Journal of International Farm Management Vol.4. No.3 - August 2008

Decision Considerations and Cost Analysis of Beneficial Management Practice Implementation in Thomas Brook Watershed, Nova Scotia

Victor Afari-Sefa[1]
Emmanuel K Yiridoe[2]
Robert Gordon[3]
Dale Hebb[4]

[1]**Victor Afari-Sefa,** Postdoctoral Research Fellow, Department of Business and Social Sciences, Agricultural and Resource Economics Research Group, Nova Scotia Agriculture College, P.O. Box 550, Truro, NS, Canada, B2N 5E3. E-mail: vafarisefa@nsac.ca. Dr. Afari-Sefa is an economist for a Watershed Evaluation of Beneficial Management Practices (WEBs) research project in Nova Scotia, Canada. His research interests include Watershed Modelling and Management, Farm Management, Agricultural and Rural Household Modelling.

[2]**Emmanuel K. Yiridoe**, Associate Professor, Department of Business and Social Sciences, Agricultural and Resource Economics Research Group, Nova Scotia Agriculture College, P.O. Box 550, Truro, NS, Canada, B2N 5E3. E-mail: eyiridoe@nsac.ca. Dr. Yiridoe teaches courses in Resource and Environmental Economics, and is the Principal Investigator on the Watershed Evaluation of Beneficial Management Practices research project for Thomas Brook Watershed, Nova Scotia, Canada.

[3]**Robert Gordon,** Associate Professor and Canada Research Chair (Agriculture Resources Management), Department of Engineering, Nova Scotia Agriculture College, P.O. Box 550, Truro, NS, Canada, B2N 5E3. E-mail: rgordon@nsac.ca. Dr. Gordon is also the Dean of Research at the Nova Scotia Agricultural College.

[4]**Dale Hebb,** Research Biologist, Agriculture and Agri-Food Canada, Atlantic Food and Horticulture Research Centre, 32 Main Street, Kentville, NS, Canada, B4N 1J5. E-mail: hebbd@agr.gc.ca. Dr. Hebb is leader of the Watershed Evaluation of Beneficial Management Practices (WEBs) research project for Thomas Brook Watershed, Nova Scotia, Canada.

Key words: Farm decision choices, beneficial management practice costs, environmental stewardship

Decision Considerations and Cost Analysis of Beneficial Management Practice Implementation in Thomas Brook Watershed, Nova Scotia

Abstract

Most agricultural beneficial management practices (BMP) require not only investment of money and forgone opportunities for farmers, but can also result in reduced farm returns, especially in the short-run, thereby making such BMP adoption costly for farmers. Two approaches were used to assess the detailed on-farm costs, and important non-economic and less quantifiable decision considerations associated with establishing and maintaining two structural BMPs and one non-structural BMP in the Thomas Brook Watershed, Nova Scotia, Canada. Labour cost and technical consultancy fees as a percentage of total BMP cost was higher for the stormwater diversion drainage system (60%) than for fencing to exclude livestock from a waterway (32%). In contrast, material costs as a proportion of total cost was higher for livestock exclusion fencing (47%) than for the stormwater diversion drainage system (6%). Results of the analysis demonstrate the complementarity of the two methods. The case study in-depth interviews on key farm and BMP specific factors considered in implementing the BMPs are consistent with the empirical economic cost analysis. Furthermore, the qualitative analysis revealed that besides economic costs, other important factors and motivations influence farmers' decisions to implement and maintain environmental conservation-compatible practices, which agricultural administrators and policy makers should not ignore.

Decision Considerations and Cost Analysis of Beneficial Management Practice Implementation in Thomas Brook Watershed, Nova Scotia

1. Introduction

Beneficial management practices[1] (BMPs) have become a common approach to not only manage non-point source pollution from agriculture, but are also accepted tools for implementing specific federal and provincial government farm environmental risk programs, and helping to comply with environmental regulations. The costs associated with designing, implementing and managing BMPs in agriculture pose a barrier to widespread adoption (Curtis & Robertson, 2003; Lambert et al., 2007; Tilman et al., 2002; Yiridoe & Marett, 2004). Indeed, Curtis & Robertson (2003) noted that a key reason for observed limited adoption of BMPs on farms is linked to landowners' reservations about the BMPs, stemming from farmers' awareness that the costs associated with such management practices cannot be recovered from farm profits. Thus, the degree of producer participation necessary to protect or improve environmental quality will depend not only on the total number of land users who implement BMPs, but also on other factors linked to BMP implementation costs (e.g., type of farming system, location of the BMP within a particular farm, and type of BMP).

Farmers and farmland owners typically are the decision makers regarding production and management practices, and bear substantial financial (and non-financial) responsibility for

---

[1] The discussion in the scholarly literature regarding whether "best management practices" or "beneficial management practices" or "conservation-compatible practices" is the more appropriate semantic is recognized. In the context of this study, BMPs refer to practical and affordable pollution-prevention farming methods and practices aimed at ensuring that risks to the environment are minimized without unreasonably compromising farm profitability.

agricultural BMP implementation on farms. Thus, estimates of cost information on BMP implementation and maintenance can allow for improved decision making by farmers and policymakers by, for example, enhancing enrolment in government environmental programs (Wossink & Osmond, 2002). In some cases, farmers may also be able to pass some or all the associated costs on to landowners (e.g., through farmland leases) or to the agri-food chain (e.g., through higher product prices). Thus, it is important for farm managers, landowners, and the agri-food industry to clearly understand the costs associated with implementing BMPs on farms. Despite this importance, a more complete and comprehensive understanding of the costs and the associated environmental and resource implications for agricultural BMPs remain largely unexplored (Curtis & Robertson, 2003), especially for many agricultural regions in Canada (Stonehouse, 1991; 1995).

Agricultural production, including BMP costs (and returns) analysis, provides basic parameters that can be used to characterize and assess performance of agricultural enterprises (American Agricultural Economics Association, 2000). Yet, Stonehouse (1991; 1995) noted that in many instances, the costs (and benefits) of most beneficial management practices are not known, are ambiguous and confusing, or are not known for a wide enough range of natural resource endowment, management skill and economic circumstances at the farm level. Several published studies have investigated costs of BMPs and BMP implementation for the forestry sector (e.g., Aust et al., 1996; Cubbage, 2004; Visser et al., 2003). However, similar studies especially for Canadian agricultural conditions are limited. Given the importance of cost analysis in agriculture, and the increasing importance of and interest in BMPs in farm environmental stewardship, it is surprising that few studies have characterized the costs of major agricultural BMPs.

Besides the implications for farm management, BMP cost analysis also has potential agri-environmental policy implications. Government regulations that require BMPs or other farm environmental stewardship efforts might compel farmland owners to absorb costs that could exceed the benefits to society of implementing particular BMPs. Such farm environmental regulations may also necessitate substantial government costs and other support schemes to implement the initiatives. Regulators may also use assessments of technically and economically feasible BMPs by area and farm type as a guide in efficiently allocating public resources. The costs to government take on a heightened dimension when considered in light of recent increasing public budget constraints in Canada. Thus, analysis of the costs of farm environmental stewardship initiatives and BMPs is important to not only provide information on magnitude of such regulatory burdens (to government and farmers), but to also allow for comparison with the estimated on and off-site benefits to society of implementing particular BMPs.

