveys out of 2,000 mailed) of these surveys were used to generate this report. These surveys appear to constitute a representative sample of the 2007 NASS Agricultural Census data, which is considered to be the most accurate sources for agricultural demographic information.

One of the primary messages of this report is the nutrient management practices adopted by Colorado producers is highly correlated with by the region of the state where the farm is located. Colorado's irrigated farming regions are diverse in terms of crop and livestock systems, irrigation systems, water sources, nutrient types and application amounts, input costs, and management styles. Additionally, crop landscapes vary from high altitude mountain hay meadows to intensive vegetable row crops in the river valleys. In fact, the Colorado NRCS has ten distinct crop management zones in Colorado as opposed to two or three in other states. Thus, the geographic and hydrologic characteristics combined with farm and producer diversity make evaluating the necessary suite of BMP systems to protect water quality a challenging task.

This survey was the first in Colorado to address the use of new technologies such as precision agriculture in managing nutrients and the cost of nutrient BMP implementation at the farm scale. The results suggested that while precision agriculture technologies are gaining acceptance among Colorado producers, only a small minority are utilizing them for sub-field scale nutrient management. Adoption is also low among respondents who may not benefit as much from their use such as those not producing row crops. The survey results also revealed that Colorado producers and willing to bear some costs for improved nutrient management and are currently implementing some practices without significant cost share programs.

Supplemental nutrients, particularly nitrogen and phosphorus, are critical components of highly productive irrigated agriculture. This study found that most Colorado producers are implementing some level of nutrient management to enhance nutrient use efficiency and prevent losses from irrigated fields. The BMPs with higher rates of adoption tend to be those with lower costs or are cost neutral to the producer, whiles others may require incentive programs to achieve higher levels of adoption. An important question that this report does not address is: What level of BMP adoption is necessary to protect water resources from nutrient impairment and have we reached that level in Colorado? Ultimately, the answers to this question is more localized than our county level data can address. The decision as to whether to implement a BMP or suite of BMPs needs to be made at the local watershed scale, where the vulnerability of the water resource, farmer preferences, and cropping system factors should also be considered.

REFERENCES

Bauder, T.A., R.M. Waskom, and W.M. Frasier. 2003. Producer Adoption of Nutrient Best Management Practices in Colorado. Western Nutrient Management Conference Proceedings 5: 102-106.

Bauder, T.A., and R.M. Waskom. 2011. Economic Considerations of Nutrient Management BMPs. Agricultural Chemicals and Groundwater Protection, Colorado Department of Agriculture. www.colorado.gov/ag/gw [Accessed October 2013].

Bauder, T.A., and R.M. Waskom. 2005. Survey of Irrigation, Nutrient, and Pesticide Management Practices in Colorado. Report No. TR0507, Colorado Agriculture Experiment Station, Fort Collins, CO.

Bauder, T., R. Waskom, R. Wawrzynski, K. Mauch, and G. Naugle. 2013. Agricultural Chemicals and Groundwater Protection in Colorado. Special Report No. 23, Colorado Water Institute, Fort Collins, CO.

Dillman, D. The Design and Administration of Mail Surveys. 1991. Annual Review of Sociology 17: 225-249.

Dillman, D., J.D. Smyth, and L. Melani Christian. 2008. Internet, Mail, and Mixed-Mode Surveys: The Tailored Design Method, 3rd edition. Hoboken, NJ: Wiley and Sons.

Dubrovsky, N. M., K.R. Burow, G.M. Clark, J.M. Gronberg, P.A. Hamilton, K.Hitt, D.K. Mueller, M.D. Munn, B.T. Nolan, L.J. Puckett, M.G. Rupert, T.M. Short, N.E. Spahr, L.A. Sprague, and W.G. Wilber. 2010. Nutrients in the Nation's Streams and Groundwater 1992-2004. USGS Circular 1350.www.pubs.usgs.gov/circ/1350/ [Accessed Nov 2013]

Frasier, W.M., R.M. Waskom, D.L. Hoag and T.A. Bauder. 1999. Irrigation Management in Colorado: Survey Data and Findings. Report No. TR-99-05, Colorado Agriculture Experiment Station, Fort Collins, CO.

