ABSTRACT

Title of Thesis: CHARACTERIZING THE USE OF BEST MANAGEMENT PRACTICES AND MEASUREMENTS OF PASTURE AND SOIL QUALITY ON MARYLAND HORSE FARMS

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Agricultural operations, including horse farms, have the potential to negatively affect the environment when managed improperly. The use of best management practices (BMPs) by horse farm operators are important for reducing their farms' environmental impact. Through the use of a mailed survey and field assessment, the use of BMPs on Maryland horse farms was characterized. In general, some BMPs were being used, especially restricting horses from surface water and maintaining vegetative cover. However, BMPs such as correct manure storage and rotational grazing had low adoption rates. A major finding was that soil erosion was a serious problem for most farms and topography, use of compacted materials, and maintenance of vegetative cover can predict occurrence of soil erosion. Results from these studies can aid in the development of future educational events designed to educate horse farm operators about adopting BMPs and preventing pollution of surface water.

CHARACTERIZING THE USE OF BEST MANAGEMENT PRACTICES AND MEASUREMENTS OF PASTURE AND SOIL QUALITY ON MARYLAND HORSE FARMS

by

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"Your graduate experience is like a roller coaster" was a phrase that I heard a number of times through these past two years. The experience truly was a ride for me, as I felt the time flew by too fast. There were times that I enjoyed and times that made me close my eyes and hold on tight, hoping it would soon be over. But, like my experience on most rides, I was surrounded by people pushing me through, providing encouragement, and going along for the ride. I was very fortunate to have Dr. Amy Burk as my advisor, as she was there to hold my hand like the Master's student that I was, but also give me the freedom to design and perform my own study. There were ups and downs to being the "only child" in her "lab": while it was convenient being the only graduate student, it was difficult at times to juggle all of the responsibilities. None the less, Dr. Burk always had confidence that I could get it done and I thank her profusely for all of her professional and personal support. I would also like to thank Dr. Josh McGrath, Ms. Kristen Wilson, and Dr. Rick Kohn, for their guidance and assistance along the way as well as Dr. Bahram Momen for his assistance with all of my statistics.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

INTRODUCTION

Agricultural operations, including horse farms, have the potential to negatively affect their surrounding environment when managed improperly. The negative effects of animal operations can be countered through farm operator awareness of agriculture's negative environmental impact and the adoption of best management practices (BMPs) on improperly managed farms (Weismiller et al. 2001).

In 2002, the first statewide equine census was performed in Maryland and the census showed 685,000 acres within the state are used for equine related activities, with over 87,100 horses kept on 20,200 equine facilities dispersed mostly through the central counties of the state (MASS 2002). Since the horse industry in MD makes up a large portion of MD agriculture, it is important that BMPs are adopted on horse farms to decrease non-point source (NPS) pollution. The difference between horse farm and other farm operators may be horse farm operators view themselves as "horse owners" instead of traditional "farmers". Horse farm operators may require specifically designed education and training to encourage them to implement BMPs on their farms. Horse farm operators may be attempting to implement some BMPs, but may require further education and assistance. Before moving forward, an assessment must first be performed to determine which BMPs are currently being used and for which practices adoption need to be increased. By assessing both use and knowledge of BMPs, it may be possible to determine where differences between use and knowledge lie and future studies may be able to determine why theses difference occur.

Previous assessments have been performed throughout North America (Chorney and Josephson 2000; Nicholson and Murphy 2005; Westendorf et al. 2010) as well as surveys performed at the county level in Maryland (MCSCD 2001; CALLC 2009). These assessments were a mixture of written surveys and field assessments. Some assessed multiple aspects of the horse industry and gathered a wide range of information, while only briefly assessing BMP use. The following studies present both a mailed survey and field assessment which were performed to address the following objectives.

1. To assess the knowledge level of Maryland horse farm operators on pasture management topics
2. To assess the use of BMPs on Maryland horse farms, both by operator-reported survey and visual assessment
3. To investigate relationship between area $horse^{-1}$ and measurements of soil health and pasture quality
4. To create a model for predicting the occurrence of soil erosion on horse farms based on BMP use on farms

CHAPTER 2

LITERATURE REVIEW

AGRICULTURE AND THE ENVIRONMENT

Nonpoint source (NPS) pollution is defined as pollution in surface water resulting from an unspecified origin, that is, it cannot be traced to one single location (Martin 1997). The origin of NPS pollution is not deliberate, meaning, pollutants are present at an unknown location and carried by water, such as runoff from precipitation, to the large body of water they are deposited in (Martin 1997). Compared to point source pollution, where the specific source is known, NPS pollution is more difficult to correct. Nonpoint source pollution is best mitigated by pollution prevention versus correction or removal (Martin 1997). Although the specific origin of pollutants is not known, agricultural operations are one of the primary sources of NPS pollution (USEPA 2004; Hubbard et al. 2004; Agourdis et al. 2005). These operations add pollutants such as nutrients, sediment, animal wastes, pathogens, and herbicides to surface waters, causing major, sometimes irreversible, damage (USEPA 2003; Hubbard et al. 2004; Airaksinen et al. 2007). Prevention of NPS pollution is done through the implementation of management practices on agricultural operations that are designed to minimize movement of pollutants.

Nitrogen and Phosphorus. Two of the main nutrients of concern that originate from agricultural operations and lead to NPS pollution are nitrogen (N) and phosphorus (P) (Hubbard et al. 2004; Lee and Jones-Lee 2004; Bilotta et al. 2007). These nutrients are commonly applied to agricultural land, and if applied to the land through excess fertilizer application or uncollected manure, these pollutants can cause long term damage to entire bodies of water.

Unpolluted waters contain basal levels of N and P, and these low levels limit the population of aquatic plants and prevent excess growth, death, and decay of plants. However, when excessive amounts of N and P are added to surface water, eutrophication can occur (Hubbard et al. 2004; Lee and Jones-Lee 2004; Bilotta et al 2007). Eutrophication refers to excess nutrients, which are normally limiting, that are supplied to aquatic plants and their growth is increased. The excess growth of plants leads to excess plant death, which produces bacteria for the breakdown of dead plant matter. The excess bacteria transform an aerobic body of water into an oxygen-depleted body of water, which can kill aquatic animal species and make water unsuitable for human consumption. This process is naturally occurring, however, NPS pollution increases the rate and severity of this process (USEPA 2003; Hubbard et al. 2004; Lee and Jones-Lee 2004).

The over-application of nutrients to farmland has been shown to cause build-up of excess nutrients, namely P, in soils (Sharpley 1995; Khiari et al. 2000). By performing a standard soil test, the soil levels of P can be measured and the amount of excess nutrients can be determined. Due to the tendency for P to be the most limiting nutrient for aquatic plant growth in fresh water, more research has focused on the effects and control of P pollution. Moreover, simply measuring the nutrient levels in soils does not give enough insight into that location's potential for nutrient leaching from the soil (Sharpley 1995; Sims et al. 2002; Shober and Sims 2007). The P saturation ratio, or Psat, is a measure of how saturated a given soil is with phosphorus. When the Psat is combined with site considerations, i.e. slope, it gives a measurement of how much P can potentially be lost from soil and transported to surface water (Sharpley 1995; Sims et al. 2002; Shober and Sims 2007).

Sediment. The deposition of sediment in surface water is a direct result of soil erosion (Owens et al. 1996; Pierzynski et al. 2000; USEPA 2003). Sedimentation can be caused by animal trampling and destruction of stream banks (Owens et al. 1996). When animals are allowed to enter surface water, the treading of their hooves causes erosion to occur in the sensitive area directly bordering the water source. Owens et al. (1996) showed a sediment decrease of 40% in a stream after livestock were fenced out.

Similar to nutrients in surface water, sediment in surface water also negatively affects aquatic and terrestrial life (Pierzynski et al. 2000). Soil solids make water more turbid, decreases sunlight, harm fish species, make water less suitable for human consumption, and decrease recreational activities (Pierzynski et al. 2000; USEPA 2003; Hubbard et al. 2004). Sedimentation is not only detrimental to water quality, but it is also detrimental to the soil surface. The soil loses nutrients, structure, and overall productivity of the land decreases because growing vegetation is losing essential nutrients and its anchor (USEPA 2003; Hubbard et al. 2004).

Animal Waste. Livestock manure typically contains excess nutrients and solids (USEPA 2003), with N and P being the nutrients of concern from poultry litter (Sims 1997), cattle manure (Van Horn and Hall 1997), and swine waste (Mikkelsen 1997). Similar to excess nutrients applied to pastures, the levels of N and P in manure become a problem when stocking density is high and manure is providing nutrients in excess of what is required for vegetation growth. Cattle feedlots with compact soil or concrete bases can pose a more severe threat to surface water, as there is a lack of vegetation present to filter runoff that may flow through manure before it reaches surface water (Baxter-Potter and Gilliland 1988). Horse and livestock manure is also a source of fecal bacteria and poses a threat to humans in drinking water. Examples of such bacteria include *Escherichia coli*, *Campylobacter jejuni*, *Salmonella*, *Vibrio cholerae*, *Listeria*, *Leptospira*, *Brucella*, *Coxiella*, *Mycoplasma* (Hubbard et al. 2004), *Cryptosporidium*, and *Giardia* (USEPA 2003).

Herbicides and Pesticides. Pesticides can cause a variety of detrimental effects on surface waters, due to the wide variety of products available (Brady and Weil 2008). Herbicide and pesticide movement to surface water is typically seasonal and occurs in the highest volume when application precedes a rain event. However, most pesticides that have demonstrated severe negative effects on plants and animals have been removed from the market (USEPA 2003).

In summary, deposition of nutrients and herbicide into surface water and buildup and movement of pathogens from animal manure are examples of how NPS pollution from agricultural operations can occur. However, each type of operation, either crop, livestock, or horse, have specific concerns that come about due to species differences and specific farm management practices. Although horse operations are commonly classified with other livestock operations, horses demonstrate unique grazing behavior that can cause different types of damage to pastures.

HORSES AND THE ENVIRONMENT

Horses, unlike other livestock, are very active animals. Their activity on pasture causes both vegetation and soil damage.

Soil Damage. The condition and quality of soil within a pasture is important to the health of a pasture. Soil is the medium by which vegetation is produced to supply nutrition to grazing livestock (Brady and Weil 2008). The goal of a farm operator should be to keep the soil at optimum conditions to maximize forage production. Horses can damage soil in three different ways: compaction, pugging, and poaching (Bilotta et al 2007). Horses and other livestock species have a major effect on soil in a pasture due to their large weight that is supported on hooves with small surface area. This force changes the structure of the soil, especially when the soil is wet. Compaction damage occurs when the pressure applied to the soil is greater than the soil's capacity to withstand the load and the total pore space of the soil is permanently decreased. This pressure expels stored water and air space from the soil and has major effects on soil hydrology and growing vegetation. Compaction damage usually occurs when soil has low moisture content (Mulholland and Fullen 1991; Bilotta et al. 2007).

Pugging damage occurs when soil has moderate moisture content and results in uneven pasture surface (Bilotta et al. 2007). Compared to compaction damage, pugging damage does not decrease total pore space, but instead soil particles shift around the area where the hoof is applied and bulk density is increased. This type of damage results in pasture surface with deep hoof prints, and is known as plastic deformation (Bilotta et al. 2007). When soil is saturated, horses and other livestock can cause poaching damage to soil (Mulholland and Fullen 1991). The high water content of the soil allows the hoof to penetrate beneath the surface of the soil and some water is pressed out of the pores. However once the hoof is removed, the pores can take the expressed water back in. Deep hoof print do not remain, as with pugging damage. This type of deformation is elastic, and the soil undergoes elastic recovery as the water is taken in again by the soil (Bilotta et al. 2007).

Any type of soil damage results in changes to the soil structure which negatively impact the growing vegetation. The more damage done to a soil surface, the more difficult it becomes for the farm operator to maintain good vegetative cover, which can lower the potential for nutrients and soil to flow off of pasture surface and be deposited into surface water.

Vegetation Damage. Although pastures are meant to supply horses with nutrition, the act of grazing can cause irreparable damage to plant structures. Horses are selective grazers, meaning they can overgraze certain areas of a pasture while ignoring other areas, especially where manure is located or where vegetation is undesirable (Archer 1973). This selectivity can leave areas where desirable vegetation is grazed below the point where it can regrow and undesirable vegetation grows freely. Grazing frequency affects vegetation, as the more frequently and closely an area is grazed will affect the regrowth time of vegetation (Matches 1992).

Decrease in vegetation is usually seen as grazing intensity increases (Matches 1992; Hubbard et al. 2004; Bilotta et al. 2007) . Most commonly, a pasture under intense grazing pressure shows a decline in production due to heavy defoliation. Plants are able to remain productive, that is regrow, when exposed to a moderate level of grazing intensity, however further increases in defoliation beyond this point lead to decreased production or inability for regrowth (Matches 1992). Although defoliation may seem to have a negative impact, moderate grazing intensity can increase forage production. At this level of defoliation, the plant experiences an overcompensation of growth to counter the defoliation and can have better production than if left ungrazed (Matches 1992; Bilotta et al. 2007). Increasing grazing intensity can lead to more even grazing or increase of forage being grazed. As there is less forage available, selective grazers tend to be less selective (Matches 1992; Singer et al. 1999). However, increasing grazing intensity to levels greater than what pasture can withstand causes decreased vegetative cover and forage production.

When vegetation is damaged beyond the point of regrowth, bare spots or undesirable weed species will be present in pastures. Decreased levels of desirable plant species lower the plane of nutrition that grazing horses are receiving as well as increasing the potential for nutrient losses from that pasture due to lack of vegetation. Soil and vegetation damage from horses and livestock are a result of grazing behavior, however damage can be prevented through various management practices to prevent NPS pollution, as will be discussed.