This study forms part of a larger Watershed Evaluation of Beneficial Management Practices research project to evaluate the economic and environmental effectiveness of selected BMPs on water quality at specified watersheds across Canada. This component of the Watershed Evaluation of Beneficial Management Practices research project is an exploratory study to assess the costs associated with implementing selected BMPs on actual farming systems managed in the Thomas Brook Watershed in Nova Scotia, Canada. The cost analysis reflects structural BMPs implemented by farmers. Similar costs estimates for the non-structural BMP of interest (i.e., nutrient management planning) were not considered partly because such costs tend to vary substantially by farm and even across farmfields within a single farm. The US Environmental Protection Agency (US EPA) (2004) also noted that non-structural BMPs are characterized by indirect and highly variable implementation levels by farmers. Given that several of the BMPs of interest were voluntarily adopted by individual farmers, it provides a unique opportunity to use case research methods to also explore what important factors and issues prompted their implementation, including site and production-system specific considerations. The investigation for nutrient management planning was an exploratory phase of a larger research initiative to provide context for further research.

2. Review of Related Studies

2.1 Structural Versus Non-structural BMPs

The US EPA (1993) classified agricultural BMPs into non-structural or source control BMPs, and structural or treatment BMPs. Non-structural BMPs generally involve using management approaches to control pollution, and do not require extensive construction, or fixed or permanent structures. Such BMPs typically require modifying farming practices or farmer behaviour necessitated by various economic or regulatory instruments (Lambert et al., 2007; Taylor & Wong, 2002). Non-structural BMPs are also sometimes referred to as source BMPs because they improve environmental quality by controlling the use, generation and accumulation of pollutants at or near a pollutant source. A non-structural BMP studied is nutrient management planning.

Structural (including vegetative) BMPs, on the other hand, can be used to control the volume of pollutants through crop rotation, physical containment and flow restrictions of pollutants (US EPA, 2004). Structural BMPs investigated in this study include livestock exclusion fencing with offstream watering, and a stormwater diversion drainage system. In what follows, the BMPs of interest are described, and key factors which can affect the BMP effectiveness are reviewed.

2.1.1 Livestock Exclusion Fencing

Although no provincial or federal law in Canada explicitly requires that livestock be fenced out of water systems, the federal Fisheries Act prohibits livestock from farms entering streams and other water systems and damaging fish and other aquatic habitats and/or result in depositing contaminants which adversely affect fish. On the other hand, fencing to restrict livestock access to water courses is an Environment Canada recommended farm management practice that can help farmers comply with the Fisheries Act (LJM Environmental Consulting, 2003). Limiting livestock access to streams and other waterways, while providing offstream drinking watering system can not only improve drinking water quality for farm animals (Zeckoski et al., 2007), but can also result in increased animal weight gain (see Table I), and milk and butter fat production (Landefield & Bettinger, 2002). The type of livestock fence that can be established on farms is specified under the Nova Scotia Fences and Impounding of Animals Act, and includes fences built using posts and rails, or posts and wires (barbed or plain),

Table I: Potential Benefits to Livestock of Alternative (to Stream) Drinking Watering System

Benefit	**Source**
a) Potential Benefits	
Increased drinking water quality	Willms et al. (2002)
More desirable water temperature	McIver (2004)
Reduced animal disease incidence (by limiting livestock contact with pathogens in stream)	Zeckoski et al. (2007)
Improved streambank stability and erosion control	Sheffield et al. (1997)
b) Reported Livestock Weight Gain from Offstream Watering System	
Cows: 0.2 -0.4 lb per day	Buchanan (1996); and Willms et al. (1994).
Calves: 0.2 – 0.3 lb per day	Dickard (1998)
Heifers: 0.6 – 1.8 lb per day	Beira (2003)
Heifer calves: 0.1 lb per day	Buchanan (1996)
Steers: 1 lb per day	Willms et al. (1994)
c) Reported Increased Milk Production from Improved Drinking Water Quality	
Lactating cows: 7 kg milk increase per day	Challis et al. (1987)

or those made from stones, pickets, boards, logs, poles, and brush (LJM Environmental Consulting, 2003). Thus, the costs associated with fencing to exclude livestock from waterways can vary not only according to the type and quality of fencing, but also on topography and other site-specific characteristics. The life span of livestock exclusion fencing and water access ramps is up to 20 years (DPRA Incorporated, 1989). In addition, effectiveness of the livestock exclusion fencing in helping to reduce non-point source pollution in a water system depends on slope and soil stability of the streambank, along with water system characteristics such as capacity of the stream to assimilate contaminants (DPRA Incorporated, 1989).

2.1.2 Stormwater Diversion Drainage System

Although stormwater runoff may be part of a natural hydrologic process, human activities, especially urban development and agriculture, can cause significant changes in patterns of stormwater flow into receiving waters, thereby generating a significant source of water pollution. A stormwater diversion drainage BMP is a technique or structural control system that can be used to manage water quantity and/or improve the quality of stormwater runoff in a cost effective manner. Provisions under the Nova Scotia Environment Act and the federal Fisheries Act require prior government approval of alterations to a watercourse or water resource by farmers.

Potential problems from stormwater runoff can be controlled by diverting manure run-off away from constructed channels, which would otherwise contaminate surface and ground water systems. Innovations for managing stormwater range from small or site specific, to large or regional scale practices (Wossink & Hunt, 2003). Factors which can affect the effectiveness of a stormwater diversion drainage system include management strategies such as careful application of site design principles, and construction techniques to prevent sediment and other pollutants from entering surface or groundwater. In addition, runoff can be treated to reduce pollutants and the impact of hydrology from farmland (US EPA, 2004).

2.1.3 Nutrient Management Planning

Nutrient management planning involves field balancing of nutrients from chemical fertilizers, manure, and soil, with crop nutrient requirements, thereby helping to enhance the economic and environmental sustainability of the agroecosystem (West, 1996). A nutrient management plan (NMP) typically includes soil nutrient testing, equipment calibration, erosion control, timing of fertilizer application and record keeping (Ribaudo & Johansson, 2007). Soil nutrient testing can be used to customize fertilizer application to crop needs. Carefully matching fertilizer amount to crop nutrient requirements can also result in reduced costs and greenhouse gas emissions (e.g., nitrous oxide). In Nova Scotia, fertilizer recommendations that are based primarily on estimated plant nutrient requirements (as opposed to soil nutrient tests) can result in farmers applying rates higher than the recommended levels (McRae et al., 2000). Soil nutrient testing can provide site-specific information on nitrogen and phosphorous availability, allowing recommendations to reflect soil conditions and/or management practices on farmfields. Such customized information on fertilizer recommendations is particularly important in Nova Scotia because some farms are located in watersheds, with significant applications of manure and inorganic fertilizer (Korol, 2004; McRae et al., 2000). Application of crop nutrients in excess of crop requirements has resulted in a gradual shift in management strategies from correcting plant nutrient deficiency symptoms, towards holistic management of whole-farm nutrient balances while, at the same time, minimizing nutrient pollution of surface and groundwater.