Frasier, W.M., R.M. Waskom, T.A. Bauder and B.A. Jordan. 2001. Estimated Cost of Adoption for Irrigation, Pest and Nutrient Best Management Practices in Colorado. Technical Report for the Colorado Department of Public Health and Environment from the Colorado Water Resources Institute, Colorado State University, Fort Collins, CO.

Inman, D., R. Khosla, D.G. Westfall, and R. Reich. 2005. Nitrogen Uptake across Site Specific Management Zones in Irrigated Corn Production Systems. Agron. J. 97:169-176.

Keske, C.M.H., T. Bauder, and A. Irrer. 2011. Colorado Nutrient Management Practices 1997-2011: Costs and Technological Advances. Submitted to the Colorado Department of Public Health and the Environment.

Mzuku, M., R. Khosla, R. Reich, D. Inman, F. Smith, and L. MacDonald. 2005. Spatial Variability of Measured Soil Properties across Site-Specific Management Zones. Soil Sci. Soc. Am. J. 69:1572-1579.

National Agricultural Statistics Service (NASS). 2007. Colorado Census Publications 1(2) County Level Data. Available at http://www.agcensus.usda.gov/index.php [Accessed September 30, 2013].

Puckett, L.J., Tesoriero, A.J. and N.M. Dubrovsky. 2011. Nitrogen Contamination of Surficial Aquifers – A Growing Legacy. Environ. Sci. Technol. 45, 839-844.

Ribaudo, M., J. Delgado, L. Hansen, M. Livingston, R. Moshiem, and J. Williamson. 2011. Nitrogen in Agricultural Systems: Implications for Conservation Policy. Economic Research Report No. 127, USDA/Economic Research Service, Washington, DC.

USDA/National Agricultural Statistics Service. 2011. Colorado Agricultural Statistics. Available at http://www.nass.usda.gov/Statistics_by_State/Colorado/Publications/Annual_Statistical_Bulletin/bulletin2011.pdf [Accessed September 30, 2013].

U.S. Census Bureau. 2012. International Programs Database. Available at http://www.census.gov/population/international/data/idb/informationGateway.php [Accessed March, 18, 2012].

United States Department of Agriculture – Economic Research Service (USDA-ERS). 2013. Fertilizer Consumption and Use—By Year (Updated May 6, 2011). Available at http://www.ers.usda.gov/Data/FertilizerUse/ [Accessed September 30, 2013].

APPENDIX A

Survey Instrument and Cover Letter

Department of Soil and Crop Sciences
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Fort Collins, Colorado 80523-1170
(970) 491-6517
FAX: (970) 491-0564
www.soilcrop.colostate.edu

January 10, 2011

Dear Colorado Agricultural Producer:

You have been randomly selected to participate in a Best Management Practice survey sponsored by the Colorado Department of Agriculture. We respectfully request your participation. The purpose of the survey is to better understand the costs that you incur as a result of implementing nutrient Best Management Practices. Results will inform policy makers of the costs agricultural producers incur to maintain a high level of environmental quality.

There are no "right" or "wrong" answers. We simply appreciate your best effort and participation in the study.

Your participation is strictly voluntary. Your personal information and identity will remain confidential at all times. Neither the Colorado Department of Agriculture nor the Colorado State University research team will be able to identify you.

It is *very important* that we receive your completed survey. We understand that your time is valuable, and we believe that it will take approximately 10-15 minutes to complete.

Please return the survey in the enclosed postage paid envelope to the National Agricultural Statistical Service (NASS). If NASS does not receive your survey in three weeks, they will send you follow-up survey.

Should you have questions or comments, please do not hesitate to contact one of the researchers on this project.

Thank you for your participation. We look forward to receiving your survey!

Mr. Troy Bauder
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Nutrient Management Practices

What does it cost you to manage crop nutrients?
Tell us about your experience.

Thank you for participating in this project. Please ensure that the individual responsible for making the nutrient management decisions completes the survey.

Your answers are confidential and your identity will remain unknown to the Colorado Department of Agriculture and the Colorado State University research team.

Your input is very important! Please ensure that you attempt to answer every question in the survey. Please return the survey in the attached postage paid envelope.
Thank you again. We look forward to receiving your survey!