BEST MANAGEMENT PRACTICES AND ENVIRONMENTAL PROTECTION

Maryland developed the Tributary Strategies Program in 2000 to accomplish a 40% reduction in nutrients and sediments in the Chesapeake Bay (MD DNR 2000). One method employed to decrease nutrients and sediment included the adoption of BMPs that included managing animal wastes, planting cover crops, and controlling erosion and sediment, and by adopting nutrient management plans (MD DNR 2000). Best management practices are structural or non-structural practices designed to minimize the amount of pollution moving from an agricultural operation to surface or ground water (USEPA 2003). Some BMPs are species- or location-specific, but all BMPs are most effective when adopted as part of a larger management plan designed to address all aspects of NPS pollution coming from farms (USEPA 2003).

Best management practices presented here are divided into categories based on the overall goal of the practices and these categories include nutrient management, erosion control, manure management, pasture management, and grazing management.

Nutrient Management. According to the Water Quality Improvement Act (WQIA) developed in 1998, any agricultural operation in Maryland that grosses at least $2500 annually or has more than eight animal units (1 A.U. = 1000 pounds) is required to develop and maintain a certified nutrient management plan (Maryland General Assembly 1998). The nutrient management plan is designed to assess what nutrients are being added to the system, in the form of fertilizer or manure, then to develop a plan of how to minimize the nutrient input in order to have less nutrients present to contribute to NPS pollution (USEPA 2003; UME 2010). The goal of the nutrient management plan is to decrease the addition of excess nutrients to pasture surface and crop fields as well as prevent loss of nutrients that may already be present in excess.

To assess nutrient inputs to the system, a standard soil and manure test should be performed. Beyond assessing initial soil nutrient levels, it is important to know soil pH to determine what amendments must be added to adjust the pH to the optimum levels for the specific pastures species to be grown. Agricultural soils can accumulate excess P, that is, greater levels than what is required by pasture grass species or crops, when P is applied to pasture but not removed (USEPA 2003). In recent years it has been shown that measurements of the amount of P present in soil is not the most accurate measure of potential P losses. The P saturation ratio (Psat describes how saturated a soil is with P (Sharpley 1995; Sims et al. 2002). The ratio divides the amount of extractable P (Mehlich 3 P concentration) by the maximum amount of P that can be held by the soil

(Mehlich 3 Al and Fe) (Sharpley 1995). Multiple studies have shown the Psat ratio to be correlated with P loss from soil, making the Psat a better predictor of P leaching and runoff than standard agronomic P tests (Sharpley 1995; Sims et al. 2002; Shober and Sims 2007). Phosphorus saturation ratio value > 0.15 represents saturated soil that does not require additional P, with value > 0.2 representing a soil with high potential for environmental damage due to P loss in runoff or leachate (Sims et al. 2002).

After initial nutrient levels have been assessed in soil and manure samples, a nutrient management plan can be developed. Recommendations can be made by the author of the plan as to which BMPs may be implemented to decrease nutrient movement from the farm. The results of the soil test will provide the farm operator with recommendations for what type and amount of amendments, such as lime or fertilizer, should be added to adjust soil nutrients to optimum levels specific to the forage species desired. When soil attributes, either levels of nutrients or pH, for example, are not maintained at optimum levels, vegetation cannot grow or be maintained at its maximum levels and undesirable weed species can outcompete desirable species (Singer et al. 1999). The application of fertilizer, lime, and other soil amendments are important to help maintain productive pastures (Singer et al. 1999), but when applied incorrectly they can have major negative environmental impacts. To keep soil at its optimum levels, it is recommended that farm owners perform frequent soil tests on their farms and apply soil amendments based on the recommendation given within soil test results (Singer et al. 1999). Besides developing nutrient management plans on horse farms, performing regular soil tests and applying soil amendments based on the results are two practices that can be used to optimize health of the soil to maintain growing vegetation on pastures.

Erosion Control. Erosion within a pasture is one of the primary ways that excess nutrients, sediments, and pathogens from manure will reach surface waters. Erosion control practices keep soil and nutrients in place on pastures to help maintain vegetation. Water erosion occurs in three common forms: sheet, rill, and gully erosion (USEPA 2003). Stream bank erosion is another form of water erosion, where banks near surface water can wash away if left bare or vegetation is damaged by animals (Owens et al. 1996).

One of the best ways to decrease soil erosion is to maintain a dense stand of vegetation on pastures. Vegetation anchors soil in place, preventing its movement with runoff, and can also filter sediment from runoff as it moves across the pasture surface (USEPA 2003; Butler et al. 2007; Brady and Weil 2008). Also, the leaf cover from the vegetation helps prevent the detachment of soil particles by protecting them from the direct effects of precipitation (USEPA 2003). Vegetative cover is defined as the amount of vegetation, including desirable species and weeds, which are actively growing on a pasture and it is typically presented as a percentage. It is recommended that farmers maintain at least 65-75% vegetative cover on their pastures to help prevent soil erosion (Costin 1980; Dadkhah and Gifford 1980; Butler et al. 2007). Less than 50% cover on pastures results in little protection against runoff (Dadkhah and Gifford 1980), while vegetative cover of 70% is adequate for slowing and filtering runoff (Costin 1980; Butler et al. 2007).

As an additional means of protection against NPS pollution, farm operators can utilize a riparian buffer between grazed pastures and surface waters. An effective buffer is typically at least 15.2 m (50 ft) wide and made up of a dense stand of vegetation and small shrubbery to filter nutrients, sediment, and pathogens before they enter surface water (Hubbard et al. 2004; Agouridis et al. 2005). While grasses are more effective at filtering sediment and nutrients, shrubs or small trees are more effective at stabilizing stream banks and protecting against erosion (Agouridis et al. 2005). Once the riparian buffer is implemented, it is critical that vegetation is maintained and this is done by excluding animals from grazing, through the use of additional fencing.

Many farmers are hesitant to restrict their animals from surface water (Agouridis et al. 2005). First, fencing can be expensive, and, second, horse farm operators may not be willing to lose a productive area of their pasture. Also, if the surface water serves as a drinking source for grazing animals, then horse farm operators must install an alternative drinking source. One option for horse farm operators not wanting to fence off these areas of their pastures is timing the grazing of these riparian zones when there is the least potential for water pollution to occur, although further research in this area is necessary (Agouridis et al. 2005; USEPA 2003).

The use of a sacrifice lot within a pasture system can help maintain vegetation on pastures by providing horses with an area to be housed during unfavorable growth and/or weather conditions (i.e. heavy rain or drought). If horses are left on pasture during these conditions, they can damage vegetation. The sacrifice area is named as such because the condition of the vegetation on this area is sacrificed in order to maintain good vegetation on the rest of the pasture. This area should be located away from surface water and be surrounded by vegetation, as the lack of vegetation in the sacrifice lot may lead to soil erosion if not managed (USEPA 2003). Additionally, when structures are present in or near pastures where horses are grazing, precipitation that flows off of roofs can cause erosion channels through pastures or sacrifice areas. This runoff can be managed by utilizing drains and gutters on the roofs of all structures which diverts water away from sacrifice areas toward areas of pastures with more dense vegetation for filtration (USEPA 2003).

Manure Management. In addition to controlling erosion, it is important to properly contain manure collected on farm, to prevent soaking of manure and formation of runoff from these areas. To minimize runoff contaminated with pathogens from manure, manure should be collected frequently. Manure left uncollected has a greater chance of runoff flowing through it, then carrying nutrients and pathogens from manure to surface water. Some pastures may be too large for daily manure collection, but these pastures can be dragged regularly to break up piles and spread nutrients evenly so as manure can be used as fertilization (Singer et al. 1999). Dragging not only spreads nutrients but it helps decrease pathogens by exposing them to external weather to kill them (Singer et al. 1999). When a sacrifice area is utilized within a pasture, it is recommended that manure deposited here be collected daily, as this area may have less vegetation and be more likely to transport runoff to surface water (Airaksinen et al. 2007).

On farms where manure is collected and managed (i.e. manure is not removed from the farm), manure should be stored on an impervious surface with walls to minimize the movement of manure runoff (Bilotta et al. 2007). Additionally, manure should be covered to keep rainwater from seeping into it and creating runoff (Bilotta et al. 2007). If surface water is present, manure should be stored 30 m (100 ft) from surface water with a dense stand of vegetation in between to filter runoff (Hubbard et al. 2004). Finally, other options for manure management include removal from farm, composting manure, and spreading either stockpiled or fresh manure on farm.

Pasture Management. The main goal of pasture management practices is to maintain optimum growth conditions for pasture species to maximize vegetative cover on pastures. Farm operators can increase their ability to maintain vegetation on pastures by selecting appropriate forage species to plant. Climate, soil type, and nutrition supplied to horses are factors to be considered when choosing plant species, however species should also be tolerant to extreme grazing by horses (Vough and Decker 1983; Singer et al. 1999). In addition to grass species, legumes can be incorporated into pastures, as legumes help fix atmospheric nitrogen for use by grasses as well as make a pasture more diverse (Singer et al. 1999). It is also necessary to reseed pastures when bare areas occur.

The use of both herbicide and mechanical means of weed control (i.e. mowing) may be necessary to prevent undesirable weed species from taking over pastures (Singer et al. 1999). As discussed previously, horses are selective grazers, and it is common for horses to consume desirable forage species while leaving undesirable weed species untouched. If these weed species are not controlled, weeds can be allowed to go to seed and will spread in the pasture. The application of herbicide or mowing a pasture after horses graze are two successful ways to prevent weeds in pastures. Maintaining soil at optimum conditions for desirable plant species, specifically pH, will make soil conditions unfavorable for weed growth.

In addition to maintaining at least 70% vegetative cover on pastures, horse farm operators are encourage to maintain at least 7.6 cm (3 inches) of grass. Maintaining a grass height of $\geq$ 7.6 cm allows the plant to regrow after it has been grazed (Matches

1966). Grazing a plant below 7.6 cm depletes the plant of its energy reserves and limits its ability to continue photosynthesis and regrow (Matches 1966).

Grazing Management. Best management practices discussed thus far have had direct impacts on maintaining vegetative cover or preventing soil erosion. However, managing the location, timing, and intensity of grazing can also aid in the prevention of NPS pollution.

Overstocking pastures, that is, grazing more animals per area than the pasture can withstand, is one practice that can inflict the most harm on pastures. A number of studies have shown decreases in vegetative cover, increases in soil erosion, and high potential for nutrient leaching associated with overstocked pastures (Matches 1992; Singer et al. 2001, 2002; Hubbard et al. 2004). There is a clear relationship between stocking density and vegetative cover: as stocking density increases, vegetative cover decreases (Singer et al. 2001; Bilotta et al. 2007). Stocking density has also been correlated to soil nutrient levels, with one study showing high stocking densities having high soil P levels and more acid pH values (Singer et al. 2001).

Using a correct stocking density is one way that horse farm operators can reduce NPS pollution. By maintaining a smaller herd, a farm operator prevents overgrazing by allowing each grazing animal more space, with the goal being less damage done to vegetation from overgrazing and treading. Overgrazing of desirable species allows undesirable weed species to take over pastures (USEPA 2003). Higher number of animals results in increased manure deposition and potential for nutrient leaching. More manure on pastures increases the horses' natural selectivity while grazing, as horses often will not eat near where manure is located, and this promotes uneven vegetation (Hubbard et al. 2004).

Literature recommending stocking density is varied, as there is no single recommended stocking density or one type of experiment conducted to determine this value (Singer et al. 2001, 2002; Bilotta et al. 2007). This value is dependent on the region of the country the farm is located in as well the level of management on that farm, as more animals may potentially be maintained on a smaller area if the farm operator is willing to manage the system more intensely. Stocking density is often a constant on many horse farms, but it should be a more fluid concept, changing with the level of available forage. As forage becomes less available during the grazing season, stocking density should be adjusted so as not to overgraze any one pasture (Bilotta et al. 2007). As it may not be feasible to decrease herd size, it is more feasible to implement alternative grazing strategies.

One such strategy that has been frequently used on livestock operations is rotational grazing. The use of rotational grazing can help farm operators maintain more vegetation on pastures, by shortening the time that grass is grazed and allowing it to rest (Heitschmidt et al. 1982; Abdel-Magid et al. 1987, Singer et al. 1999), as well as increase water quality in nearby surface water (Agouridis et al. 2005). In a rotational grazing system, large pastures are divided into smaller paddocks and horses are allowed to graze as a herd in one small paddock at a time (Singer et al. 1999). While horses are grazing one paddock, the other paddocks in the system are allowed time to rest and regrow. This system of rest allows a pasture to maximize forage production (USEPA 2003). Rotational grazing helps control undesirable weed species, as more vegetation will be maintained on pastures and have the competitive advantage over undesirable weed species. Finally, preventing horses from gaining access to surface water on farms can decrease NPS pollution by directly preventing it. The less access animals have to surface waters, the less likely they are to eliminate wastes directly into water and the less damage they will do to stream banks and riparian areas (USEPA 2003; Agourdis et al. 2005).

Agricultural operations are one of the main sources of NPS pollution in surface water and adoption of BMPs on these operations is one of the most effective ways to prevent NPS pollution. Although differences exist on operations housing different species, the maintenance of vegetation on pastures, the prevention and correction of soil erosion, the correct storage of manure, and the use of effective grazing strategies are practices that can be used on any operation to prevent runoff to surface water. Increasing adoption of these practices will take further education of farm operators, with more specific education events tailored to horse farm operators needed to address issues specific to horse farms. However, through education and assistance with BMP adoption, more practices can be adopted to minimize NPS pollution reaching surface water, moving the horse industry closer to the goal of decreasing the overall negative environmental impact of horse farms.