An efficient NMP is environmentally sound, maximizes crop benefits and feed quality, minimizes nutrient loss during manure collection, storage and application, and maximizes nutrient use by crops (Chizmazia, 1996). Given these multiple objectives, a NMP has to be site-specific to help address production system-specific conditions. A standard NMP is based on soil tests to determine nutrients available in fields, an assessment of nutrient credits from previous crops and manure application, and realistic yield expectations (Wossink & Osmond, 2002).

Although nutrient management planning inherently requires substantial time commitment, it has the potential to reduce the amount and cost of fertilizer applied. On average, the additional benefits should offset the costs of nutrient management planning. In other words, the savings from reduced fertilizer application should exceed any additional costs of implementing the NMP. Nutrient management planning can increase or decrease net farm returns, depending on farm type (i.e., crop or livestock) and farm characteristics (see, for example, Ribaudo & Johansson 2007). Non-structural BMP (such as nutrient management planning) can help control pollution at source, thereby helping to eliminate or reduce the need for costly “end-of-pipe” treatment using structural BMPs (Water Environment Federation & American Society of Civil Engineers, 1998).

Nutrient management plan implementation may be voluntary, as in Nova Scotia (Canada) and Virginia (US), involve a combination of voluntary and regulatory strategies as in New Brunswick and Prince Edward Island (Canada), or be completely regulated as in Quebec (Canada) and Pennsylvania (US) (Jacques Whitford Environment Ltd. & LJM Environmental Consulting, 2001). Generally, compared to voluntary adoption, regulating NMPs tends to result in more widespread adoption (and likely effectiveness) (Jacques Whitford Environment Ltd. & LJM Environmental Consulting, 2001; Korol, 2004). For example, only 5.2% of farmers surveyed in Nova Scotia implemented NMPs in 2001, compared to 47% in Quebec (Korol, 2004). Monitoring and enforcement effectiveness of non-structural BMPs (such as nutrient management planning) can be complicated, and also involves costs for laboratory analysis. The US EPA (2004) noted that non-structural BMP monitoring program approaches may fail to generate the desired results in a watershed if the monitoring effort is not linked to specific pollutants or effluents. The failure may also be due to problems with monitoring non-point source contaminants in a large watershed.

2.2 BMP Cost Analysis and Adoption Decisions

Costs associated with establishing BMPs tend to vary from farm to farm, and depend on factors such as season in a particular year, site conditions and topography, accessibility of equipment, economies of scale, and government regulations (US EPA, 2004). Compared to structural BMPs, the costs associated with non-structural BMPs are difficult to quantify, partly because of their indirect and highly variable implementation levels (US EPA, 2004). Partly because of this, the importance of non-structural BMPs in watershed management and planning are not always recognized (Clar et al., 2003). In addition, data on such BMP performance tends to be limited. For this study, indepth interviews were used to obtain important but less quantifiable factors farmers considered in implementing livestock exclusion fencing from streams, stormwater diversion drainage system, and nutrient management planning.

Methods for estimating BMP costs may be classified broadly as follows (US Department of Defense, 1995):

i) Bottom-up Approach: costs are estimated item-by-item using information from a database or other cost-estimation reference source.

ii) Analogy Method: estimates the costs of an existing BMP or project by extrapolating from the cost of previously completed projects. This approach is especially relevant when BMP design information is available.

iii) Expert Opinion Method: experts or consultants provide cost estimates based on experience and understanding of the BMP.

iv) Parametric Method (also known as top-down estimation): estimations using mathematical relationships between cost and BMP design parameters.

Although studies have addressed various components of cost estimation for BMPs (see, for example, DPRA Incorporated, 1989; Ferguson et al., 1997, South-eastern Wisconsin Regional Planning Commission, 1991; Water Environment Research Foundation, 2003), most of these focus on installation or construction costs (e.g., Sample et al., 2003; Young et al., 1996). Other important aspects of BMP costs that have been assessed include design, operating and maintenance costs (Center for Watershed Protection, 2000; US EPA, 1999a). In addition, indirect regulatory costs, along with opportunity costs of forgone production, may be relevant.

Studies on agricultural BMP adoption and implementation decisions, such as stream fencing as a riparian management strategy, have used convergent interview methods (see for example Dick, 1998), to identify factors which influence farmers' adoption decision considerations (Bewsell et al., 2007; Grunert & Grunert, 1995; Kaine, 2004). Convergent interview methods can be used to assess representative respondent actions and decisions from questions administered through a combination of structured and unstructured interviews. The technique was adapted and used to identify key decisions by farmers in establishing the BMPs studied. A case research approach allowed for in-depth estimation and analysis of cost information for the two BMPs. Case study methods are also relevant when the researcher is interested in an in-depth exploration of key decisions connected with voluntary adoption of BMPs (Bewsell et al., 2007; Yin, 1994*)*. Investigating such qualitative factors and insights required use of case-specific and situationally-constructed meanings. Berentsen et al. (2007) noted that such empirical methods are relevant when assessing key economic costs, and other important but less quantifiable factors connected with establishing and maintaining BMPs.

3. Research Methods and Data

Data for the analysis was obtained primarily through the Watershed Evaluation of Beneficial Management Practices research project management team at the Agriculture and Agri-Food Canada (AAFC) Research Station in Kentville, Nova Scotia. Following consultations with the project management team, farmers within the watershed who implemented the BMPs were identified. The cost analysis was based on data obtained from farmer records, and estimates from technical experts involved in BMP design, construction, and implementation, along with farmer estimates on BMP maintenance costs. Survey questions were used to elicit information from farmers on the BMP adoption considerations.

For the two structural BMPs investigated, data on construction, maintenance and other costs were collected in the summer of 2007. For the qualitative analysis, the first part of the interview instrument elicited responses on experience and crucial considerations in adoption, including: (i) key environmental and regulatory concerns which prompted implementation of the BMP; (ii) farm management considerations that influenced design and construction of the BMP and (iii) site characteristics considered in the BMP design. The second part of the questionnaire related to BMP construction material and maintenance costs, as appropriate. Costs of materials employed in BMP construction and establishment were estimated by multiplying the input levels used, by 2007 prices obtained from local retailers. Machinery and equipment for stormwater diversion drainage system construction was assumed to be rented at current retail rates.

To capture all the economic costs, opportunity costs of in-kind technical assistance and farmer time were included in the analysis. These included costs for BMP structural design and consultancy offered to farmers under the Watershed Evaluation of Beneficial Management Practices research project. Labour costs for construction varied depending on the task. The actual amounts paid by farmers were computed by multiplying hourly rates by the number of hours of hired labour. The opportunity cost of land used for constructing structural BMPs was also included. It was assumed that a five metre wide strip of land was fenced to exclude livestock from the waterway, and thus was unavailable for other productive activities (Fritz, 2003).