3

Section A. General Farm/Ranch Information

1. What is the total size of your farm or ranch? _____________ acres

2. Please list your **major** farm enterprises in Colorado:

Crop	Total Crop Acres*	Approximate Number of Irrigated Acres

Livestock Type	Peak # of Head in Past Three Years

*Total number of dryland and irrigated acres

3. What portion of your acres are rented or leased from someone else?

   ______________% or _____________ acres

4. **Approximately** what percentage of irrigation water used on your farm comes from the following sources? (allocations should total 100 percent)

   Groundwater well _______ % Surface water _______ %

5. **Approximately** what percentage of your irrigated acreage is served by the following systems? (allocations should total 100 percent)

   Flood or furrow_______ % Sprinkler_______ % Drip_______ % Other ___________ %

Section B. Nutrient Management Experience

Please share with us your experience with managing crop nutrients. Please refer to the insert if you have questions about the terms used.

1. With respect to your crop nutrient (fertility) management do you?
Please check all that apply:
☐ Keep written records ☐ Establish crop yield goals ☐ Take plant tissues samples
☐ Use soil test analysis to determine fertilizer rate ☐ Use a paid crop consultant
☐ Use dealer rep for fertilizer recommendation ☐ Deep (subsoil) soil test
☐ Other ____________ ☐ None of these used.

2. If you soil test, approximately what percent of your **irrigated** acreage was soil sampled in: 2010? ________% The last three years? ________%

3. Do you use livestock manure, compost, or effluent for fertilizer?
☐ Yes ☐ No **If no, skip to question 7**

4. How do you determine your manure or compost application rate?
Please check all that apply:
☐ Soil test analysis ☐ Manure analysis ☐ Manure nutrient table values
☐ Spreader capacity ☐ Paid crop consultant ☐ Same amount each time
☐ None of these are used ☐ Other ____________

5. During what season(s) are you most likely to apply manure?
Please check all that apply:
☐January/February ☐ March/April ☐May to September
☐October to December ☐ Varies

6. Manure is typically incorporated after application within:
☐ Two days ☐ One week ☐ One month
☐ After one month ☐ Not incorporated ☐ Other____________

7. Do you reduce your fertilizer or manure rate to account for nutrients from any of the following sources? **Please check all that apply:**
☐ Previous manure application ☐ Previous legume crop
☐ Irrigation water nitrate ☐ No
☐ Determined by crop consultant Other ________

8. Check **all** the application methods that you use to apply fertilizer.
☐Broadcast ☐ Sidedress ☐ Do not apply commercial fertilizer
☐Injection ☐ Fertigation ☐ None of these application methods
☐Subsurface band ☐ Topdress ☐ Other ____________
☐Foliar ☐Dribble

9. Check **all** the times when you apply fertilizer.
☐ Fall pre-plant ☐ Planting (starter) ☐ Do not apply commercial fertilizer
☐ Spring pre-plant ☐In-season ☐ None of these application methods
☐ Other ___________________________

10. Do you utilize any of the following fertilizer products? **Please check all that apply:**
☐ Urease inhibitors (e.g. Agrotain) ☐ Nitrification inhibitors (e.g. N-Serve)
☐ Slow release or coated fertilizers ☐ Other ___________________________ ☐None

11. Do you utilize any of the following practices on your farm? **Please check all that apply:**
☐ Filter or buffer strips ☐ Cover Crops ☐ Grassed Waterways
☐ Linear Polyacrylamide (PAM) ☐ Conservation tillage (mulch till, strip-till, etc.)
☐ Rotate between shallow and deep rooted crops
☐ Convert from flood or surface irrigation to sprinkler or drip to reduce runoff
☐ None used ☐Other ___________________________

12. Have you attended workshops, meetings or conferences where you have received information related to nutrient management and fertilization practices during the past five years?
☐ Yes ☐ No

Section C. Technology and Nutrient Management

Please answer the following questions related to the technology and nutrient management of your farm operation as accurately as possible.