CHAPTER 3

CHARACTERIZING THE USE OF RECOMMENDED BEST MANAGEMENT PRACTICES ON HORSE FARMS IN MARYLAND
(Manuscript 1)

Characterizing the use of recommended best management practices on horse farms in Maryland

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Abstract: Numerous laws have been passed in the U.S. since the 1960's aimed at decreasing water pollution originating on agricultural operations. Despite government regulations that require some horse farms to implement nutrient management plans and encourage them to adopt best management practices, the current use of best management practices (BMPs) on Maryland horse farms is not yet known. A mailed survey was designed to assess BMP use and knowledge level of Maryland farm operators as well as develop a model to predict the occurrence of soil erosion on horse farms. One thousand surveys were mailed to horse farm operators throughout the state in January 2009, with 382 completed surveys returned (43.5% response rate). Respondents reported having the highest knowledge of appropriate stocking density, use of rotational grazing, and correct manure management. The majority of farm operators used most recommended BMPs correctly on their farms. Farm operators that reported using a low stocking density (greater pasture area horse^{-1}) were more likely to have reported using BMPs correctly compared to farm operators using higher stocking densities. Respondents reported high knowledge of some BMPs but then reported low use of those same BMPs. Using logistic regression, authors found variables that predicted the occurrence of soil erosion included maintenance of 70% vegetative cover, use of compacted materials in heavy use areas, and topography of pastures. This model may be used to determine a farm's potential to

negatively impact the environment by evaluating the use of certain BMPs. Further research needs to be performed to determine the cause of the discrepancy between BMP knowledge and use so BMP use, in order to understand why some BMPs have low implementation rates.

Introduction

Detrimental effects on water quality from non-point source pollution originating from agricultural farms has been a concern in the United States since at least the 1960's (Martin 1997). Excess nutrients and sediment in runoff from agricultural operations increase growth of aquatic plant species, cause fish kills, and, in general, decrease water quality (Weismiller et al. 2001; Hubbard et al. 2004; Bilotta et al. 2007; Butler et al. 2007). Laws have been passed with the goal of reducing nutrients in US waterways including the 2002 Clean Water Act (US Congress 2002). Additionally, the Chesapeake Bay Agreement was signed by four states, each of which committed to a reduction in nutrient loading into the Chesapeake Bay (MD DNR 2000). The Water Quality Improvement Act (WQIA) of 1998 (Maryland General Assembly 1998) required animal operations in Maryland grossing more than $2,500 or maintaining at least eight animal units (1 animal unit = 1000 pounds) to develop and maintain a nutrient management plan to control nutrient discharge into surface water. Moreover, the Tributary Strategies Program was developed in states located within the Chesapeake Bay Watershed, which encourages agricultural operations upstream of the Bay to decrease nutrient deposition into surface water by adopting recommended best management practices, or BMPs (MD DNR 2000). The preferred solution to preventing and reducing nutrients and sediment in the Bay is through the adoption of BMPs (Weismiller et al. 2001).

Best management practices are structural or non-structural practices designed to minimize the amount of pollution moving from an agricultural operation to surface or ground water (USEPA 2003). Best management practices discussed in this paper are divided into four categories: erosion control, manure management, pasture management, and grazing management. Erosion control practices are those aimed at minimizing erosion in grazed pastures and preventing channels that transport runoff to surface water (Hubbard et al. 2004). Manure management practices contain manure and prevent nutrient leaching, as it is one of the main ways animal housing operations pollute surface water (Hubbard et al. 2004; Bilotta et al. 2007; Butler et al. 2007). The goal of pasture management BMPs are to maintain vegetation on pastures to prevent soil erosion. Finally, grazing management BMPs adjust the length and location of grazing animals and often work in conjunction with other BMPs to maintain vegetative cover on pastures and prevent pollution from reaching surface water.

The potential for horse farms to contribute to surface water pollution has often been overlooked, as it was not until the creation of the WQIA in 1998 that horse farms were required to have nutrient management plans (Maryland General Assembly 2002). Although the WQIA was passed fairly recently, follow-up county-wide surveys in MD found a 53% increase in the adoption of nutrient management plans on horse farms between 2001 and 2008 (MCSCD 2001; CALLC 2009). In 2002, a MD equine census was performed and it revealed the magnitude of the equine industry in the state, with a little over 87,100 horses kept on 20,200 locations (MASS 2002). The adoption of nutrient management plans and the use of other BMPs has been assessed in county-wide surveys (MCSCD 2001; CALLC 2009) as well as other studies performed across North America (Chorney and Josephson 2000; Nicholson and Murphy 2005; Westendorf et al. 2010). However, there has not yet been a statewide assessment of BMP use on MD horse farms.

A statewide survey would provide information about what BMPs are currently being used so that future educational events can be designed to focus on the BMPs with lower adoption rates and well as give insight into why some BMPs are adopted less frequently. Therefore, a mailed survey was designed to address the following objectives: 1) to identify the use of pasture BMPs by horse farm operators in Maryland, 2) to identify the knowledge level of horse farm operators regarding a number of pasture management topics and BMPs, and 3) to create a model utilizing the use of BMPs to predict the occurrence of soil erosion.

Materials and Methods

Design and Procedures. A 4-page written survey instrument was developed to address the objectives of the study (Appendix A). Survey questions were developed using the Maryland Horse Outreach Workgroup's handout titled, "Environmental Impact" (HOW 2007). The survey included 35 questions, broken into 3 categories: questions which assessed BMP use, questions which assessed BMP knowledge, and demographic questions. Questions which assessed BMP use were multiple choice format, with answer choices following the pattern of most correct use, moderately correct use, and incorrect use of the BMP. Knowledge assessment questions asked respondents to rank their knowledge level on a 1-5 likert scale, with one representing lowest knowledge and five representing highest knowledge. Finally, demographic questions were either multiple choice or fill-in type questions.

After the initial development of the questions, the survey instrument was reviewed by experts in the field for content and face validity. Additionally, the survey was pilot tested to ten Maryland horse farm operators and to several USDA Natural Resources Conservation Services employees. With consideration to their comments and suggestions, the final version of the survey was developed. Addresses of horse farm operators in Maryland were collected from the Maryland Horse Industry Board, Maryland Horse Breeders Association, University of Maryland Extension, and Maryland Soil Conservation Districts. After receiving 1,968 addresses, 1,000 addresses were randomly selected to receive the survey. All mailed documents were approved by the University of Maryland Internal Review Board and all respondent information was kept confidential.

Mailing Technique. The multiple wave mailing technique outlined by Dillman (2007) was used. Dillman (2007) suggests that multiple contacts are essential for maximizing response to mailed surveys. A system of four contacts was utilized. On week 1, participants were mailed a letter explaining the purpose of the survey and informing them that they would be receiving the survey by mail. On week 2, all participants were mailed a package containing a cover letter, survey instrument, and business reply envelope. On week 4, a reminder postcard was mailed to all participants thanking the respondents who had completed the survey and encouraging non-respondents to complete and return the survey. On week 7, all non-respondents received a duplicate packet containing the cover letter, survey instrument, and business reply envelope and on week 12 the data collection period ended. Data was collected from January through the end of March 2009.

Statistical Analysis. All respondents were categorized into three groups based on stocking density (area horse^{-1}) (table 1): high stocking density of <0.4 ha horse^{-1} (<1 ac horse^{-1}) (HIGH), moderate stocking density of 0.4-0.77 ha horse^{-1} (1-2 ac horse^{-1}) (MED), or low stocking density of >0.8 ha horse^{-1} (>2 ac horse^{-1}) (LOW). Frequency analysis (PROC FREQ, SAS Institute 2009) was performed to determine percent response for each question, mixed model ANOVA with Tukey's test (PROC MIXED, SAS Institute 2009) was performed to compare mean responses for knowledge questions, and Chi square test was performed to assess the relationship between BMP usage and farm stocking density. Logistic regression analysis (PROC LOGISTIC, SAS Institute 2009) was performed to create a model for predicting the presence of soil erosion in pastures. Variables in the model included stocking density (ac horse^{-1}) maintenance of ≥ 70% vegetative cover, use of sacrifice lot, use of compacted materials in heavy-use areas, condition of vegetative buffer between pasture and surface water, use of drains and gutters on structures in pastures, topography of pastures, and use of rotational grazing.

Results and Discussion

Demographic Information. Out of 1,000 surveys mailed, 34 surveys were returned because of an incorrect address and 88 surveys were returned because the recipient did not own a horse farm, horses, or have acreage for turnout. Of 878 remaining mailed surveys, 382 surveys were returned completed, resulting in a response rate of 43.5%. Mean acres, hectares, horses, and stocking density are reported in table 2.

Recommended stocking density for horse farms is 0.4-0.8 ha $horse^{-1}$ (1-2 ac $horse^{-1}$) (Singer et al. 2002) and the average stocking density for farms surveyed was within this recommended range. Of the 382 total farms, 208 reported using the recommended stocking density (1-2 ac $horse^{-1}$), with 62 farms that reported less than the recommended stocking density (< 1 ac $horse^{-1}$) and 112 that had stocking density > 2 ac $horse^{-1}$. Assessed farms in CA maintained more horses on less area (Nicholson and Murphy 2005), while survey respondents in Canada utilized more area per grazing animal (Chorney and Josephson 2000). However, in a survey performed in Montgomery County, MD, farms had an average of 0.85 ha $horse^{-1}$ (2.1 ac $horse^{-1}$) (MCSCD 2001), which is similar to the average stocking density found in this survey. Other studies have shown decrease in vegetative cover, increase in soil erosion, and high potential for nutrient leaching associated with overstocked pastures (Singer et al. 2001, 2002; Hubbard et al. 2004; Bilotta et al. 2007).

The most common use of the farms were for pleasure/recreational followed by boarding, breeding, instruction, training, and retirement or rescue (table 3). Most survey respondents were female (63%). The mean age of respondents was 56 ± 0.6 years of age. Most farms were located in Montgomery County, followed by Harford, then Anne Arundel and Baltimore (table 3). Most respondents (61%) reported gradual slopes in their horse pastures, compared to moderate (35%) and steep (4%) slopes. The topography of a farm is an important consideration given that steeper and longer slopes are associated with a higher risk of soil erosion (Brady and Weil 2008).

Knowledge Level. The level of knowledge that respondents had for a particular management topic is presented from highest to lowest in figure 1. In general, respondents reported having only moderate knowledge of all pasture management topics presented, and mean knowledge level for all topics ranged from 2 -3.6. Increasing the horse farm operator's knowledge of BMPs may be one way to increase their adoption of BMPs (Benham et al. 2007) and subsequent reduction of environmental impact.

Erosion Control. More than half of respondents reported that they have observed moderate or severe soil erosion on their pastures (table 4). When the responses were separated out by stocking density, the LOW group had a greater number of respondents that report slight erosion and the fewest number of respondents that reported severe erosion (table 5). Farms surveyed in CA had a greater percentage of farms that reported soil erosion in pastures compared to respondent in MD. However, that may be related to the increased average stocking density (less area per horse) used by their study population (Nicholson and Murphy 2005), as increased stocking density has been shown to lower vegetation and increase soil erosion (Matches 1992; Hubbard et al. 2004) .

Despite the high percentages of our respondents reporting soil erosion on their pastures, almost 80% of those reported maintaining at least 70% vegetative cover on their pastures (table 4). When responses were separated out by stocking density, the LOW group has a greater number of respondents that reported ≥ 70% cover and the fewest respondents that reported < 50% cover (table 5). A similar finding was reported by the Montgomery County Soil Conservation District (2001). Maintaining vegetation on pastures prevents soil movement with runoff by anchoring it in place and can also filter sediment from runoff as it moves across soil surface (USEPA 2003; Butler et al. 2007; Brady and Weil 2008).

The high percentage of respondents reporting both soil erosion and good vegetative cover seemed to be in contrast to each other. One possibility for this might be that erosion is more associated with heavy use areas (gates, feeders, run-in shed) in a pasture instead of areas of the pasture used mainly for grazing. Another possibility might be that the respondents do not have enough skill to accurately assess vegetative cover, and that a follow-up observational field study is required.

The presence of vegetative buffers between pastures and surface water are important for filtering nutrients and sediment from runoff before it enters surface water (Agouridis et al. 2005). Less than half of respondents (40.8%) did not have surface water bordering their properties. Of those that did, less than half reported maintaining optimum vegetative buffers between pastures and surface water (table 4). Optimum buffer conditions to slow and filter runoff consist of a 15.2 m (50 ft) buffer with at least 60% vegetative cover (Hubbard et al. 2004). Responses separated by stocking density showed that the LOW group had the most respondents reporting optimum buffer conditions and the fewest respondents reporting the least desirable buffer conditions (table 5).   Of the horse farms surveyed in CA, a greater percentage of farms were found to have vegetative buffers between pastures and surface water (Nicholson and Murphy 2005). Less than 30% of respondents statewide reported always using sacrifice lots within pastures during inclement weather (table 4), however MCSCD found 60% of respondents in Montgomery County used sacrifice lots (MCSCD 2001).

Managing roof runoff prevents the formation of erosion channels through pastures by diverting the flow of precipitation towards vegetation and slowing runoff speed (USEPA 2003). Less than half of respondents reported using drains or gutters on some structures (vs. all or none) located within or near horse pastures to redirect roof runoff (table 4). Similarly, a small percentage of horse farm operators surveyed in Montgomery County, MD used drains and gutters on structures (CALLC 2009). In contrast, 80% of horse farm operators in CA used drains and gutters (Nicholson and Murphy 2005). Use of drains and gutters to control roof runoff may be used more prevalently in other areas of the country where water may need to be collected as it may not be as readily.