The expected lifetime of BMPs vary and, therefore, complicate cost comparisons. To allow for costs to be compared for BMPs with varying lifetimes, total BMP costs were reduced to annual values using the relationship (Degarmo et al., 1997; Gitau et al., 2004):

$$A_{BMP} = \frac{Z\left(\frac{r}{100}\right)}{1-\left(1+\frac{r}{100}\right)^{-n}} \qquad (1)$$

where A_{BMP} is the annualized cost for a BMP (\$), Z is the capital cost of a BMP (\$), r represents the time value of money (%) and n is the expected lifetime of the BMP (years). The expected lifespan of the stormwater diversion drainage system and the livestock fencing system were 25 years, and 20 years respectively. Interest rate assumed for the time value of money was 8%.

4. Results and Discussion

Results of the qualitative analysis of BMP implementation decision considerations by farmers are presented first, followed by the costs associated with adopting and implementing the two structural BMPs studied. The results are shown separately for each of the BMPs, including key reasons and unique management and farm attributes considered in designing and implementing particular BMPs.

4.1 BMP Design and Implementation Decision Considerations

4.1.1 Livestock Exclusion Fencing

Fencing to exclude livestock from a waterway was undertaken by a farmer who managed 170 dairy animals, milking 50 cows on 29 ha pasture. The total farmland area was 316 ha. The livestock exclusion fence was 75 m long and 0.91 m high, consisting of a strand of high tensile electrical fence, and reinforced with 0.1 m by 1.83 m (4 in by 6 ft) treated wooden posts. To reduce costs, some materials from an existing fence were used to establish parts of the new fence. In addition, an offstream watering system to reduce on-stream watering damage was built, and consists of a standing water pipe and a livestock drinking water tank. The fencing work was started and completed in March 2005.

The most important environmental concern that prompted construction of the livestock fence was not merely to exclude livestock from the waterway, but to help reduce soil compaction along a riparian zone, and reduce the likelihood of livestock manure entering the stream (Table II). In contrast, the most important farm management issues considered in designing the livestock exclusion fence was to minimise the land taken out of pasture production. In addition, it was reported that a minimum acreage of pasture was required to adequately manage grazing rotation lengths. Furthermore, the location of an offstream watering system for livestock for efficient grazing management was a major consideration in establishing the fence.

In summary, both livestock management and environmental factors were considered in building the fence to exclude cattle from the waterway. In a survey of New Zealand farmers, Bewsell et al. (2007) reported that promoting stream and riparian fencing is strongly linked to farm-level management factors and financial benefits to farmers. As noted earlier, although farmers in Nova Scotia are not required to adopt livestock exclusion fencing to protect waterways, voluntary adoption can help prevent manure spillage into waterways as required under the provincial Environment Act and federal Fisheries Act. The results are consistent with those found by Ribaudo & Johansson (2007), who reported that local ordinances on farming practices, combined with educational campaigns on water quality and public complaints, can motivate farmers to more widely adopt conservation practices than would be the case if adoption decisions are based solely on considering private benefit.

4.1.2 Stormwater Diversion Drainage System

The stormwater diversion drainage system construction was initiated and completed in December 2004. The drainage system pipe was 213.36 m (700 ft) long and 0.10 m (4 in) wide and buried 1.22 m (4 ft) below ground. The most important farm-level factors considered in constructing the stormwater diversion drainage system are summarized in Table II.

Table II: Summary of Reported Primary Decision Considerations and Motivations For Implementing Selected BMPs

Item	**Reported key decision considerations and motivations**
1. *Livestock exclusion fencing*	
Environmental/regulatory consideration	Livestock exclusion to: • reduce soil compaction along riparian zone; and • reduce likelihood of livestock manure entering waterway.
Management consideration	Concerns about the amount of land that would be taken out of (pasture) production after constructing the fence.
Site characteristics	Location of an offstream watering source for livestock once animals were fenced out of the waterway.
2. Stormwater diversion drainage system	
Environmental/Regulatory Consideration	Reduce and manage on-farm manure runoff.
Management consideration	On-farm equipment traffic: • ensuring accessibility of machinery and equipment to/from farm buildings • cultivation of land after construction of the water diversion drainage system.
Site characteristics	The farmland gradient/slope, area and layout of farm buildings in relation to direction of stormwater flow.
3. *Nutrient management planning*	
Environmental/Regulatory consideration	Achieve multiple environmentally-sound farm management objectives, including: • improving production efficiency • reducing potential negative impacts of excessive fertilizer application on soil, air and water quality. • eligibility for government lime transportation subsidy
Management consideration	Concerns with possible increased production costs arising from: • consultancy fees for NMP development. • calibration of manure spreader. • finding markets for new crop produce introduced because of NMP requirements. • labour intensive requirements of a NMP.
Site characteristics	Facilitate soil testing and NMP implementation by considering: • soil sampling at different locations to account for heterogeneity in nutrient balance. • size and slope of individual fields. • suitability of field for particular crops. • access to irrigation water. • distance (access) from field to manure storage.

The farmer's effort to reduce manure runoff into an adjacent stream reflects provincial livestock manure management regulations (see Nova Scotia Department of Agriculture and Fisheries, 2006). Although manure is not explicitly regulated under current provincial and federal environmental regulations, accidental spills of manure which impairs surface or ground water (including well water) quality could result in violation of the federal Fisheries Act and provincial Environment Act (LJM Environmental Consulting, 2003).

Production and management issues considered in designing and constructing the stormwater diversion drainage system included accessibility of machinery and equipment to and from farm buildings, and the ability to cultivate farmland after building the water diversion drainage system. In addition, topography, farmland slope, and layout of farm buildings were reported as important site characteristics considered in designing the stormwater diversion drainage system. Engineering, hydrologic and topographical factors affected construction, maintenance and, ultimately, costs of the stormwater diversion drainage system. Schueler (1987) and Young et al. (1996) noted that the performance of stormwater diversion drainage systems is especially sensitive to location and the drainage system should reproduce, as closely as possible, pre-existing natural hydrological conditions in the watercourse prior to any previous human alteration. The Centre for Watershed Protection (2000) also noted that pervious land surface areas and characteristics need to be used to enhance site design and effective stormwater treatment.

4.1.3 Nutrient Management Planning

Farmers reported that the most important reasons for implementing nutrient management planning were to achieve multiple farm management objectives, including: i) improving production efficiency; ii) reducing potential negative impacts of excessive fertilizer application on soil, air and water quality; and iii) eligibility for a government lime subsidy (Table II). Under the Nova Scotia Farm Investment Fund, farmers are eligible for a lime transport subsidy if recommended by a nutrient management planning specialist (Nova Scotia Department of Agriculture and Fisheries, 2007). Currently, the total cost of a new NMP, including consultation fees, soil nutrient and manure sample test fees, and field mapping are covered under the program, up to a maximum of $1,500. In addition, there is a 50% cost-share funding (up to $750) for subsequent NMPs implemented on the same farm (Nova Scotia Department of Agriculture and Fisheries, 2007). The government lime trucking subsidy in 2007 for the study area was $12.00 per tonne.