1 . Have you employed any of the following technologies on your farm? **Please check all that apply**:
☐ Light bar guidance system ☐ Auto steering ☐ Grid soil sampling
☐ Management zones ☐ Crop sensing ☐ Field mapping
☐ Yield monitoring/mapping ☐ None used
☐ Variable rate fertilizer application
☐ Other _____________________

2. Have you ever used the information provided by your yield monitoring system to make fertilizer management decisions?
☐ Yes ☐ No ☐ I do not use a yield monitor

3. Do you currently use any soil or crop sensing technology to test for fertility? (e.g. soil EC, soil color, crop (canopy) sensors)
☐ Yes ☐ No

4 (a). Do you take separate soil samples to account for variability within a field?
☐ Yes ☐ No (I take one composite sample) ☐ I do not soil sample

4 (b). If **yes** check all that apply:
☐ I collected the sample ☐ A consultant collected the sample
☐ Used GPS to sample in grids or zones ☐ I don't know if GPS was used to sample

5. If you would like to share information about other practices that you use on your operation with regards to crop fertility and nutrient management, please use the space below.

Section D. Costs of Nutrient Management

Please ***estimate*** the costs that you incurred during 2010 for nutrient management. Costs may include soil sampling, lab analysis fees, consulting fees, labor, equipment (or other direct costs).

1. I spent $_____________ per acre on nutrient management in 2010, **not including fertilizer**.

2. I spent a total of $__________ during 2010 on nutrient management, **not including fertilizer**.

3 (a). As you know, farm input costs vary each year. Given a 15% increase in the price of fertilizer, how much less fertilizer would you apply? **Please check one:**

_____ 0% (not affected) _____10% less _____15% less
_____25% less _____33% less ______ Other (Please specify)

3(b). Would you change your nutrient management practices if your **total operation costs** increased by 10%? ☐ Yes ☐ No

Please explain, below:

4. **(a)** Please consider the following three options (A, B, C) for managing plant nutrients. What level **of cost share** (e.g. reimbursement) would you need in order to use the following nutrient management options?

Practice options Check **one** box per management option	**Minimum cost share in $/acre**			
	$0.00	**$5.00**	**$15.00**	**$25.00**
Option A: 1. Soil test fields at least once every 3-5 years, 2. Reduce fertilizer rate to account for legume, manure and/or water nutrients <u>when appropriate</u>, and 3. Maintain records of nutrient applications, rotations, and yields for at least 5 years	☐	☐	☐	☐
Option B: Use all of the practices in Option A, plus soil test fields <u>every year</u>.	☐	☐	☐	☐
Option C: Use all of the practices in Option A, **and** utilize GPS or other technologies that vary your fertilizer rate according to yield zones, crop sensors or soil variability.	☐	☐	☐	☐

4(b) What is the most that you would be willing to spend for the following nutrient management practices, if you did **<u>not</u>** receive reimbursement?

Practice options Check **one** box per management option	**$/acre**			
	$0.00	**$5.00**	**$15.00**	**$25.00**
Option A: 1. Soil test fields at least once every 3-5 years, 2. Reduce fertilizer rate to account for legume, manure and/or water nutrients <u>when appropriate</u>, and 3. Maintain records of nutrient applications, rotations, and yields for at least 5 years	☐	☐	☐	☐
Option B: Use all of the practices in Option A, plus soil testing <u>every year</u>.	☐	☐	☐	☐
Option C: Use all of the practices in Option A, **and** utilize GPS or other technologies that vary your fertilizer rate according to yield zones, crop sensors or soil variability.	☐	☐	☐	☐

Section E. Please tell us something about yourself.

These last few questions will help us evaluate how well our sample represents Colorado farm operators. **Your answers will be kept strictly confidential and will only be used for the analysis of this study. It will not be given to anyone or used for any other purpose. You will not be identified in any way.**

1. How many years have you been involved in farming or ranching?
   ________________Years

2. For how many years have you been the primary operator of your current property?

   _________________Years

3. In what county is the ***majority*** of your farm located? ______________ County

4. Are you? _____Male _____Female

5. Age? _____Years

6. Do you or a spouse have an off farm job?
   _____No _____Yes

   If yes, what percentage of your combined income is from farming? _______%

7. Your highest level of formal education? (Please circle one)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20+
(Elementary) (Junior High/Middle) (High School) (College or Technical) (Graduate or Professional)

8. Your estimated annual gross farm sales:

_____ under $50,000 _____ $100,000 - $249,999 _____ $500,000 - $1,000,000

_____ $50,000- $99,999 _____ $250,000 - $499,999 _____ over $1,000,000

Thank you for completing the survey!