In general, soil erosion was a serious problem on the participating farms and the prevention of erosion by maintaining vegetative cover is one of the first steps to decreasing nutrients and sediments in surface water. Although survey respondents appear to be taking the first steps to preventing erosion, there is less adoption of BMPs that prevent movement of runoff from erosion, such as using vegetative buffers and managing roof runoff.

Manure Management. When asked about manure collection and storage, the majority of respondents reported collecting manure and managing it on farm, with only 6% of respondents reporting that manure is never collected on their farms (table 4). Nicholson and Murphy (2005) and Westendorf et al. (2010) found similar results in that the majority of farms collect manure and manage it on their farms. In 2001, 50% of survey respondents in Montgomery County, MD reported storing manure on their farms (MCSCD 2001) while 75% of respondents in 2008 in the same county reported storing manure on farm (CALLC 2009). These results show a trend of increasing manure storage on farms in the county.

Manure should be stored at least 30.5 m (100 ft) from surface water to allow for maximum filtration before entering water (Hubbard et al. 2004). Almost all respondents reported storing manure at least 30.5 m (100 ft) from surface water (table 4). Westendorf et al. (2010) reported a similar percentage of respondents storing manure greater than the recommended distance of 30.5 m (100 ft), however less than half of farms assessed in CA stored manure the recommended distance from surface water (Nicholson and Murphy 2005).

Less than 20% of respondents reported storing manure covered on an impervious surface in order to control runoff from manure storage areas. Most respondents reported storing manure uncovered and on any type of surface, providing the least protection against runoff movement to surface water (table 4). Farms assessed in CA had a similar low percentage of farms storing manure on an impervious surface (Nicholson and Murphy 2005). It is interesting to note the discrepancy between reported knowledge level and respondent reported use of the BMP. Correct manure management had the third highest reported knowledge level (figure 1); however, most respondents reported storing their manure incorrectly. Of the respondents who reported using sacrifice lots on their farms, less than half remove manure regularly from this area, while more than ten percent never remove manure from sacrifice lots (table 4). The removal of manure from sacrifice areas can prevent runoff contamination with nutrients when runoff is present, especially because these areas of pastures tend to have less vegetation to filter and slow runoff movement (Airaksinen et al. 2007).

In general, most respondents report managing manure on their farms, but they are not managing it correctly to prevent the production and transport of runoff from manure. Additionally, the discrepancy between knowledge and use of correct manure management infers that some other factor besides knowledge is preventing correct manure management from being adopted on more horse farms.

Pasture Management. Forage species planted in horse pastures should be selected based on soil type, topography, adaptability to environment, and persistence, as horse pastures often encounter trampling and close grazing (Vough and Decker 1983). More than half of respondents reported selecting forage species for their pastures based on personal preference or using pre-mixed horse pasture seed mix, with less than one third of respondents selecting forage species based on soil conditions and pasture suitability (table 6). More than half of respondents also reported sometimes applying seed to pastures when needed and more than ten percent of respondents reported never reapplying seed to their pastures (table 6). More than half of the livestock farmers surveyed in Canada reseed their pastures (Chorney and Josephson 2000). It may be necessary to reapply seed to pastures in order to maintain enough vegetative cover to prevent runoff. Although it was not investigated, it would be interesting to evaluate the species of forages that the respondents had in their pastures, given the reported vegetative cover was so high.

The use of both herbicide and mechanical means of weed control may be necessary to prevent undesirable weed species from forming seeds (Singer et al. 1999). Less than ten percent of respondents reported using herbicide to control weeds, however more than half of respondents reported mowing or non-chemical means to control weeds (table 6). All other studies reported similar trends of low herbicide use and greater use of mowing for weed control (Chorney and Josephson 2000; MCSCD 2001; Nicholson and Murphy 2005; CALLC 2009). Horse farm operators appear to be relying heavily on mowing to control weeds, and this may be due to lack of knowledge about herbicides and their often high cost of application. By controlling weeds in pastures, farm operators can ensure pastures contain desirable plant species to offer maximum nutrition to horses while maximizing filtration of runoff.

Soil testing is a necessary practice in order to use soil amendments properly when enhancing or maintaining soil fertility. When asked about soil testing frequency, about half of respondents performed soil tests every 1-3 years, while almost fifteen percent never performed soil tests (table 6). Fifteen percent of respondents in Montgomery County, MD in 2008 reported performing regular soil tests (CALLC 2009), while Singer et al. and Westendorf et al. reported 34% and 32% of respondents in NJ never performed soil test on their pastures, respectively (Singer et al. 2001; Westendorf et al. 2010). This is another example of the discrepancy observed between knowledge level and BMP use. Soil sampling had the fourth highest reported knowledge level, however only about half of survey respondents are actually testing their soil as frequently as recommended.

Soil amendments, such as lime, should always be applied based on soil test recommendations to reach an optimum soil pH for pasture vegetation (Singer et al. 1999). Less than half of respondents reported sometimes applying lime to pastures, however that application may or may not be based on soil test results. Less than half of respondents reported always applying lime, with application based on soil test results and recommendations (table 6). A greater percentage of farms in Montgomery County, MD reported applying lime to pastures, however the survey did not assess if lime was applied based on soil test recommendations (MCSCD 2001). By applying soil amendments based on soil test results, farm operators can avoid the addition of excess nutrients to pastures that could potentially run off into surface water.

In general, survey respondents have poor pasture management practices, with less than half of respondents reporting adequate pasture species selection, appropriate reseeding practices, use of herbicide, and correct application of lime. The use of good pasture management practices can help the maintenance of vegetation on pastures.

Grazing Management. The majority of respondents reported turning their horses out on pasture with the goal of providing both exercise and nutrition (table 6). Similarly, a previous study of Montgomery County, MD horse farm operators reported that 74% of respondents used pastures for both nutrition and exercise (MCSCD 2001). Less than one third of our survey respondents reported always rotating horses through multiple pastures and resting pastures long enough to allow for plant regrowth (table 6). Most respondents in Canada and Montgomery County, MD used rotational grazing (Chorney and Josephson 2000; MCSCD 2001), while most farms in Montgomery County, MD reported resting pastures. However, only 8% of respondents rotated horses through multiple pastures in a more recent study (CALLC 2009). This is the third example of the discrepancy between knowledge and BMP use, as rotational grazing had the second highest reported knowledge level while less than one third of respondents are correctly rotating horse and resting pastures.

When asked about horse access to surface water, most respondents reported horses were restricted from and kept at least 15 m (50 ft) from surface water, however almost one third of respondents reported allowing horses unlimited access to surface water on their properties (table 6). In contrast, other studies in Canada, Montgomery

County, MD, and CA reported fewer respondents allowing animals free access to surface water (Chorney and Josephson 2000; MCSCD 2001; Nicholson and Murphy 2005). Restricting horses from surface water can increase water quality by preventing direct deposition of manure into water, by preventing erosion of stream banks, and maintaining a buffer to filter runoff (Owens et al. 1996).

Half of respondents (50.8%) did not have wetlands on their property. Of those that did have wetlands, less than one third reported keeping their horses at least 30.5 m (100 ft) from wetlands (table 6). Finally, respondents were asked to report how much impact they felt horse farms can have on the environment. It was interesting to note only 40% of respondents felt horse farms have a strong potential to impact the environment, 57% felt horse farms have moderate potential to impact the environment, and 2% reported they felt horse farms have no potential to impact the environment. Benham et al. (2007) discussed a number of studies that found that most farm operators do not feel soil erosion is a problem and that their farm cannot impact the environment.

Practices related to rotational grazing, including rotating horses and resting pastures, were not reported by a large number of survey respondents. The use of rotational grazing can help farm operators maintain more vegetation on pastures, by shortening the time that grass is grazed and allowing it to rest (Heitschmidt et al. 1982; Abdel-Magid et al. 1987, Singer et al. 1999), as well as increase water quality in nearby surface water (Agouridis et al. 2005). Most respondents were restricting their horses from surface water, which is one of the ways to prevent nutrient and pathogen deposition on surface water. However low adoption of this BMP is common, as it is often expensive for farm operators to fence animals out of water (Agourdis et al. 2005). Horse farm owners may not be able to fully understand the importance of using recommended BMPs until they understand and recognize their farms' potential to impact the environment.

Prediction of Occurrence of Soil Erosion. Multiple regression was used to create a model to predict the occurrence of soil erosion in pastures based on survey responses. Variables found to significantly predict soil erosion included maintaining 70% vegetative cover on pastures ($P = 0.0198$), the use of compacted materials in heavy-use areas ($P = 0.0399$), and topography of the pasture ($P = 0.0141$). Pastures with < 70% cover are three times more likely to have soil erosion present than pastures with at least 70% cover. Pastures that did not have compacted materials present in all heavy-use areas and pastures that have steep slopes are two times more likely to have soil erosion than pastures with compact materials in all heavy-use areas and pastures with gradual (less steep) slopes, respectively. After completion of further research, it may be possible to determine farm water pollution risk and severity of soil erosion by assessing these significant variables.

Summary and Conclusions

Horse farm operators reported using some recommended BMPs on their farms, but others were not consistently used. Respondents appeared to be taking the towards preventing erosion and NPS pollution from their farms, however, they reported using fewer BMPs that may require more intense management. Although farm operators reported having high knowledge of important BMPs, such as rotational grazing, manure management, and soil testing, they did not report using these BMPs as frequently. Further studies need to be performed to investigate why this discrepancy occurred and how can it be overcome to increase adoption of BMPs. Results of the logistic regression can be used to create a model for predicting soil erosion and potential for nutrient leaching from farms. Results of this study can be used to develop educational events for horse farm operators focused on increasing adoption of BMPs used less frequently by survey respondents.

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Table 1.
Classification of participants by stocking density.

Stocking Density Group	Range	Farms
	ha horse^{-1}	%
High	< 0.4	16.2
Med	0.4 - 0.8	48.2
Low	> 0.8	35.6

Table 2.
Demographic information of study participants.

Item	Mean ± SEM	Range
Horses	16.8 ± 1.6	1 – 500
Hectare	11.6 ± 1.6	0.1 – 15.1
Acres	28.6 ± 4.0	0.4 - 566
Stocking density (ha $horse^{-1}$)	0.8 ± 0.03	0.004 – 6.1

Table 3.
Classification of participants by primary use and county.

Primary Use	Farms
	%
Recreation	32.9
Boarding	30.7
Breeding	14.7
Instruction	11.1
Training	1.9
Rescue	1.6
County	
Montgomery	19.2
Harford	10.0
Anne Arundel	9.7
Baltimore	9.7
Frederick	8.4
Howard	6.3
Carroll	6.1
Charles	4.0
Calvert	3.4
Prince George’s	3.4
Queen Anne’s	3.2
St. Mary’s	3.2
Cecil	2.9
Washington	2.9
Wicomico	2.1
Talbot	1.1
Caroline	0.8
Kent	0.8
Allegany	0.5
Garrett	0.5
Worcester	0.3
Dorchester	0
Somerset	0

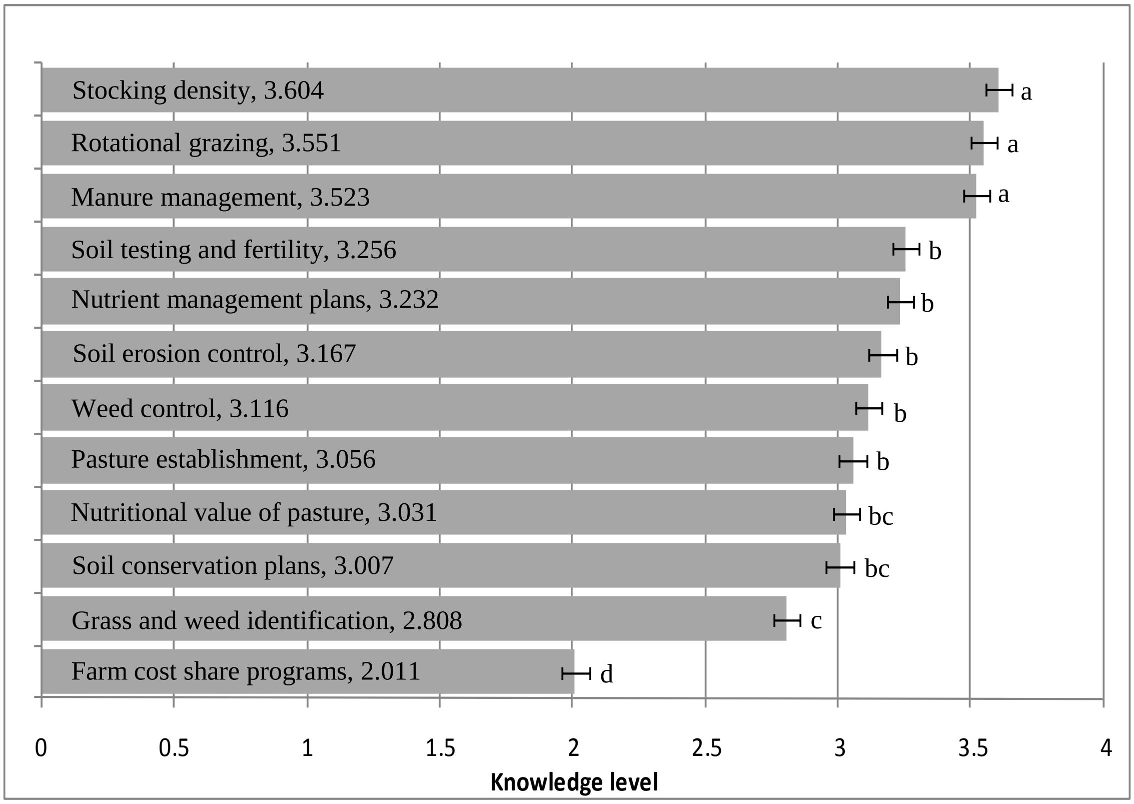

Figure 1.
Respondents were asked to rank their knowledge of pasture management topics on a 1 (no knowledge) to 5 (very high knowledge), whole number scale. Knowledge scores for each topic were averaged. [a,b,c,d] Means with unlike superscripts differ at $P < 0.05$.