The opportunity cost of time spent in developing the NMP was reported as a major concern to farmers. Farmers also reported difficulties with finding markets for new crops (e.g., oats, winter wheat, rye and clover-based pasture) grown as part of the recommendations under the NMP program. Inability to market such crops, and reduced crop yield due to lower fertilization rates, increases risks associated with nutrient management planning and, therefore, can hamper adoption of NMPs.

In contrast to the two structural BMPs studied, the major site characteristics considered in implementing NMPs included the need to sample soils at representative locations, to account for heterogeneity in nutrient balance across different fields. Other important on-farm factors considered in implementing NMPs included size and slope of individual fields, their suitability for particular crops, access to irrigation water, and distance (access) from fields to manure storage system.

4.2 BMP Cost Analysis

4.2.1 Livestock Exclusion Fencing

The major costs associated with livestock exclusion fencing included materials, labour and technical personnel, and the opportunity cost of land (not available for growing pasture) (Table III). Total cost to establish the 75 m fence, including maintenance for the estimated lifespan of 20 years was \$3136, or \$42 m^{-1} with an annual cost of \$319.34. Landphair et al. (2000) noted that structural BMP costs need to include not only design, maintenance and construction costs, but also any costs required to remove pollutants. Thus, the costs estimated also included expenditure for an offstream watering system, described earlier.

A substantial proportion of total fencing costs (i.e., 47%) was for materials used in constructing the electrical fence and offstream watering system (Figure 1). By comparison, miscellaneous labour and consultancy fees were 32% of total BMP costs (or \$1011), of which 89% were fees for design and consultancy. The opportunity cost of land was relatively small (i.e. 7%) partly because the farm is located in rural Nova Scotia. In contrast, for example, Wossink (2000) reported that the amount of land dedicated to buffer strips to trap sediment and nutrients along the Neuse River in North Carolina was the most important annual cost of a riparian buffer. The US EPA (2004) also noted that opportunity cost of land can be substantial, especially where farms are located near urban residential settlements. Annual maintenance of the fencing system includes labour to clear weeds, monitoring electrical wire fence controllers or energizers, and monitoring and cleaning the offstream drinking water system. Annual maintenance cost was \$24.44, or 8% of annualized BMP cost.

Table III: Cost Estimates for Livestock Exclusion Fencing and Offstream Watering

Item	Unit cost ($)	Quantity	Total cost ($)	Annualized cost ($)
a. BMP Establishment Costs				
Material costs				
Fence wire	1.00 m^{-1}	75	75.00	7.64
Corner posts	5.50	25	137.50	14.00
Wooden posts	4.50	10	45.00	4.58
Stock watering tanks	496.79	2	993.58	101.2
Plumbing fittings	95.85	1	95.85	9.76
Water hose	108.50	1	108.50	11.05
Other inputs				
Labour (general)	12.00 hr^{-1}	3	36.00	3.67
Backhoe service	50.00 hr^{-1}	1.5	75.00	7.64
System design	150.00 hr^{-1}	3	450.00	45.83
Technical consultancy	150.00 hr^{-1}	3	450.00	45.83
Interest on operating expenses[1]			197.31	20.10
Opportunity cost of land	308.75 ha^{-1}	0.0375	231.60	23.59
b. Maintenance costs				
Labour	12.00 hr^{-1}	1	240.00	24.44
Total BMP costs			**3,135.34**	**319.34**
Cost per unit length of fencing			\$41.80 m^{-1}	\$4.26 m^{-1}

[1] Interest on operating expenses was 8% of material costs and other inputs.

By comparison, the maintenance cost was US$170 a year, or 5% of total investment expenditure in a US study for the Great Lakes Basin (DPRA Incorporated, 1989). Annual maintenance cost per unit length for the Great Lakes Basin study was \$0.11 m^{-1}, compared to \$0.33 m^{-1} for this study. The higher annual maintenance cost for this study was due to the additional cost incurred for cleaning the offstream waterers.

4.2.2 Stormwater Diversion Drainage System

The total cost for the stormwater diversion drainage system was \$6755 (Table IV), or \$32 m^{-1} of drainage system. Sixty percent of the total cost (i.e., 60%) was for professional/technical consulting and miscellaneous labour ($4080) (Figure 1), followed by equipment rental ($1468 or 22% of total costs).

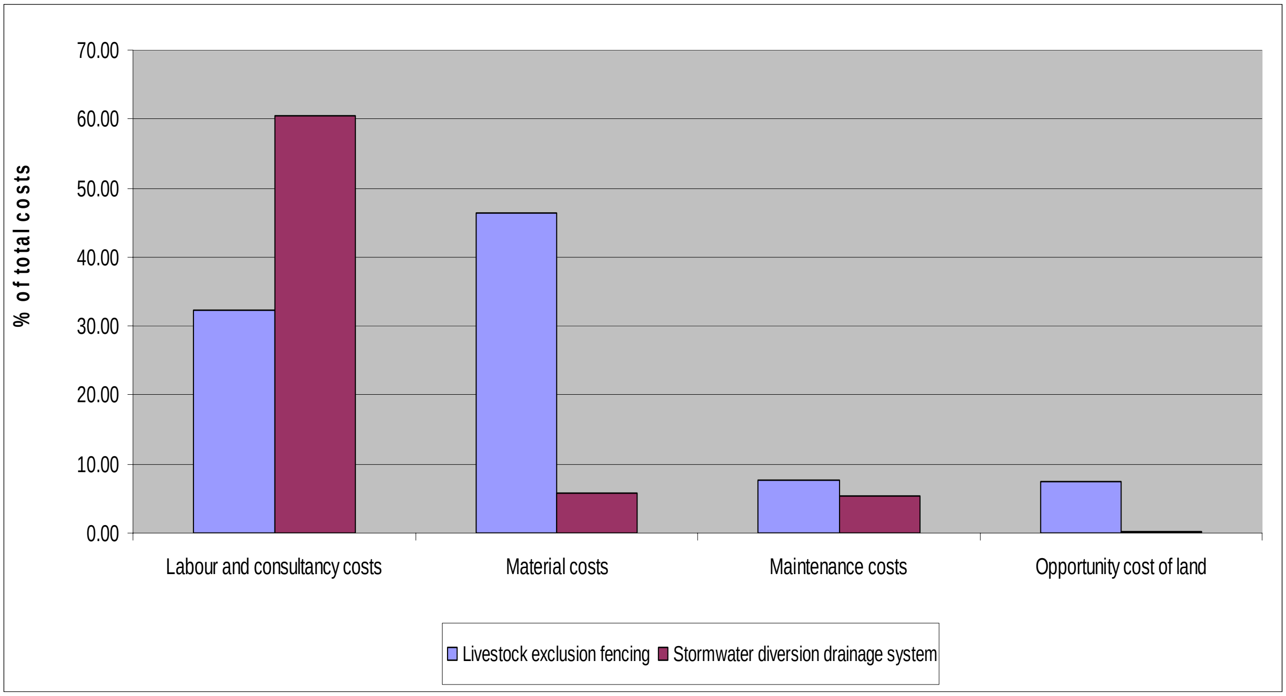
Table IV: Cost Estimates for Stormwater Diversion Drainage System