If you have any additional comments please feel free to write them on the next page. When you are finished, **please place the survey in the postage paid return envelope and mail it back to us.**

APPENDIX B

Supporting Data Tables

Table B1. Percentage of respondents within each farm size classification

	Farm Size[a] (acres)					
Region	**50 to 249**	**250 to 499**	**500 to 999**	**1,000 to 2,499**	**2,500 to 4,999**	**over 5,000**
			% of respondents			
S. Platte	19%	24%	22%	21%	8%	6%
E. Plains	**	**	17%	31%	26%	19%
Ark	13%	23%	13%	21%	13%	20%
SLV	17%	22%	25%	23%	9%	**
Mts.	15%	12%	15%	24%	20%	13%
W. Slope	31%	22%	17%	15%	7%	8%
Colorado	19%	19%	19%	22%	12%	10%

[a] Includes all irrigated and dry cropland, pasture, and rangeland

** Five respondents or fewer in category

Table B2. Percentage of respondents with irrigated acreage within each size classification

	Irrigated Acres[a]					
Region	**50 to 249**	**250 to 499**	**500 to 999**	**1,000 to 2,499**	**2,500 to 4,999**	**over 5,000**
			% of respondents			
S. Platte	19%	27%	19%	15%	3%	**
E. Plains	23%	24%	19%	27%	**	**
Ark	32%	36%	20%	**	**	**
SLV	30%	25%	24%	17%	6%	**
Mts.	52%	23%	15%	10%	**	**
W. Slope	59%	24%	12%	4%	**	**
Colorado	41%	26%	18%	13%	3%	**

[a] Includes all irrigated and dry cropland, pasture, and rangeland
** Five respondents or fewer in category

Table B3. Number of surveys returned by county and region*

Survey Respondents by Region				
Region	**County**	**# of Surveys Sent**	**# of Usable Returned Surveys**	**% Captured**
South Platte	Adams	23	7	30%
	Boulder	26	11	42%
	Larimer	48	16	33%
	Logan	80	27	34%
	Morgan	87	29	33%
	Sedgwick	27	6	22%
	Weld	252	115	46%
	Total	543	211	39%
Eastern Plains				
	Arapahoe	7	1	14%
	Baca	38	8	21%
	Cheyenne	16	2	13%
	Douglas	6	1	17%
	El Paso	12	3	25%
	Elbert	14	1	7%
	Jefferson	1	0	0%
	Kit Carson	74	19	26%
	Lincoln	16	2	13%
	Phillips	44	13	30%
	Washington	33	8	24%
	Yuma	118	36	31%
	Total	379	94	25%
Arkansas Valley				
	Bent	29	10	34%
	Crowley	10	2	20%
	Kiowa	12	2	17%
	Las Animas	21	9	43%
	Otero	43	15	35%
	Prowers	55	10	18%
	Pueblo	26	8	31%
	Total	196	56	29%
San Luis Valley				
	Alamosa	50	21	42%
	Conejos	73	29	40%

	Costilla	15	5	33%
	Rio Grande	68	32	47%
	Saguache	51	21	41%
	Total	257	108	42%

Region	**County**	**# of Surveys Sent**	**# of Usable Returned Surveys**	**% Captured**
Mountains				
	Chaffee	17	7	41%
	Custer	17	11	65%
	Eagle	12	4	33%
	Fremont	11	5	45%
	Grand	22	12	55%
	Gunnison	26	12	46%
	Huerfano	15	4	27%
	Jackson	25	13	52%
	Ouray	9	4	44%
	Park	10	4	40%
	Pitkin	5	3	60%
	Routt	43	19	44%
	Summit		1	
	Total	212	99	47%
Western Slope				
	Archuleta	11	7	64%
	Delta	59	23	39%
	Dolores	12	1	8%
	Garfield	43	18	42%
	La Plata	48	26	54%
	Mesa	58	29	50%
	Moffat	28	12	43%
	Montezuma	53	19	36%
	Montrose	70	26	37%
	Rio Blanco	25	7	28%
	San Miguel	6	2	33%
	Total	413	170	41%
Non Response			4	