Table 4.
Percent response of erosion control and manure management questions.

Question	Responses		
	%		
Degree of soil erosion	Slight 44.7	Moderate 44.4	Severe 10.9
Percent vegetative cover	> 70% 78.7	50 – 70% 16.8	< 50% 4.5
Vegetative buffer conditions (Width, % cover)	50 ft, 60% cover 43.7	50 ft, < 60% cover 3.8	< 50 ft, < 60% cover 11.7
Sacrifice lot use	Always 27.3	Sometimes 33.2	Never 39.5
Roof runoff management	On all structures 29.7	On some structures 37.4	Not used 34.8
Manure Management	Collected / Removed from farm 29.5	Collected / Managed on farm 64.3	Never collected 6.2
Distance from manure to surface water	> 100 ft 94.7	50 – 100 ft 3.5	< 50 ft 1.9
Manure storage	Covered, impervious surface 19.4	Sometimes covered, on any surface 9.2	Uncovered, on any surface 71.4
Manure collected in sacrifice lots	Regularly 43.2	Sometimes 45.5	Never 11.5

Table 5.
Percent responses to select questions by stocking density.

Response	Stocking density HIGH	MED	LOW
		%	
Soil erosion			
Slight erosion	30.7	40.1	57.5[a]
Moderate erosion	46.8	47.8	38.8[a]
Severe erosion	22.6	12.1	3.7[b]
Vegetative cover			
> 70% cover	48.4	80.9	89.7[a]
50 – 70% cover	37.1	15.3	9.6[b]
< 50% cover	14.5	3.8	0.7[b]
Vegetative buffer conditions			
50 ft width, 60% cover	19.3	46.3	51.6
50 ft width, < 60% cover	3.5	4.9	2.5
< 50 ft width, < 60% cover	17.5	8.5	13.1
No surface water on property	59.7	40.2	32.8

[a,b] Means with unlike superscripts differ ($P < 0.0001$)

Table 6.
Percent response of pasture and grazing management questions.

Question	Responses %		
Pasture species selection	Site conditions, pasture suitability 30.8	Personal preference 58.0	No criteria 11.2
Reseeding practices on pastures	Always reseeded 29.2	Sometimes reseeded 57.1	Never reseeded 13.7
Herbicide used for weed control	Always 7.4	Sometimes 41.0	Never 51.6
Mowing used for weed control	Always 75.1	Sometimes 23.8	Never 1.1
Soil testing frequency	1 – 3 years 54.9	> 3 years 30.9	Never tested 14.3
Lime application	Always based on soil test results 36.3	Sometimes based on soil test results 46.3	Never applied 15.5
Pasture use	Exercise 9.7	Nutrition 4.7	Both 83.7
Use of rotational grazing	Always 27.7	Sometimes 47.1	Never 25.2
Length of pasture rest	Always rested until grass height is 6-10" 31.1	Sometimes rested until grass height is 6-10" 64.8	Never rested 4.1
Horse access to surface water	Restricted / kept > 50 ft away 55.6	Restricted / kept < 50 ft away 13.7	Allowed access to surface water 30.7
Horse access to wetlands	Restricted / kept > 100 ft away 23.8	Restricted / kept < 100 ft away 10.4	Allowed access to wetlands 10.4

CHAPTER 4

USE OF BEST MANAGEMENT PRACTICES AND PASTURE AND SOIL QUALITY ON MARYLAND HORSE FARMS
(Manuscript 2)

Use of best management practices and pasture and soil quality on Maryland horse farms

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Abstract: Agricultural operations, including horse farms, can contribute non-point source (NPS) pollution to surface water. The use of best management practices (BMPs) is the most effective way to prevent damage to surface water from non-point source pollution. Previous mailed survey studies have assessed the use of BMPs at the county (MCSCD 2001; CALLC 2009) and state level (Fiorellino et al. 2010), however a visual assessment of horse farms is necessary to validate survey results. An observational field study was conducted to assess BMP use, soil and pasture quality, and to create a model to predict soil erosion on Maryland horse farms. Fifty-one farms were selected based on stocking density (ac $horse^{-1}$), farm use, and presence of water on property. All farms were visited from September through November 2009. In each pasture with grazing horses, the correct use of BMPs was assessed, grass height and vegetative cover were measured, and composite soil samples were collected. Less than half of the 18 assessed BMPs were being used by participants. Although most participants maintained the recommended vegetative cover and grass height, soil erosion was a major problem in pastures. The majority of farms had optimum soil nutrient concentrations (Ca, K, and P), excessive Mg values, and basic soil pH. Vegetative cover and grass height measurements were positively correlated to stocking density ($P < 0.0001$ and $P = 0.0004$, respectively).

Farm use was the only variable that predicted soil erosion on farms (*P* = 0.006). Farms used for pleasure were least likely to have soil erosion whereas farms used for breeding were more likely to have soil erosion (*P* = 0.0058). Despite the low to moderate adoption of BMPs, the maintenance of recommended vegetative cover and grass height as well as optimum values of soil nutrients indicate participating Maryland horse farms have a low potential for nutrient leaching and NPS pollution.

Introduction

Agricultural operations are one of the primary contributors to NPS pollution in the United States (USEPA 2004; Hubbard et al. 2004; Agourdis et al. 2005) and the adoption of best management practices (BMPs) on these operations may be the most effective way to prevent NPS pollution from entering surface water (Martin 1997; Weismiller et al. 2001; USEPA 2003). When public and government concern over water quality grew, regulations were created, and later modified, to limit the amount of pollution originating from agricultural operations. In fact, it was not until 1998 that horse operations were included in legislation requiring animal feeding operations to develop nutrient management plans in Maryland (Maryland General Assembly 1998). Then, in 2002, a statewide census was conducted which reported that MD had over 87,000 horses located on 20,200 equine operations (MASS 2002). With the large size of the horse industry in MD came more encouragement from the government for the adoption of (BMPs) to prevent NPS pollution from horse farms.

A number of studies have been conducted in the U.S surveying various aspects of the horse industry, with some characterizing the use of BMPs on farms (Chorney and

Josephson 2000; Nicholson and Murphy 2005; Westendorf et al. 2010). Two surveys conducted in Montgomery County, MD provided useful, but limited information about the use of BMPs by MD horse farm operators (MCSCD 2001; CALLC 2009). More recently, a statewide survey of MD horse farm operators found some BMPs were being used on the majority of surveyed farms; however the respondents reported having high knowledge of some topics while reporting low implementation (Fiorellino et al. 2010). Although this study gave an initial idea of what BMPs are used on horse farms in MD, a visual assessment was needed to help verify the accuracy of the reported BMP use. That study also brought to light the fact that area $horse^{-1}$ and farm use may have an effect on BMP use as well as pasture and soil conditions on farms. The objectives of this study were to conduct an observational field study designed to: 1) further characterize the use of BMPs on Maryland horse farms, 2) investigate a relationship between area $horse^{-1}$, farm use, and measurements of pasture health and soil quality, and 3) create a model to potentially predict the occurrence of soil erosion on assessed farms.

Materials and Methods

Farm Selection. Various equine organizations were asked to provide the authors with addresses of Maryland horse farm operators. Approximately 650 addresses were compiled from the Maryland Horse Industry Board, Maryland Thoroughbred Registry, county Soil Conservation Districts, and participants in a prior study (Fiorellino et al. 2010). An initial interest letter was mailed in the summer of 2009 describing the study and asking horse farm operators to enroll in the study. The mailing also contained a postcard asking horse farm operators who wished to participate to submit their address, number of horses, number of acres grazed by horses, presence of surface water on property, and primary and secondary use of the farm. Horse farm owners were given 4-6 weeks to return the postcard to participate in the study.

Once the postcards were returned, farms were selected with an attempt made to capture an even distribution of farm use and stocking density. Seventy two farm operators throughout central Maryland returned the postcard, with 51 farms enrolled and visited from September through the end of November 2009. Participating farm operators were mailed an initial written survey (Appendix B) to determine use of BMPs that could not be assessed by farm visit. Those BMPs included application of lime and fertilizer, collection and disposal of manure, frequency of soil testing, and use of rotational grazing.

BMP Assessment. A BMP checklist was developed by the authors to assess the use of eleven recommended BMPs in each assessed pasture (Appendix C and D). The BMPs of interest were use of compacted material in heavy-use areas, evidence of an attempt to correct soil erosion in pastures, drains and gutters on roofs of structures to divert runoff away from pastures and manure, use of 30.5 m (100 ft) buffer with vegetation between pasture and surface water, distance of 30.5 m (100 ft) from heavy-use area to surface water, stream banks with healthy stand of vegetation, prevention of movement of runoff into surface water, prevention of horse access to surface water, and use of sacrifice lot within pastures.

Prior to each farm visit, farm operators were called to schedule a date and time for the visit and confirm the number of pastures and the address. A soil map for each available farm was accessed online through Web Soil Survey (NRCS 2009) and used to estimate location of soil samples to be collected. A team of six investigators (one graduate student, one laboratory technician, one Maryland Department of Agriculture consultant, and three undergraduate students) were trained to take all measurements. On the day of the farm visit, between two and three individuals took measurements. During the entire study, the same investigator assessed use of BMPs and measured grass height in all assessed pastures, whereas soil sampling and vegetative cover measurements were performed by more than one trained investigator.

At each farm visit, each pasture with grazing horses was assessed for use of BMPs using the BMP checklist. Vegetative cover was assessed in each pasture using a modified line intercept method (Herrick et al. 2009). A 7.62 m (25 ft) tape measure was extended in a random position thrice within a pasture and the investigator recorded what intercepted each 0.3 m (1 ft) measurement. Options included grass, legume, weed, bare soil, or other. A total of 75 measurements were recorded for each pasture, regardless of size. Percentages of grass, legume, weed, bare, or other were calculated out of the 75 total measurements. Total vegetative cover was determined by adding the percentage of grass, legume, and weeds.

Grass height was measured using a meter stick inserted through a polystyrene foam plate. The meter stick was placed on the soil and the free-moving polystyrene foam plate was released from above the vegetation and measurement was recorded where the polystyrene foam plate settled on vegetation. Ten height measurements were taken at random in each grazing pasture, averaged, and reported as mean grass height. Both vegetative cover and grass height measurements are reported for each assessed pasture.

Soil samples. One to three composite soil samples were taken from each farm visited. Each composite sample was taken in locations where there was a difference in soil type, topography, or management. The number and location of composite samples was determined either before arriving at each farm or upon arrival. If the soil map for the farm was available online, then sample locations were selected prior to visit based on differences in topography or soil type. If soil map was not available online, sample locations were decided upon after arrival at each farm based on differences in topography or management.

Soil cores, approximately ten to fifteen centimeters deep, were taken using a JMC soil probe from up to 15 random locations within a designated sampling area to make up each composite sample. All cores for a composite sample were mixed together and sub-sampled. Composite samples were dried in a force-draft oven at 110°C for 7 days then sieved to pass through a 2-mm sieve. Samples were analyzed using Mehlich 3 extraction for Al, Ca, Fe, K, Mg, and P (Mehlich 1984) by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Nutrient ranges (low, medium, optimum, excessive) were determined by calculating fertility index values (FIV) for each nutrient according to the state of Maryland conversion factor (UME 2006).

Cation exchange capacity (CEC) was calculated using the summation method (Chapman 1965; Ross 1995). Base saturation (Bsat) was calculated as the % Ca, % K, and % Mg in the soil (Brady and Weil 2008). Mehlich 3 P saturation ratio (Psat) was calculated as Psat = M3-P / (M3-Al + M3-Fe) (Sims et al. 2002). Soil pH was measured using Fisher Scientific Accumet pH meter and soil samples were prepared in a 1:1 soil to water volume ratio.

Statistical Analysis. Frequency of responses for BMP assessment questions were calculated using PROC FREQ (SAS Institute 2009). An analysis of covariance (PROC

MIXED; SAS Institute 2009) was performed using vegetative cover, grass height, and soil nutrients as response variables, farm use as the explanatory variable, and area horse^{-1} as the covariate. When farm use was not significant, it was removed from the model. When stocking density was significant, correlation analysis (PROC CORR; SAS Institute 2009) was performed.

A logistic regression (PROC LOGISTIC; SAS Institute 2009) was performed to determine which variables may be used to create a model to predict the occurrence of soil erosion within pastures. Variables in the model included area horse^{-1}, primary use of farm, use of compact materials in heavy-use areas, maintenance of ≥ 70% vegetative cover, maintenance of ≥ 7.6 cm (3 inches) grass height, horse access to surface water, presence of buffer between pasture and surface water, and maintenance of vegetation within buffer areas.