Item	Unit cost ($)	Quantity	Total cost ($)	Annualized cost ($)
a. BMP Establishment Costs				
Material costs				
Polyethylene pipe (PE)	0.0325 in^{-1}	750.0	0.98	2.28
Perforated PE pipe	0.0325 in^{-1}	500.0	0.65	1.52
4-inch tile TEE	4.70	3.0	0.56	1.32
4-inch tile coupler	2.75	6.0	0.66	1.55
Hickenbottom drain	174.00	4.0	11.84	27.73
4-inch PVC Pipe	10.90	1.0	0.44	1.02
4-inch Rodent trap	6.85	1.0	0.27	0.64
Equipment/machine rental				
Trenching and filling (backhoe loader)	50.00 hr^{-1}	20.0	40.00	93.68
Site work (skidsteer)	78.00 hr^{-1}	6.0	18.72	43.84
Other Inputs				
Miscellaneous (i.e., unskilled) labour	12.00 hr^{-1}	27.5	13.20	30.91
System design	150.00 hr^{-1}	15.0	90.00	210.78
Technical consultancy	150.00 hr^{-1}	10.0	60.00	140.52
Interest on operating expenses[1]			17.75	41.58
Opportunity cost of land	308.75 ha^{-1}	0.0023	0.71	1.66
b. Maintenance costs				
Labour	12.00 hr^{-1}	1.2	14.40	33.72
Total BMP cost			**6754.57**	**632.76**
BMP cost per herd			$39.73	$3.72
BMP cost per unit length of stormwater diversion drainage system			$31.56 m^{-1}	$2.96 m^{-1}

[1] Interest on operating expenses was 8% of material costs and other inputs.

In contrast to the cost estimates for the livestock exclusion fencing, cost of materials for stormwater diversion drainage system was $385 or 6% of total cost, compared to 47% for livestock exclusion fencing. The difference in the relative magnitude of the cost of materials between the two structural BMPs is because of the substantial costs for technical consulting required for designing and constructing the stormwater diversion drainage system. In addition, renting of equipment for preliminary construction work (22% of the total cost for the stormwater diversion drainage system) was not required for the livestock exclusion fencing. The opportunity cost of land for the stormwater diversion drainage system was 0.3 % of total cost (Figure 1). Most studies on stormwater diversion drainage system cost estimation have been for urban settings, where land values are influenced by residential property values. The life expectancy of the drainage system was estimated at 25 years, and required $33.72 for annual maintenance. Regular maintenance of stormwater diversion drainage systems is important and can help reduce growth of algae (which result in offensive odours), insect and weed infestation, and sediment build up (thereby affecting water quality) (Wossink & Hunt, 2003). Annual maintenance cost was 5% of total cost. The results are consistent with a study in the US, where fencing maintenance costs (and water access ramps) was 5% of total investment costs, or US$130 to $170 per year (DPRA Incorporated, 1989).

Figure 1: Costs as a Proportion of Total BMP Cost



As shown in Figure 1, labour cost and drainage system design and technical consultancy fees as a percentage of total cost was higher for the stormwater diversion drainage system (60%) than for livestock exclusion fencing (32%). In contrast, material costs as a proportion of total cost was higher for livestock exclusion fencing (47%) than for the stormwater diversion drainage system (6%). Furthermore, maintenance cost as a proportion of total cost was higher for the stormwater diversion drainage system than for the livestock exclusion fencing. The relative importance of maintenance costs for both structural BMPs is consistent with DPRA Incorporated (1989) and Wossink (2000) who reported average annual maintenance costs for riparian buffer strips and stormwater diversion drainage system in the range of 3-5%.

5. Conclusion: Management and Agri-environmental Policy Implications

In general, a complete accounting of the costs (and associated benefits) of agricultural practices is required for society as a whole to realize maximum net benefits from agricultural production. Furthermore, given that such cost accounting tends to provide the context for both agri-environmental policy and farmer action (Tilman et al., 2002), the findings from this research are important in several respects. As noted earlier, analysis of the costs and benefits associated with BMP provides basic information for assessing farm enterprise performance. If BMP adoption cost exceeds the expected benefit, farmers will likely not change their behaviour without incentives to do so. Besides costs, there are other important considerations linked to BMP implementation. Consequently, the two complementary approaches used in this study, involving empirical cost estimates and qualitative analysis of key BMP implementation considerations, together, provide a more complete and comprehensive understanding of the key financial and non-financial issues.

The results show that material costs are important for livestock exclusion fencing, and technical consulting fees in the case of the stormwater diversion drainage system. Annual maintenance costs for livestock exclusion fencing include non-trivial expenditure for periodically inspecting and cleaning offstream waterers, fence posts, and access ramps, and ranged from 4–8% of total BMP costs.

The economic cost estimates disaggregated into various BMP cost categories provide insights into the magnitude and structure of on-farm costs required to establish and maintain particular BMPs, while the qualitative analysis documents other important (non-financial) factors that farmers should take into account when implementing specific BMPs. Compensation payments to farmers for reduced farm incomes associated with implementing particular BMPs that have demonstrated benefits in improving environmental quality need to be based on such empirical BMP costs. Thus, the farm-level cost estimates can be useful to farm environmental program administrators contemplating the level of financial assistance to farmers to encourage adoption of conservation-compatible practices.

In addition, the case study research results demonstrate empirically that important location-specific attributes and production system factors (such as foregone use of land set aside for BMP establishment, and governmental regulations) also influence the BMP implementation decision choices of farmers. Recognition of such factors and the types of BMP costs can help administrators in program design (e.g., cost-share arrangements) and also determine what kind of technical assistance, if any, can lead to more widespread adoption of BMP. Engineering consultancy, for example, accounted for more than half of the total costs of establishing the stormwater diversion drainage system. These consultancy services may be provided by one source (e.g., government engineers) at a reasonable cost, while also ensuring consistency in structural design and construction. The BMP cost analysis can also help policy makers better assess costs to taxpayers and farmers. Overall, the findings suggest that a combination of policy instruments such as regulation and financial incentive (e.g., cost-share) schemes could lead to increased adoption of the BMPs studied.-

Acknowledgements

The authors gratefully acknowledge financial support for this research from Agriculture and Agri-Food Canada, and the collaborating farmers on this research project.

References

American Agricultural Economics Association. (2000) Commodity Costs and Returns Estimation Handbook. A Report of the AAEA Task Force on Commodity Costs and Returns. Ames, Iowa, US.

Aust, W.M., Shaffer, R.M. & Burger, J.A. (1996) Benefits and Costs of Forestry Best Management Practices in Virginia, Southern Journal of Applied Forestry, Vol. 20, No.1, 23-29.

Berentsen, P.B.M., Hendriksen, A., Heijman, W.J.M. & van Vlokhoven, H.A. (2007) Costs and Benefits of On-farm Nature Conservation, Ecological Economics, Vol. 62, No. 3-4, pp. 571-579.