Table B4. Crops grown on respondents' farms

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	Regional Crop Characteristics					
Alfalfa hay						
Average Crop Acres	286	221	349	197	402	261
% of Total Crop Acres Irrigated	98%	94%	82%	100%	95%	94%
% of Respondents Growing	75%	23%	58%	62%	66%	62%
Barley						
Average Crop Acres		80		94	427	
% of Total Crop Acres Irrigated		0%		96%	100%	
% of Respondents Growing	0%	1%	0%	7%	30%	0%
Beans						
Average Crop Acres	161	173		107		85
% of Total Crop Acres Irrigated	100%	100%		96%		77%
% of Respondents Growing	2%	12%	0%	8%	0%	8%
Corn						
Average Crop Acres	197	1,192		439	60	120
% of Total Crop Acres Irrigated	100%	68%		98%	100%	100%
% of Respondents Growing	63%	80%	0%	69%	1%	16%
Grass hay						
Average Crop Acres	311	240	651	145	397	218
% of Total Crop Acres Irrigated	100%	79%	80%	95%	85%	94%
% of Respondents Growing	5%	2%	35%	13%	18%	24%
Other High Value Crop						
Average Crop Acres	80	410		251	359	122
% of Total Crop Acres Irrigated	100%	100%		100%	98%	100%
% of Respondents Growing	5%	9%	0%	18%	20%	6%
Other Low Value Crop*						
Average Crop Acres	149	672	55	540	179	164
% of Total Crop Acres Irrigated	68%	28%	100%	27%	84%	43%
% of Respondents Growing	34%	23%	1%	15%	20%	10%
Pasture						
Average Crop Acres	2,148	1,078	1,010	385	272	826
% of Total Crop Acres Irrigated	93%	3%	51%	17%	75%	28%
% of Respondents Growing	11%	5%	12%	14%	19%	26%
Wheat						
Average Crop Acres	821	1,036	100	458	416	135
% of Total Crop Acres Irrigated	50%	10%	0%	25%	100%	37%
% of Respondents Growing	38%	64%	1%	42%	17%	10%

** Five respondents or fewer in category

Table B5. Livestock raised on respondents' farms.

	Region					
	Ark	E. Plains	Mts	S. Platte	SLV	W. Slope
	Regional Livestock Characteristics					
Beef Cow						
Total # of Head	3,525	4,498	8,616	7,802	3,502	8,205
Average # of Head	220	214	345	217	175	195
% of Respondents With Livestock	29%	22%	25%	17%	18%	25%
Beef Fat						
Total # of Head	1,485	6,280	370	20,910	**	570
Average # of Head	495	1,570	185	5,228	**	114
% of Respondents With Livestock	5%	4%	2%	1%	**	3%
Beef Stocker						
Total # of Head	2,968	28,508	18,008	75,172	5,668	15,947
Average # of Head	165	1,056	340	1,474	202	228
% of Respondents With Livestock	32%	29%	53%	24%	263%	41%
Dairy Cow						
Total # of Head	**	**	**	5,790	**	**
Average # of Head	**	**	**	827	**	**
% of Respondents With Livestock	**	**	**	3%	**	**
Horse						
Total # of Head	**	**	508	202	565	886
Average # of Head	**	**	24	12	43	28
% of Respondents With Livestock	**	**	21%	8%	12%	18%
Sheep						
Total # of Head	**	**	**	**	**	4,090
Average # of Head	**	**	**	**	**	682
% of Respondents With Livestock	**	**	**	**	**	3%
Poultry, Goats, Swine or Other						
Total # of Head	**	**	**	**	**	**
Average # of Head	**	**	**	**	**	**
% of Respondents With Livestock	**	**	**	**	**	**

** Five respondents or fewer in category

Table B6. Actual crop provided and categorization used for other low and high value crops.

Crop	# Responses	Crop	# Responses
Other High Value		Other Low Value	
Sugar beets	32	Sunflowers	25
Potatoes	21	Oats	25
Sweet corn	3	Sorghum/milo	25
Onions	10	Millet	11
Sod (turf)	8	Fallow	10
Peaches	4	CRP	9
Carrots	3	Triticale	7
Vegetable	2	Canola	6
Pumpkins	2	Forage Sorghum	6
Spruce trees	2	Oat Hay	5
Turnips	1	Summer fallow	4
Grapes	2	Hay grazer	4
Peas	1	Other	3
Apples	2	Feed	3
Cherries	2	Sudangrass	3
Plums	1	Rye	2
Cover crop radishes	1	Wasteland	1
Pears	2	Open farm grain	1
Hops	1	Misc	1
Certified organic veggies	1	Hay-feed	1
		Green manure	1
		dry Land	1
		dry	1
		Cane	1
		Bolhent?	1