Results and Discussion

Descriptive Data. Horse farm operators housed an average of 17.1 ± 2.3 horses on 10.2 ± 1.5 hectares (25.3 ± 3.8 acres). The average stocking density was 0.7 ± 0.06 hectares horse^{-1} (1.74 ± 0.15 ac horse^{-1}). Table 1 shows the distribution of farms by farm use and stocking density. Of the 51 farms visited, 29 farms had surface water present on their properties. Table 2 shows the number of farms with water on their property in each farm use/stocking density category. An attempt was made to enroll an even number of farms in each farm use stocking density category, however this proved to be challenging, as some of the categories have < 5 farms. This fact should be taken into account when interpreting results of this study. An attempt was also made to enroll an even number of farms with and without water present on their properties. Farms were visited during the fall growing season, in order to avoid drought conditions, observe vegetation during the one growing season, and observe signs of soil erosion during a time period of adequate precipitation. Farm visits were halted due to impending frost conditions. A greater number of farms would have been more ideal, however that was not possible due to staff limitations.

BMP Summary. Results for the BMP assessment are presented in tables 3 and 4. Soil erosion was observed in 81% of the pastures. The severity of erosion ranged from small amounts of sheet erosion to large gullies bisecting pastures. Most pastures exhibited erosion in heavy-use areas (i.e. near gates, feeders, waters, and run in structures). Attempts by horse farm operators to correct soil erosion was observed in 34% of the pastures. The most common practice was moving a portable feeder to a new location within the pasture. Nicholson and Murphy (2005) reported a similar finding of the amount of soil erosion in horse pastures while Fiorellino et al. (2010) reported fewer incidences of soil erosion. It is likely that Nicholson and Murphy (2005) found a similar percentage of farms with erosion due to the fact that their study was also based on visual assessment of farms, while Fiorellino et al. (2010) performed a mailed survey. Respondents may have had difficulty judging the severity of soil erosion on their own farms, making it difficult for them to accurately respond to the question.

Compacted stone material used to prevent erosion in heavy-use areas was used in 13% of assessed pastures. Thirty-eight percent of assessed pastures had an adjacent sacrifice area or area utilized during wet or dry weather to preserve the condition of the grazing pastures. Both Fiorellino et al. (2010) and MCSCD (2001) reported 60% of survey respondents used sacrifice areas on farms. The lower percentage observed in our study may be due to lack of knowledge of use of sacrifice areas or respondents in previous surveys may have incorrect understanding of the definition of a sacrifice area.

Drains and gutters were used to manage roof runoff in 26% of the pastures that had structures (i.e. run-in sheds or shelters). These results were similar to a mailed survey performed in MD (Fiorellino et al. 2010). However, a wide range of responses were seen in other studies (Nicholson and Murphy 2005; CALLC 2009). These differences may be regional, as it may be more important to control or even collect roof runoff in other regions of the country where water may be less abundant than it is in the Mid-Atlantic region.

In our study, BMPs that involve managing areas of a farm that border surface water were only assessed in pastures that directly bordered surface water. Forty-three percent of pastures bordering surface water had a 30.5 m (100 ft) vegetative buffer between pasture and surface water that was not grazed by horses. Out of those observed buffers, 96% had a dense stand of vegetation (i.e. at least 70% cover). Similar results were reported by Fiorellino et al. (2010), however a greater percentage of farms with discharge potential in CA had vegetative buffers with dense vegetation (Nicholson and Murphy 2005). Farm operators are sometimes unwilling to implement vegetative buffers as it usually means they must fence their animals out of an area of their pasture that may have good vegetation, potentially causing the operator to give up pasture space and money (Agourdis et al. 2005).

Of the pastures which bordered surface water, most (82%) had at least 30.5 m (100 ft) of vegetation between heavy-use areas and surface water. Almost all pastures

(92%) prevented flow of runoff from heavy-use areas to surface water, mostly by orienting heavy-use areas as far from surface water as possible. Seventy-five percent of pastures bordering surface water had some type of barrier or fencing to prevent horse access to surface water and maintained a healthy stand of vegetation in stream banks with no signs of animal presence. Fewer respondents reported restricting horses from and keeping them at least 15 m (50 ft) from surface water in MD (Fiorellino et al. 2010) and CA (Nicholson and Murphy 2005), however 87% of respondents in Canada fenced livestock out of surface water (Chorney and Josephson 2000). Higher percentage of farms restricting livestock from surface water may be due to the size of agricultural operations in Canada. Agricultural operations in Canada tend to be larger than in the US (Chorney and Josephson 2000) therefore, restricting horses from water may not cause as severe of a loss of acreage to Canadian farm operators. It appears that most operators are taking steps towards protecting water quality by fencing their horses out of surface water. However, the adoption of vegetative buffers between pastures and surface water is not being used as frequently, possibly due to costs inferred by farm operators.

Eight percent of horse farm operators reported using herbicide to control weeds on their farm, while 63% reported using regular mowing. Similar results were found in other studies in that there is a reluctance by horse farm operators to use chemical weed control methods (Chorney and Josephson 2000; MCSCD 2001; Nicholson and Murphy 2005; CALLC 2009; Fiorellino et al. 2010). It may be possible that the low reported use of herbicide is due to farm operators lacking knowledge of how to correctly utilize herbicide or their unwillingness to allow horses to graze in areas where herbicide has been applied. Farm operators may not know where to gain information about selecting appropriate herbicides or may be concerned with expense associated with applying herbicide to a large pasture.

More than half of horse farm operators (57%) reported collecting soil samples and having their soil tested every 1-3 years. Similar results were found in a statewide survey (Fiorellino et al. 2010), however, surveys performed in Montgomery County (CALLC 2009) and NJ (Singer et al. 2001; Westendorf et al. 2010) reported lower percentages of respondents regularly performing soil tests. Forty-three percent of respondents reported applying lime to pastures based on soil test recommendations. Thirty-six percent of survey respondents reported applying lime based on soil test results (Fiorellino et al. 2010) however 63% of respondents in Montgomery County, MD reported applying lime (MCSCD 2001), although it is not stated whether this application is based on soil test recommendations. The percentage in Montgomery County, MD may be higher due to farm operators applying lime without soil test recommendations. Most respondents (52.9%) reported they did not spread their manure, while 27.5% and 19.6% reported spreading manure on non-grazed and grazed land, respectively. Results for fertilizer application are presented in table 5. Most participating farm operators reported performing regular soil tests, however the percentage of farm operators applying lime based on test recommendations should be increased to prevent over-application of lime and fertilizer.

Twenty-one percent of horse farm operators reported always using rotational grazing on their farms, while a little over half of horse farm operators (54%) reported sometimes using rotational grazing. Previous studies performed reported use of rotational grazing that ranged from 8% to 91% (Chorney and Josephson 2000; MCSCD

2001; CALLC 2009; Fiorellino et al. 2010). This wide range of responses is likely due to differences in how the survey questions were asked. For example, if the question and answer choices describe rotational grazing (Fiorellino et al. 2010), answers may be more accurate than if the question asked if rotational grazing is being used or not (CALLC 2009). Farm operators may believe they are using rotational grazing, but due to lack of knowledge of rotational grazing, they may be incorrectly assessing their use. For example, horse farm operators routinely move horses in and out of pastures based on social behavior. They may be incorrectly viewing that as rotational grazing.

In regards to manure management, 41% of farms visited collected manure regularly and stockpiled it. Similar percentages were found in previous studies (MCSCD 2001; Nicholson and Murphy 2005; CALLC 2009; Fiorellino et al. 2010; Westendorf et al. 2010). One third (33%) of horse farm operators reported collecting manure and removing it from the farm, 14% reported never collecting manure, and 12% reported collecting manure and composting it. Only 6% of survey respondents statewide reported never collecting manure (Fiorellino et al. 2010). However, 72% of farms assessed in CA did not regularly remove manure from pastures (Nicholson and Murphy 2005). The authors did note that in their area regular manure collection is not recommended unless there is a large number of horses present (Nicholson and Murphy 2005). Sixteen percent of farms surveyed in CA utilized composting to dispose of manure (Nicholson and Murphy 2005) however other studies showed much higher percentages of respondents composting manure (MCSCD 2001; CALLC 2009; Westendorf et al. 2010). Correct composting practices are time consuming and require intensive management, and it is possible that farm owners may believe and report they are composting manure, when they may only be stockpiling it.

The prevalence of soil erosion observed in our study indicates that it may be a major mechanism for the transport of sediments and sediment-based nutrients to surface water. Best management practices that were being used in more than half of assessed pastures included locating heavy-use areas away from surface water (82%), preventing horses from accessing surface water (75%), keeping vegetation on stream banks (96%), and performing soil tests regularly (57%). Practices being used less frequently include preventing (19%) and correcting soil erosion problems (34%), using a sacrifice area (38%), implementing roof runoff management systems (26%), maintaining vegetative buffers between grazed pastures and surface water (43%), rotational grazing (21%), and correct lime application (43%). Some theories were provided as to why some BMPs are being preferentially adopted over others, but further research is required to be able to provide more definitive reasons. It is important to obtain accurate information about the current implementation rates of BMPs prior to the creation of education programs and government regulations.

Soil Nutrients. The University of Maryland reports soil test results on a continuous, relative scale called fertility index values (FIV). On the FIV scale, values from zero to 25 are low, and 26 to 50 are medium, 51 - 100 are considered optimum, and >100 is excessive. Crop response to fertilizer is not expected on soils testing optimum or above for any given nutrient. The majority of farms had concentrations within the "normal range" for Ca (25/51) and K (39/51). Thirty of 51 farms had P concentrations in the medium category while almost all participating farms (46/51) had Mg in the excessive category. Of the 51 total farms, ten had excessive K levels and seven had excessive Ca levels. Most farms assessed had soil concentrations within normal limits for Ca, K, and P, while most farms assessed had excessive Mg concentrations (table 6). This may be a common theme among soils in Maryland and Mg is not a soil nutrient of particular concern with regards to NPS pollution. Results of the analysis of covariance showed an effect of farm use on soil Ca values ($P = 0.032$). Pleasure farms had the lowest mean Ca value, however this value was only significantly lower than breeding farms (table 7).

Phosphorus saturation ratio gives a measure of how saturated a soil is with P. The ratio divides the amount of extractable P (Mehlich 3 P concentration) by the maximum amount of P that can be held by the soil (Mehlich 3 Al and Fe) (Sharpley 1995). A value of 0.2 represents a sample that is fully saturated with P there is a high potential that P will be released in runoff or leachate and have negative environmental impacts (Sims et al. 2002). This is a more accurate measurement of potential for release of P from soil, as it takes into account soil chemistry (Sharpley 1995). Only two farms had excessive P concentrations, with one of these farms having a Psat ratio > 0.2 and the remaining farms had Psat ratios < 0.2. Although two farms had excessive P concentrations, only one farm had a high Psat ratio, showing excessive P concentrations do not always mean potential environmental impact (Sims et al. 2002; Shober and Sims 2007).

Average CEC and Bsat for farms were 3.9 ± 0.2 mEq/100 g and 40 ± 1.1%, respectively. Mean and individual CEC values were fairly low for assessed farms, ranging from 1.05 to 7.96. Low CEC values mean the sampled soils are unable to hold water and nutrients, with a greater possibility of nutrient release (Kelley 1948). Cation exchange capacity can be greatly influenced by the presence of organic matter in the soil (Kelley 1948), and since most horse pastures lack organic matter (when compared to crop fields), this likely explains the low CEC values observed. Base saturation is the percentage of the CEC that is made up of Ca, K, and Mg and gives a measure of the number of sites available for nutrient exchange (Brady and Weil 2008). The values for Bsat combined with the low CEC values may not be meaningful, as the soil has already been determined to have low nutrient exchange and increased leaching potential (Brady and Weil 2008).

Nine of the 51 farms had soil pH levels < 6.5, sixteen farms had soil pH values 6.5-7.0 and the majority of farms (26) had soil pH values > 7.0. It is interesting to note that 50% of farms had basic pH values and only 43% of farm operators reported applying lime based on soil test results. Basic pH values suggest farm operators may be applying lime at concentrations greater than what is required for optimal growing conditions needed by desired forage. This may be related to the significant effect of farm use on Ca: if breeding farms have the highest average soil Ca concentrations they are most likely over-applying lime to their pastures. Horse farm operators also may not be performing soil tests as frequently as needed and may not be aware that they may be applying lime in excess. Seven farms assessed had acidic pH values, which is conducive to undesirable weed growth when coupled with improper management (Singer et al. 1999). Farm use also had a significant effect on soil pH values (P = 0.018), with pleasure farms found to have the lowest pH, with this value different from mean pH of breeding farms (P = 0.021) (table 8).

Pasture Quality Measurements. Average grass height for assessed pastures was 8.9 ± 0.3 cm (3.49 ± 0.1 inches) and average vegetative cover was 90.5 ± 0.7 %. Almost all pastures had vegetative cover of ≥ 70% (92%) while more than half of pastures (64%) had grass height of ≥ 7.6 cm (3 inches). It is recommended that horse farm operators maintain ≥ 70% vegetative cover to prevent movement of runoff (Butler et al. 2007). Grass height of ≥ 7.6 cm (3 inches) is the minimum height vegetation can be grazed to in order for the plant to be able to regrow (Matches 1992). Grazing a plant below 7.6 cm (3 inches) depletes the plant of its energy reserves and limits its ability to continue photosynthesis (Matches 1966). However, it has been shown that some level of defoliation can result in vigorous plant regrowth, compared to a plant that is not grazed and allowed to go to seed (Matches 1992; Bilotta et al. 2007). In any case, overgrazing forages is detrimental to plant health and longevity (Matches 1992).

Both vegetative cover ($r = 0.38$, $P < 0.01$) and grass height ($r = 0.4$, $P < 0.01$) were positively correlated with area horse^{-1} (figures 1 and 2). Therefore, as horses are provided with more area to graze, they may be returning to a specific area less frequently, allowing that area time to rest and regrow. Less frequent grazing of one area will allow more vegetation to be maintain and at a greater height. The negative effect of overgrazing on vegetative cover and grass height has been shown in a number of other studies (Matches 1992; Hubbard et al. 2004; Bilotta et al. 2007), with our study only confirming these findings.