Bewsell, D., Monaghan, R.M. & Kaine, G. (2007) Adoption of Stream Fencing Among Dairy Farmers in Four New Zealand Catchments, Environmental Management, Vol. 40, No. 2, pp. 201-209.

Buchanan, B. (1996) Clean Water Boosts Cattle Performance. Prairie Water News, Vol. 6, No. 1. Available online at: http://www.quantumlynx.com/water/back/vol6no1/story2.html [Accessed on May 25, 2007].

Center for Watershed Protection. (2000) An Introduction to Better Site Design, In: Schueler, T.R. & Holland, H.K. (Eds.). The Practice of Watershed Protection, Ellicott City, Maryland, US, pp. 623-632.

Challis, D.J., Zeinstra, J.S. & Anderson, M.J. (1987) Some Effects of Water Quality on the Performance of High Yielding Cows in an Arid Climate, Veterinary Record, Vol. 120, No. 1, pp. 12-15.

Chizmazia, R. (1996) Water Quality: Best Management Practices. Proceedings of the AgriFuture Farm Technology Expo and Conservation Workshop Proceedings, Feb. 22-24, Red Deer, AB, Canada.

Clar, M., Barfield, B.J. & Yu, S. (2003) Considerations in the Design of Treatment Best Management Practices (BMPs) to Improve Water Quality. US EPA Report No. 600/R-03/103 (October), US EPA Office of Research and Development, Cincinnati, Ohio, US. Available online at: http://www.epa.gov/ORD/NRMRL/Pubs/600r03103/600r03103.htm [Accessed on July 30, 2007].

Cubbage, F.W. (2004) Costs of Forestry Best Management Practices in the South: A Review, Water, Air, and Soil Pollution: Focus, Vol. 4, No. 1, pp. 131-142.

Curtis, A., & Robertson, A. (2003) Understanding Landholder Management of River Frontages, The Goulburn Broken, Ecological Management and Restoration, Vol. 4, No.1, pp. 45-54.

Degarmo, E.P., Sullivan, W.G., Bontadelli, J.A. & Wicks, E.M. (1997) Engineering Economy. Prentice Hall, Upper Saddle River, New Jersey, US.

Dick, B. (1998) Convergent Interviewing: A Technique for Data Collection. Resource Papers in Action Research, Graduate College of Management. Southern Cross University, Sydney, Australia. Available online at: http://www.scu.edu.au/schools/gcm/ar/arp/iview.html [Accessed on July 30, 2007].

Dickard, M.L. (1998) Management Strategies for Improved Cattle Distribution and Subsequent Riparian Health. MSc. Thesis, University of Idaho, Moscow, US.

DPRA Incorporated. (1989) An Evaluation of the Cost Effectiveness of Agricultural Best Management Practices and Publicly Owned Treatment Works in Controlling Phosphorus Pollution in The Great Lakes Basin. US EPA Research Report, Washington, DC, US. Available online at: http://yosemite.epa.gov/ee/epa/eermfile.nsf/vwAN/EE-0317.pdf/$file/EE-0317.pdf [Accessed on October 05, 2007].

Ferguson, T., Gignac, R., Stoffan, M., Ibrahim, A. & Aldrich, J. (1997) Cost Estimating Guidelines, Best Management Practices and Engineered Controls. Rouge River National Wet Weather Demonstration Project, Wayne County, Michigan, US.

Fritz, D. (2003) Cornwallis River Riparian Management Project. Friends of the Cornwallis River/Eastern Habitat Joint Venture. Final Report Submitted to Nova Scotia Department of Natural Resources, NS, Canada (June). Available online at: http://www.gov.ns.ca/natr/wildlife/habfund/proposal/Riparianreport.pdf [Accessed on November 03, 2007].

Gitau, M.W., Veith, T.L. & Gburek, W.J. (2004) Farm-level Optimization of BMP Placement for Cost-Effective Pollution Reduction, Transactions of American Society of Agricultural Engineers (ASAE), Vol. 47, No. 6, pp. 1923-1931.

Grunert, K.G. & Grunert, S.C. (1995) Measuring Subjective Meaning Structures by the Laddering Method: Theoretical Considerations and Methodological Problems, International Journal of Research in Marketing, Vol. 12, No. 3, pp. 209-295.

Jacques Whitford Environment Ltd. and LJM Environmental Consulting. (2001) Technical and Policy Options for Nutrient Management Planning in Prince Edward Island (PEI). Final Report to PEI Department of Agriculture and Forestry, Project No. PEC80450 (May).

Kaine, G. (2004) Consumer Behaviour as a Theory of Innovation Adoption in Agriculture. Social Research Team Working Paper 01-04. 26 pp. AgResearch, Hamilton, New Zealand.

Korol, M. (2004) Fertilizer and Pesticide Management in Canada. In: Farm Environmental Management in Canada, Statistics Canada Research Catalogue, Vol. 1, No.3, Catalogue No. 21-021- MIE-No. 003 Available online at http://www.statcan.ca/english/research/21-021-MIE/21-021-MIE2004002.pdf [Accessed on October 17, 2007].

Lambert, D.M., Sullivan, P., Claassen, R. & Foreman, L. (2007) Profiles of US Farm Households Adopting Conservation-compatible Practices, Land Use Policy, Vol. 24, No. 1, pp. 72-88.

Landefeld, M. & Bettinger, J. (2002) Water Effects on Livestock Performance. Ohio State University of Agriculture and Natural Resources Report No. ANR-13-02. Columbus, Ohio, US. Available online at: http://ohioline.osu.edu/anr-fact/0013.html [Accessed on November 06, 2007].

Landphair, H.C., McFalls, J.A. & Thompson, D. (2000) Design Methods, Selection, and Cost-Effectiveness of Stormwater Quality Structures. Report No. FHWA/TX-01/1837-1, Texas Transportation Institute, The Texas A&M University System, College Station, Texas, US.

LJM Environmental Consulting. (2003) A Resource For Farm Businesses: Concise Answers to Legal Questions on the Environment and Land Use. Nova Scotia Federation of Agriculture (NSFA) Legal Resources. NSFA, Truro, NS. Available online at: http://www.nsfa-fane.ca [Accessed on September 02, 2007].

McIver, S. (2004) Using Off-Stream Water Sources as a Beneficial Management Practice in Riparian Areas - A Literature Review. Agriculture and Agri-Food Canada Report, Prairie Farm Rehabilitation Administration. Available online at:
http://www.agr.gc.ca/pfra/land/OffStreamWatering_e.pdf [Accessed on December 04, 2007].

McRae, T., Smith, C.A.S. & Gredorich, L.J. (Eds.). (2000) Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project. Agriculture and Agri-Food Canada, Ottawa, ON, Canada. Also available on line at:
http://www4.agr.gc.ca/resources/prod/doc/policy/environment/pdfs/aei/fullreport.pdf
[Accessed on September 02, 2007].

Nova Scotia Department of Agriculture and Fisheries (NSDAF). (2006) Manure Management Guidelines. Truro, NS, Canada. Available online at:
http://www.gov.ns.ca/agri/rs/envman/manureguide_2006lowres.pdf [Accessed on October 02, 2007].