Table B7. Literature review of BMP adoption costs

Costs as reported in literature and not adjusted for inflation

Management Practice	Per Acre Cost	Sources[1]
Soil Sampling	$0.88 - $1	• HRWCI – Phosphorus Management and Water Quality Protection • HRWCI – Nutrient Management and Water Quality Protection • USDA EQIP Article 590 C – Nutrient Management • Kansas State – Water Quality Best Management Practices • CDA – Agricultural Chemicals and Groundwater Protection
Keep Written Records	$0-$1	• USDA EQIP Article 590 C – Nutrient Management • CDA – Agricultural Chemicals and Groundwater Protection
Establish Realistic Yield Goals	$0 - $0.75	• USDA EQIP Article 590 C – Nutrient Management • CDA – Agricultural Chemicals and Groundwater Protection
Plant Tissue Samples	$1	• University of California – Sample Costs to Establish and Produce Alfalfa • USDA EQIP Article 590 C – Nutrient Management
Deep Soil Testing	$1.12 - $1.38	• HRWCI – Phosphorus Management and Water Quality Protection • HRWCI – Nutrient Management and Water Quality Protection • USDA EQIP Article 590 C – Nutrient Management • Kansas State – Water Quality Best Management Practices • CDA – Agricultural Chemicals and Groundwater Protection

Management Practice	**Per Acre Cost**	**Sources**[1]
Use a Paid Crop Consultant for Fertility Recommendation	$2 - $4	• Personal Communication – Three Anonymous Consultants
Dealer Recommendation	$0	• Personal communication with 3 dealers provides free recommendations to all customers. • HRWCI – Phosphorus Management and Water Quality Protection • HRWCI – Nutrient Management and Water Quality Protection • Kansas State – Water Quality Best Management Practices
Crediting[2]	$0.75-$0.85	• HRWCI – Nutrient Management and Water Quality Protection • CDA – Agricultural Chemicals and Groundwater Protection
Manure Nutrient Table Values	$0 - $1	• HRWCI – Nutrient Management and Water Quality Protection
Placement	$3.5 - $8	• HRWCI – Phosphorus Management and Water Quality Protection • HRWCI – Nutrient Management and Water Quality Protection • HRWCI – Cost Effective Water Quality Protection • Kansas State – Water Quality Best Management Practices
Advanced Fertilizer Products	$5 - $12	• HRWCI – Nutrient Management and Water Quality Protection • HRWCI – Cost Effective Water Quality Protection • USDA EQIP Article 590 C – Nutrient Management • Personal communication with fertilizer sales

Management Practice	Per Acre Cost	Sources[1]
Establish Management Zones	$5 - $12	• USDA EQIP Article 590 C – Nutrient Management • Tyrell Fickenscher, Personnel communication, Cooperative Producers Inc. • John Fabian Personnel communication - Fontanelle Seed
Variable Rate Fertilizer Application	$4.5 $2,000 - $3,000 capital cost for controller	• NRCS- Support for Emerging Technologies • USDA EQUIP Article 590 C – Nutrient Management
Yield Monitoring System	$4,000 - $7,000 capital cost	• NRCS- Support for Emerging Technologies
Grid Soil Sampling	$5.5 - $8	• USDA EQIP Article 590 C – Nutrient Management • Delta Farm Press – Grid and Zone Sampling

[1]Full source citations for all associated cost estimates can be found in Table 6.1.3.

[2]Crediting sources include manure, legumes and irrigation water nitrate.