Logistic Regression. Farm use was the only variable that could be used to predict the occurrence of soil erosion in assessed pastures ($P = 0.006$). The model showed farms used for pleasure or recreation were least likely to have erosion present, while boarding farms were ten times more likely to have erosion than recreational farms. Finally, breeding farms were the most likely to have erosion present in pastures, in fact, breeding farms were 34 times more likely to have erosion than pleasure farms. These results warrant further investigation, as sample size for this study was small and these results may not correctly represent the entire horse industry in Maryland.

Summary and Conclusion

Half of the 18 recommended BMPs assessed in this study were being used by the majority of participating horse farm operators. In addition, soil P concentrations were at or below agronomic optimum concentrations for 49 of the 51 farms evaluated and Psat was below 0.2 at all but one of the farms. These results indicate that the horse farms do not represent a high risk as P sources to surface water. However, many studies have clearly shown that P transport to surface water is a function of both P sources present (e.g. manure, fertilizer, P-saturated soil) and transport factors (e.g. erosion, runoff, subsurface drainage) (Buda et al. 2009; Gburek et al. 2000; Sharpley et al. 2008). The majority of farms evaluated maintained $\geq$ 70% vegetative cover and 7.6 cm (3 inches) grass height, indicating low probability of soil erosion from the general pasture areas. However, significant soil erosion appeared to be localized in heavy use areas. Even though this erosion was not evident across the broader pasture areas, the prevalence of soil erosion observed in heavy use areas indicates that it may be a major mechanism for the transport of sediments and sediment-based nutrients to surface water on the assessed farms. Therefore, participating horse farms should be encouraged to adopt BMPs designed to minimize the transport of nutrients, not the source of nutrients. Breeding farms were more likely to have erosion present than boarding farms or farms used for recreation, suggesting the need for further investigation of management practices on breeding farms that may be contributing to soil erosion.

Results of this study may be used to develop future educational events and other efforts focused on encouraging the adoption of the less frequently used BMPs. Further research needs to be performed to investigate a possible relationship between area $horse^{-1}$ and measures of soil quality and whether implementation of underutilized BMPs could alleviate soil erosion and thus NPS pollution from pastures. Finally, tools to identify and direct management decisions to reduce NPS pollution, such as the Maryland Phosphorus Site Index, were designed with production agriculture in mind, not horse operations (Coale et al. 2002). Therefore, research should be directed towards validating and possibly modifying existing tools for use with horse operations.

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Table 1.

Classification of the number of farms surveyed by stocking density and primary use

Stocking Density	Boarding	Breeding	Pleasure/Recreation	Total
	Farms			
High (< 0.4 ha $horse^{-1}$)	7	3	2	12
Med (0.4-0.8 ha $horse^{-1}$)	8	10	4	22
Low (> 0.8 ha $horse^{-1}$)	6	4	7	17
Total	21	17	13	51

Table 2.

Number of farms, classified by area horse^{-1} and primary use, that had surface water present on their property.

Stocking Density	Boarding	Breeding	Pleasure/Recreation	Total
	Farms			
High (< 0.4 ha horse^{-1})	2	2	0	4
Med (0.4-0.8 ha horse^{-1})	6	5	2	13
Low (> 0.8 ha horse^{-1})	4	3	5	12
Total	12	10	7	29

Table 3.
Percentage of assessed pastures where there was a demonstrated correct use of BMP.

BMP	Correct Usage	
	%	n
Buffer between pasture and surface water had vegetation	96.4	55
70% vegetative cover maintained	92.2	192
Prevention of runoff from heavy use area to surface water	92.0	50
> 100 ft from heavy use area to surface water	81.8	55
Horses restricted from surface water	75.4	57
Stream bank had healthy stand of vegetation	74.6	55
Grass height ≥ 3 inches	63.5	192
Use of 100 ft buffer between pasture and surface water	42.9	56
Sacrifice lot used	37.9	58
Evidence of attempt to correct soil erosion	33.4	151
Roof runoff management used	25.8	97
No erosion present	18.9	185
Compacted material used in heavy use area	14.0	186

Table 4.
Percentage of horse farm operators indicating correct use of BMP on pre-visit surveys*†.

BMP	Always used
	%
Use of mowing to control weeds	62.8
Soil samples taken and tested every 1-3 years	56.9
Lime applied based on soil test recommendations	43.1
Rotational grazing always used	20.8
Use of herbicide to control weeds	7.8

* Questions contained three answer choices that were typically in always, sometimes, never format

† n = 51

Table 5.
Response frequency for fertilizer application by farm operators (n=51)

Question	Response	Response Frequency
		%
Last date of fertilizer application	1980	2
	1990	2
	2001	2
	2005	5.9
	2006	5.9
	2007	9.8
	2008	21.6
	2009	27.5
	No answer/Not sure	23.5
No. of pasture acres fertilizer applied	1 – 10	25.5
	11 – 20	13.7
	21 – 50	17.6
	51 – 100	5.9
	> 100	2
	No answer/Not sure	35.3
Percent N-P-K of product	2-4-4	2
	10-10-10	9.8
	15-22-22	2
	18-22-18	2
	19-19-19	3.9
	20-10-10	2
	20-10-50	2
	40-0-0	2
	46-0-0	2
	50-0-0	7.8
	50-80-80	2
	60-30-50	2
	65-15-0	2
	No answer/Not sure	56.9
Pounds of product applied per acre	20 – 100	15.7
	> 100	15.7
	No answer/Not sure	64.7

Table 6.
Number of farms having low, medium, optimum, or excessive levels of soil nutrient concentration as determined by Mehlich 3 extraction*

Nutrient	Low	Medium	Optimum	Excessive
	No. of farms			
Phosphorus	1	30	18	2
Potassium	0	2	39	10
Calcium	6	13	25	7
Magnesium	0	0	5	46

*Multiple soil samples per farm were analyzed then averaged for each farm

Table 7.
Effect of primary use on mean soil calcium values

Primary Use	Mean Soil Ca
	mg/kg
Boarding	627.5 ± 50.9[ab]
Breeding	730.0 ± 58.7[b]
Pleasure	499.6 ± 60.9[a]

[a,b] Means with unlike superscripts differ (P = 0.024)

Table 8.
Effect of primary use on mean soil pH

Primary Use	Mean pH value
Boarding	7.03 ± 0.09^{ab}
Breeding	7.11 ± 0.10^{b}
Pleasure	6.70 ± 0.11^{a}

^{a,b} Means with unlike superscripts differ (*P* = 0.021)

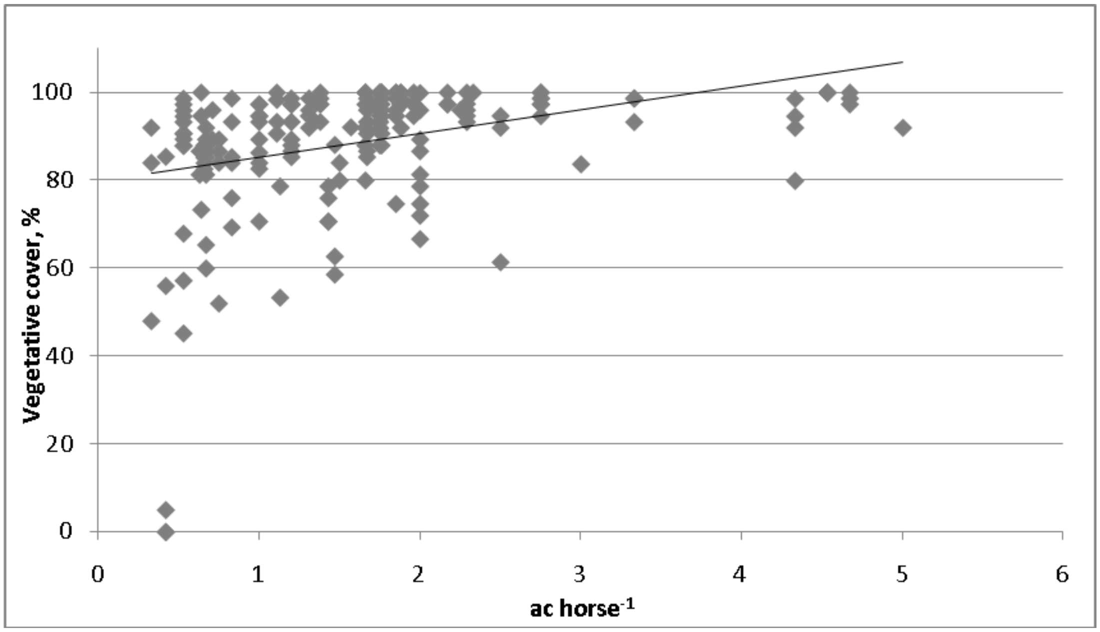

Figure 1.
Vegetative cover by area horse^{-1}. Pasture vegetative cover was positively correlated with area horse^{-1} (n = 194, r = 0.295, $P < 0.0001$).

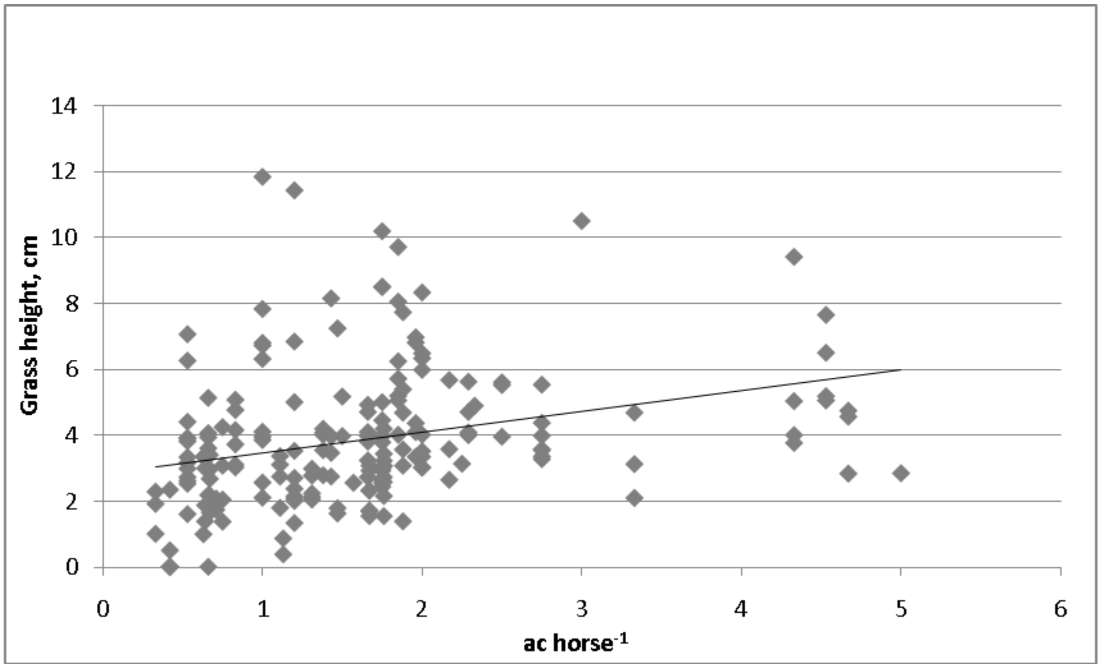

Figure 2.
Grass height by area horse^{-1}. Pasture grass height and area horse^{-1} were positively correlated (n = 195, r = 0.273, *P* = 0.0004).

CHAPTER 5

APPENDICES

Appendix A. Mailed Survey (Manuscript 1)

UNIVERSITY OF MARYLAND HORSE PASTURE MANAGEMENT SURVEY

Please <u>circle one option</u> for each question that best corresponds to your opinion. All individual responses will be confidential.

1. Are you an owner or manager of a horse farm in Maryland?
   A. Yes
   B. No → If answer B is chosen, please skip to question #36 and return survey.

2. How often do you have horse pasture management related questions?
   A. Never
   B. Rarely
   C. Occasionally
   D. Often
   E. Very often

3. How interested are you in obtaining more information about horse pasture management practices?
   A. Not at all interested
   B. Slightly interested
   C. Moderately interested
   D. Very interested
   E. Don't know

4. What is your primary goal when turning out horses on pasture?
   A. For horses to receive exercise
   B. For horses to receive nutrition
   C. For horses to receive both exercise and nutrition
   D. Other: ___________________________

5. Please rank your level of knowledge of the following horse pasture management topics. *(Circle one answer for each topic)*

Topic	None	Low	Medium	High	Very High
Farm cost-share programs	1	2	3	4	5
Grass and weed identification	1	2	3	4	5
Manure management	1	2	3	4	5
Number of horses that should be turned out on each acre of pasture	1	2	3	4	5
Nutrient management plans	1	2	3	4	5
Nutritional value of pasture	1	2	3	4	5
Pasture establishment	1	2	3	4	5
Rotational grazing	1	2	3	4	5
Soil conservation plans	1	2	3	4	5
Soil erosion control	1	2	3	4	5
Soil testing and fertility	1	2	3	4	5
Weed control	1	2	3	4	5

Please answer the following questions by <u>circling one letter</u> that best relates to your horse operation.