Nova Scotia Department of Agriculture and Fisheries. (2007) Farm Investment Fund Factsheet. Truro, NS, Canada. Available online at: http://www.gov.ns.ca/agri/prm/programs/fifguide.shtml [Accessed on October 02, 2007].

Ribaudo, M.O. & Johansson, R.C. (2007) Nutrient Management Use at The Rural-Urban Fringe: Does Demand For Environmental Quality Play a Role?, Review of Agricultural Economics, Vol. 29, No. 4, pp. 689-699.

Sample, D.J., Heaney, J.P., Wright, L.T., Fan, C-Y., Lai, F-H. & Field, R. (2003) Cost of Best Management Practices and Associated Land for Urban Stormwater Control, Journal of Water Resources Planning and Management, Vol. 129, No. 1, pp. 59-68.

Schueler, T.R. (1987) Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments, Washington, DC, US.

Sheffield, R.E., Mostaghimi, S., Vaughan, D.H., Collins, J.E.R. & Allen, V.G. (1997) Off-stream Water Sources for Grazing Cattle as a Stream Bank Stabilization and Water Quality BMP, Transactions of the American Society of Agricultural Engineers (ASAE), Vol. 40, No. 3, pp. 595-604.

South-eastern Wisconsin Regional Planning Commission. (1991) Costs of Urban Nonpoint Source Water Pollution Control Measures. Technical Report No. 31 Waukesha, Wisconsin, US. 107 pp.

Stonehouse, D.P. (1991) The Economics of Tillage for Large-Scale Mechanized Farms, Soil and Tillage Research, Vol. 20, No. 2-4, pp. 333-351.

Stonehouse, D.P. (1995) Profitability of Soil and Water Conservation in Canada, Journal of Soil and Water Conservation, Vol. 50, No. 2, pp. 215-219.

Taylor, A. & Wong, T. (2002) Nonstructural Stormwater Quality Best Management Practices: An Overview of their Use, Cost and Evaluation. Technical Report 02/11, Cooperative Research Center for Catchment Hydrology, Victoria, Australia. Available online at: http://www.catchment.crc.org.au/pdfs/Technical200211.pdf [Accessed on October 17, 2007].

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. & Polasky, S. (2002) Agricultural Sustainability and Intensive Production Practices, Nature, Vol. 418, No. 8, (August). Available online at: http://www.nature.com/nature/journal/v418/n6898/full/nature01014.htm [Accessed on December 02, 2007].

United States Department of Defense. (1995) Parametric Cost Estimating Handbook. Second Edition, Joint Government/Industry Initiative, US.

United States Environmental Protection Agency. (1993) Handbook – Urban Runoff Pollution Prevention and Control Planning. Report No. EPA-625-R-93-004. US EPA, Washington, DC, US.

United States Environmental Protection Agency. (1999a) Stormwater Management Fact Sheet. EPA-832-F-99-001 through EPA-843-F-99-050. Washington, DC, US.

United States Environmental Protection Agency. (1999b) Preliminary Data Summary of Urban Stormwater Best Management Practices. Office of Water Report No. EPA-821-R-99-012, Washington, DC, US.

United States Environmental Protection Agency. (2004) The Use of Best Management Practices in Urban Watersheds. US EPA Office of Research and Development Report No. EPA/600/R-04/184, Washington, DC, US.

Veira, D.M. (2003) Livestock Water: Impacts on Production and Behaviour. Proceedings of the Western Range Science Seminar on Rangelands and Ranching: Achieving a Viable Future, January 19-21, Medicine Hat, AB, Canada.

Visser, R., Aust, W.M., Gallagher, T., Roberts, T. & Poirot, M. (2003) Cost of Six Different Stream Crossing Options in the Appalachian Area, Southern Journal of Applied Forestry, Vol. 27, No. 1, pp. 66-70.

Water Environment Federation and American Society of Civil Engineers. (1998) Urban Runoff Quality Management. WEF Manual No. 23, ASCE Manuals and Reports on Engineering Practice No. 87, Alexandra/Reston, Virginia, US.

Water Environment Research Foundation. (2003) Post-project Monitoring of BMPs/SUDS to Determine Performance and Whole-Life Costs. Project Number: 01-CTS-21T, Alexandria, Virginia, US.

West, B. (1996) Water Quality: Best Management Practices for Manure Application. Proceedings of the AgriFuture Farm Technology Expo and Conservation Workshop, Feb. 22-24, Red Deer, AB, Canada, pp. 111-115.

Willms, W., Colwell, D. & Kenzie, O. (1994) Water from Dugouts Can Reduce Livestock Performance. Prairie Water News, Vol. 4, No. 1. Available online at: http://ww.quantumlynx.com/water/back/vol4no1/v41_st1.html [Accessed on May 26, 2007].

Willms, W.D., Kenzie, O.R., McAllister, T.A., Colwell, D., Veira, D., Wilmshurst, J.F., Entz, T. & Olson, M.E. (2002) Effects Of Water Quality On Cattle Performance, Journal of Range Management, Vol. 55, pp. 452-460.

Wossink, G.A.A. (2000) The Economics of BMPs to Control Nitrogen in the Neuse River Basin. North Carolina State University. College of Agricultural and Life Sciences (NCSU-CALS) Publication No. AGW-2, Raleigh, North Carolina, US. Available online at: http://www2.ncsu.edu/unity/lockers/users/g/gawossin/Papers/bmpecon.pdf [Accessed on 21 August 2007].

Wossink, G.A.A. & Osmond, D.L. (2002) Farm Economics to Support the Design and Selection of Cost-Effective BMPs: Nitrogen Control in the Neuse Rives Basin, North Carolina, Journal of Soil and Water Conservation, Vol. 57, No. 4, pp. 213-220.

Wossink, G.A.A. & Hunt, B. (2003) The Economics of Structural Stormwater BMPs in North Carolina. University of North Carolina Water Resources Research Institute Report Number UNC-WRRI-2003-344, Raleigh, North Carolina, US. Available on line at: http://www.bae.ncsu.edu/stormwater/PublicationFiles/EconStructuralBMPs2003.pdf [Accessed on August 21, 2007].

Yin, R. K. (1994) Case Study Research: Design and Methods. Second Edition, Sage Press, Thousand Oaks, California, US.

Yiridoe, E.K. & Marett, G.E. (2004) Mitigating the High Cost of ISO 14001 EMS Standard Certification: Lessons from Agribusiness Case Research, International Food and Agribusiness Management Review, Vol. 7, No. 2, pp. 37-62.

Young, G.K., Stein, S., Cole, P., Kammer, T., Graziano, F. & Bank, F. (1996) Evaluation and Management of Highway Runoff. Water Quality Technical Report, Department of Environmental Programs, Metropolitan Washington Council of Governments, Washington, DC, US.

Zeckoski, R., Benham, B. & Lunsford, C. (2007) Streamside Livestock Exclusion: A Tool for Increasing Farm Income and Improving Water Quality. Virginia Cooperative Extension Publication No. 442-766, Virginia Polytechnic Institute and State University, Virginia, US.