Table 7.1. Meta-analysis of nutrient transport management costs

Costs as reported in literature and not adjusted for inflation

Management Practice	Per Acre Cost	Sources[1]
Filter or Buffer Strips	$40 $100 per acre capital cost	• HRWCI – Phosphorus Management and Water Quality Protection • Kansas State – Water Quality Best Management Practices • USDA EQIP Article 393 - Filter Strip
Grassed Waterways	$41 -$57	• USDA EQIP Article 412 Grassed Waterways
Linear Polyacrylamide (PAM)	$12	• USDA EQIP Article 450 – PAM Erosion Control • Oregon State University – Make PAM Work for You
Conservation Tillage[2]	$0 – 8.71	• HRWCI – Phosphorus Management and Water Quality Protection • USDA EQIP Article 329 - Residue and Tillage Management • CSU Extension- Custom Rates for Colorado Farms and Ranches • University of Missouri Extension- No-Tillage and Conservation Tillage: Economic Considerations • Kansas Department of Agriculture: Custom Rates
Cover Crops	$28.06 - $43.17	• USDA EQIP Article 340 –Cover Crops
Rotate Between Shallow and Deep Rooted Crops	$0-$0.75	• HRWCI – Phosphorus Management and Water Quality Protection • HRWCI – Nutrient Management and Water Quality Protection • HRWCI – Cost Effective Water Quality Protection • USDA EQIP Article 328 - Conservation Crop Rotation

[1]Full source citations for all associated cost estimates can be found in Table B7.2.

[2]Per acre cost estimates reflect the annual cost associated with transitioning from conventional tillage to conservation tillage

Table B7.2: Source citations for cost estimates presented in Table B7.1 and Table B7.2

Full Source Citations for Cost Estimates
Coblentz, B. "Grid and Zone Soil Sampling." 2004. Delta Farm Press. http://deltafarmpress.com/grid-and-zone-soil-sampling. Accessed on August 15, 2011. Devlin D., C. Rice and T. Kastens. 2003. "Water Quality Best Management Practices, Effectiveness and Cost for Reducing Contaminant Losses from Cropland." Kansas State University Agricultural Experiment Station. MF-2572. Iida, C.L., and C.C. Shock. 2008. "Make Polyacrylamide Work for You." Oregon State University Cooperative Extension: EM-958-E. Massey, R.E. 1997. "No-Tillage and Conservation Tillage: Economic Considerations." University of Missouri Extension. http://extension.missouri.edu/p/G355. Accessed on October 2, 2011. McLoud P.R, and R. Gronwald. 2007. "Precision Agriculture: NRCS Support for Emerging Technologies." United States Department of Agriculture: Natural Resource Conservation Service. Agronomy Technical Note No. 1: p. 6 Mueller S.C., C.A. Frate, and M. Canevarie, M. Campbell-Mathews. 2008. "Sample Costs to Establish and Produce Alfalfa." University of California Cooperative Extension. AF-SJ-08-2: p. 10-16. Ranek D., S. Habets, E.J. Theissen, E. Wells, G. Stock and J. Allison. 2007. "Rates Paid by Farmers for Custom Work." USDA NASS Kansas Field Office in Association with Kansas Department of Agriculture. Tranel J.E, R.L. Sharpe and J. Deering. 2009. "Custom Rates for Colorado Farms and Ranches in 2009." Agriculture and Business Management Notes. Colorado State University Extension. United States Department of Agriculture: Environmental Quality Incentives Program Article 328. Conservation Crop Rotation. 2011 United States Department of Agriculture: Environmental Quality Incentives Program Article 329. Residue and Tillage Management. 2011 United States Department of Agriculture: Environmental Quality Incentives Program Article 340. Cover Crops. 2011. United States Department of Agriculture: Environmental Quality Incentives Program Article 393. Filter Strips. 2011.

Full Source Citations for Cost Estimates
United States Department of Agriculture: Environmental Quality Incentives Program Article 412. Grassed Waterways. 2011. United States Department of Agriculture: Environmental Quality Incentives Program Article 450. PAM Erosion Control. 2011. United States Department of Agriculture: Environmental Quality Incentives Program Article 590C. Nutrient Management. 2011. Bauder, T.A. and R.M. Waskom. 2011. "Economic Considerations of Nutrient Management BMPs." Colorado Department of Agriculture. Agricultural Chemicals and Groundwater Protection. Wortman C.S. 2005. "Phosphorus Management and Water Quality Protection in the Midwest." Heartland Regional Water Coordination Initiative. RP 187: p 20. Wortman C.S. 2006. "Nitrogen Management and Water Quality Protection in the Midwest." Heartland Regional Water Coordination Initiative. RP 18p: p 29. Wortman C.S. 2011. "Cost Effective Water Quality Protection in the Midwest." Heartland Regional Water Coordination Initiative. RP 197: p 8-9.