6. On average, how much of your horse pastures consist of bare soil in the spring?
    A. Less than 30%
    B. Between 30% and 50%
    C. Greater than 50%

7. How would you describe the seeding practices for the horse pastures on your farm?
    A. Seed is always applied to pastures when needed (i.e. spring and/or fall)
    B. Seed is sometimes applied to pastures when needed
    C. Seed is never applied to pastures

8. How do you select the type of forage species to be planted in your horse pastures?
    A. Selection is based on soil, site conditions, and its suitability for the use of the pasture
    B. Selection is based on personal preference and/or recommended horse pasture seed mix
    C. No criteria is used in selection

9. How would you describe the use of herbicide in your horse pastures?
    A. Herbicide is always used when needed
    B. Herbicide is sometimes used when needed
    C. Herbicide is never used

10. How often do you mow your pastures for weed control purposes?
    A. Pastures are always mowed to control weeds
    B. Pastures are sometimes mowed to control weeds
    C. Pastures are never mowed to control weeds

11. How is lime applied to your horse pastures?
    A. Lime is always applied to reach optimum pH levels for plant growth based on soil test results
    B. Lime is sometimes applied and may or may not be based on soil test results
    C. Lime is never applied

12. How often do you take soil samples from your horse pastures and submit them for soil fertility?
    A. Every 1-3 years
    B. More than 3 years allowed between soil tests
    C. Soil is never sampled and tested

13. When do you use sacrifice, dry or loafing lots on your property?
    A. Always used for feeding or exercise of horses when pastures are wet, overgrazed, under renovation or drought stricken
    B. Sometimes used for feeding or exercise of horses when pastures are wet, overgrazed, under renovation or drought stricken
    C. No sacrifice, dry, or loafing lots used or used only for horses with health issues → If answer C is chosen, please skip to question #15.

14. How do you manage manure within the sacrifice, dry, or loafing lot?
    A. Manure is regularly removed on a daily or weekly basis
    B. Manure is occasionally removed
    C. Manure is never removed

15. How do you <u>primarily</u> manage horse manure on your property?
    A. Manure is collected and removed from farm →
    B. Manure is collected and managed on farm (i.e. spread, composted, piled)
    C. Manure is never collected on the farm →

If answer A or C is chosen, please skip to question #18.

16. How do you store the manure that was collected from your farm?
    A. Manure is stored on an impermeable surface, and is always covered
    B. Manure is stored on any surface, and is sometimes covered
    C. Manure is stored on any surface, and is left uncovered

17. How close is manure stored to surface water (i.e. streams, ponds, and springs)?
    A. Manure is stored greater than 100 ft. from surface water
    B. Manure is stored between 50 and 100 ft. from surface water
    C. Manure is stored less than 50 ft. from surface water

18. Do you use compacted material (i.e. stone dust, wood chips) in high traffic areas (i.e. in front of gates, waterers, entrances to barns, etc.) to reduce mud accumulation and soil loss?
    A. Yes, in all high traffic areas
    B. Yes, in some high traffic areas
    C. No, compacted material is not used on any high traffic areas

19. What is the condition of the grass barrier between surface water and horse pastures on your property?
    A. At least 50 ft. in width with greater than 60% of ground covered with growing forage
    B. At least 50 ft. in width with less than 60% of ground covered with growing forage
    C. Less than 50 ft. in width with less than 60% of ground covered with growing forage
    D. No surface water on property → If answer D is chosen, please skip to question #21.

20. How do you manage the horse's access to surface water on the property?
    A. Horses are restricted from and kept more than 50 ft. from surface water
    B. Horses are restricted from and kept less than 50 ft. from surface water
    C. Horses allowed unlimited access to surface water
    D. No surface water on property

21. How do you manage the horse's access to wetland areas (i.e. swamp, marsh, bog) on the property?
    A. Horses are restricted from and kept more than 100 ft. from wetlands
    B. Horses are restricted from and kept less than 100 ft. from wetlands
    C. Horses allowed unlimited access to wetlands
    D. No wetlands on property

22. Which of the following options best describes the level of soil erosion in your horse pastures (i.e. the level of physical wearing of the earth's surface).
    A. Soil rarely moves in wet or windy weather, no gullies present, and there is clear or no runoff
    B. Some evidence of soil drifting, few rill or gullies (up to 2 inches deep), and some colored runoff
    C. Obvious soil drifting, with large gullies (over 2 inches deep) joined together, and rapid, colored runoff

23. How many of your barns and/or run-in sheds have rainwater runoff systems to divert runoff to berms or collection systems?
    A. All roofs have drains or gutters placed so rainwater run-off is diverted to berms or collection systems
    B. Some roofs have drains or gutters placed so rainwater run-off is diverted to berms or collection systems
    C. No roofs have drains or gutters placed so rainwater run-off is diverted to berms or collection systems

24. What is the topography on the majority of your horse pastures?
    A. The majority of horse pastures have gradual slopes
    B. The majority of horse pastures have moderate slopes
    C. The majority of horse pastures have steep slopes

25. If you have multiple turnout areas used for grazing, how do you manage the horses within those turnout areas?
    A. Groups of horses are always rotated together between subdivided pastures before or when plant height reaches 3 inches
    B. Groups of horses are sometimes rotated together between subdivided pastures before or when plant height reaches 3 inches
    C. Groups of horses are never rotated together between subdivided pastures and pastures are continuously grazed without rest

26. If you use rotational grazing, how much rest do the pastures receive once the horses are removed?
    A. Pastures are always allowed to rest long enough for plants to grow back to the recommended grazing height (6-10 inches, depending on species of grass)
    B. Pastures are sometimes allowed rest long enough for plants to grow back to the recommended grazing height
    C. Pastures are never rested to allow plants to grow back to the recommended grazing height

27. What is your belief about the relationship between horse farms and the environment?
    A. Horse farms have a strong potential to impact the environment
    B. Horse farms have a modest potential to impact the environment
    C. Horse farms have no potential to impact the environment

28. From the list of options below, identify the primary and secondary use of the horse farm you operate.

    Options: Boarding, Breeding, Instruction, Pleasure/Recreation, Retirement/Rescue, Training, Other (please specify)

    Primary______________________________ Secondary_________________________________

29. What is the average number of horses maintained on the property?________

30. How many acres of the property are used for horse turnout?________

31. How many acres of horse turnout identified in question #30 are used for grazing? ________

32. On average, how many hours per day do your horses spend grazing pastures in the following seasons? Please enter a number for each of the seasons listed below.

Winter: ______________ Spring:________________ Summer:______________ Fall:_________________

33. In what year were you born? 19__ __

34. What is your gender?
    A. Male
    B. Female

35. In what county is your farm located? _________________________

36. What comments and/or suggestions do you have about educational programs and ways that University of Maryland Cooperative Extension can assist you with pasture management issues?

____

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Thank you for completing our survey! Please mail it back in the self-addressed envelope.
Visit us on the web at www.equinestudies.umd.edu

Appendix B. Pre-Visit Survey (Manuscript 2)

UNIVERSITY OF MARYLAND HORSE PASTURE ASSESSMENT

Management Practices Survey

Farm Location ______________________________

____

____

Average number of hours per day horses spend grazing on pasture during the fall

____

Phone ____________________________

1. How would you describe the use of herbicide to control weeds in your horse pastures?
   A. Herbicide is always used when needed
   B. Herbicide is sometimes used when needed
   C. Herbicide is never used

2. How often do you mow your pastures for weed control purposes?
   A. Pastures are always mowed to control weeds
   B. Pastures are sometimes mowed to control weeds
   C. Pastures are never mowed to control weeds

3. How often do you take soil samples from your pastures and submit them for soil tests?
   A. Every 1-3 years
   B. >3 years between soil tests
   C. Never perform soil tests on pastures

4. How is lime applied to your horse pastures?
   A. Lime is always applied to reach optimum pH levels for plant growth based on soil test results
   B. Lime is sometimes applied and may or may not be based on soil test results
   C. Lime is never applied

5. If you have multiple turnout areas used for grazing, how do you manage the horses within those turnout areas?
   A. Groups of horses are always rotated together between subdivided pastures before or when plant height reaches 3 inches
   B. Groups of horses are sometimes rotated together between subdivided pastures before or when plant height reaches 3 inches
   C. Groups of horses are never rotated together between subdivided pastures and pastures are continuously grazed without rest

6. Check all that apply to your farm situation:
   - ☐ Manure is collected regularly and removed from farm
   - ☐ Manure is collected regularly and spread on farm
   - ☐ Manure is collected regularly and stockpiled on farm
   - ☐ Manure is collected regularly and composted on farm
   - ☐ Manure is never collected on the farm

Turn over to continue →

7. Please check all that apply IF you spread manure on your farm.
   - ☐ I do not spread manure
   - ☐ Manure is spread on non-grazed land
   - ☐ Manure is spread on land grazed by animals
   - ☐ Average spreading rate used (i.e. lbs manure/acre): ____________________

8. Please answer the following questions regarding the last time you fertilized your horse pastures:
   - Date applied: ____________________
   - Acres of pastures applied (i.e. 20 acres): ____________________________
   - Percentage of nitrogen (N), phosphorous (P), and potassium (K) in the product used (Example: 20-10-10) ______________________
   - Pounds of product applied per acre (i.e. 50 lbs/acre): _______________________

Farm visits will begin on Monday, September 7, 2009 and conclude the week of Monday, October 5, 2009. Our team will be visiting farms on weekdays. Please mark an "X" next to the week(s) that you would prefer our team to visit your farm. Remember, you do not have to be present for our visit.

_____ Week of September 7, 2009
_____ Week of September 14, 2009
_____ Week of September 21, 2009
_____ Week of September 28, 2009
_____ Week of October 5, 2009

The week of October 12, 2009 will be scheduled in the event that a farm visit is cancelled, due to weather, scheduling issues, etc.

If you have questions regarding this survey, please contact Nicole Fiorellino at nfiorell@umd.edu

Appendix C. BMP Assessment Sheet for Farms with Surface Water (Manuscript 2)

University of Maryland Horse Pasture Assessment Form

Farm Name:	Date and Time:	Performed by:
Field description:		
# of horses in pasture:	# of acres in pasture:	
Surface water location relative to pasture:		

?	BMP	Is BMP being used?		Comments
1	Horses are restricted by use of fencing from surface water and/or wetlands on property	Yes	No	If no, describe situation:
2	Use of a buffer strip between pasture and surface water, at least 100 ft	Yes	No	If no, what's the distance to surface water/wetlands:
3	Buffer strips has vegetation (vs. bare soil)	Yes	No	Describe topography:
4	Evidence of prevention of direct runoff from heavy use (gate, feeding, run-in areas) into surface water	Yes	No	Runoff source:
5	Compacted material used in heavy use areas	Yes	No	Describe condition of heavy use areas:
6	Maintain > 100 ft from heavy use/feeding areas to surface water	Yes	No	Distance:
7	No sign of erosion in pasture (evidence of rills/gullies)	Yes	No	Condition of rills/gullies:

?	BMP	Is BMP being used?		Comments
8	Streambank has healthy stand of vegetation, no sign of animal presence in streambank	Yes	No	Condition of streambank:
9	Evidence of attempt to correct soil erosion problems in pasture (bridge over stream, artificial drains, temp fence)	Yes	No	If yes, describe.
10	Sacrifice lot utilized in pasture	Yes	No	If yes, condition of lot:
11	Pasture has =70% vegetative cover	Yes	No	% Grass: % Legumes: % Weeds: % Soil: % Other:
12	Pastures are not grazed to less than 3"	Yes	No	Average Grass Height:
13	Drains/gutters on roofs, diverting runoff to collection system or away from pastures/manure	Yes	No	Location of runoff diversion:

Comments:

Pasture name: ____

Grass Height Measurement

1	2	3	4	5	6	7	8	9	10	Avg	Notes

Ground Cover Measurements

Label each mark as either "GRASS, LEGUME, WEED, BARE, ETC."

Point	Label	Point	Label	Point	Label
1		1		1	
2		2		2	
3		3		3	
4		4		4	
5		5		5	
6		6		6	
7		7		7	
8		8		8	
9		9		9	
10		10		10	
11		11		11	
12		12		12	
13		13		13	
14		14		14	
15		15		15	
16		16		16	
17		17		17	
18		18		18	
19		19		19	
20		20		20	
21		21		21	
22		22		22	
23		23		23	
24		24		24	
25		25		25	

Appendix D. BMP Assessment Sheet for Farms without Surface Water (Manuscript 2)

University of Maryland Horse Pasture Assessment Form

Farm Name:		Date and Time:	Performed by:
Field description:			
# of horses in pasture:	# of acres in pasture		

Question	BMP	Is BMP being used?		Comments
1	Evidence of prevention of direct runoff from heavy use (gate, feeding, run-in areas) into surface water	Yes	No	Runoff source:
2	Compacted material used in heavyuse areas	Yes	No	Describe condition of heavy use areas:
3	No sign of erosion in pasture (evidence of rills/gullies)	Yes	No	Condition of rills/gullies:
4	Evidence of attempt to correct soil erosion problems in pasture (artificial drains, temp fence)	Yes	No	If yes, describe.
5	Pasture has =70% vegetative cover	Yes	No	% Grass: % Legumes: % Weeds: % Soil: % Other:
6	Pastures are not grazed to less than 3"	Yes	No	Average Grass Height:
7	Drains/gutters on roofs, diverting runoff to collection system or away from pastures/manure	Yes	No	Location of runoff diversion:

Pasture name: ____

Grass Height Measurement

1	2	3	4	5	6	7	8	9	10	Avg	Notes

Ground Cover Measurements
Label each mark as either "GRASS, LEGUME, WEED, BARE, ETC."

Point	Label	Point	Label	Point	Label
1		1		1	
2		2		2	
3		3		3	
4		4		4	
5		5		5	
6		6		6	
7		7		7	
8		8		8	
9		9		9	
10		10		10	
11		11		11	
12		12		12	
13		13		13	
14		14		14	
15		15		15	
16		16		16	
17		17		17	
18		18		18	
19		19		19	
20		20		20	
21		21		21	
22		22		22	
23		23		23	
24		24		24	
25		25		25	

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