Available online at www.sciencedirect.com
ScienceDirect
Agriculture, Ecosystems and Environment 117 (2006) 135–144
Agriculture Ecosystems & Environment
www.elsevier.com/locate/agee

Alternative practices for sediment and nutrient loss control on livestock farms in northeast Iowa

Philip W. Gassman [a,*], Edward Osei [b], Ali Saleh [b], John Rodecap [c], Stuart Norvell [d], Jimmy Williams [e]

[a] *Center for Agricultural and Rural Development, Department of Economics, Iowa State University, Ames, IA 50011, United States*
[b] *Texas Institute for Applied Environmental Research, Tarleton State University, Stephenville, TX 76402, United States*
[c] *Maquoketa Watershed Project, Iowa State University Extension, Fayette, IA 52142, United States*
[d] *Texas Water Development Board, 1700 North Congress Avenue, Austin, TX 78711-3231, United States*
[e] *Blacklands Research and Extension Center, Texas Agricultural Experiment Station, 720 East Blackland Road, Temple, TX 76502, United States*

Received 3 September 2005; received in revised form 10 March 2006; accepted 20 March 2006
Available online 2 May 2006

Abstract

A number of structural and managerial practices were evaluated to determine their environmental and economic effectiveness on animal feeding operations in the upper Maquoketa river watershed in northeast Iowa. Economic and environmental model simulations were performed over a 30-year time horizon for each of these practices using extensive data collected from the study area.

Results from model simulations indicate that while most of the practices (including terraces, no till farming, contouring, and in-field contour buffers) would reduce sediment and sediment-bound nutrient losses significantly, they have very little benefit on soluble nitrogen and phosphorus losses. This is primarily because the increased infiltration rates resulting from those practices leads to greater losses of subsurface and return flow in the heavily tile-drained watershed. Nonetheless, when these practices are combined with judicious commercial fertilizer use, appreciable reductions in soluble nutrient losses are also indicated, and improvements in sediment loss are maintained.

Terraces are indicated to provide the greatest sediment loss reduction (over 60% reduction) at the watershed level, relative to the status quo. Accordingly, installed terraces also lead to the highest simulated reductions in organic nitrogen and organic phosphorus (over 70%). Predicted reductions in sediment for most of the other practices ranged from almost 30% to about 45%. Corresponding reductions in simulated organic nitrogen and organic phosphorus losses range from about 35% to almost 50%.

Economic model simulations also show varied impacts. In general, costs of sediment reducing practices range from about $6 per hectare of implemented area with contouring to almost $65 per hectare when terraces are installed on high-slope cropland. Terraces also indicated the greatest sediment loss reduction. On the other hand, judicious commercial fertilizer use is indicated to offset these costs by as much as roughly $50 per hectare. The study indicates that programs that offer producers some flexibility in choosing practice combinations may lead to the best outcomes.

Keywords: Agricultural BMPs; Water quality modeling; Nonpoint source pollution; Economic analysis; Tile drainage; Sediment; Nutrients

1. Introduction

Over the past three decades there have been increased efforts toward reduction in nutrient and sediment loss from agricultural lands in the United States. This is due mainly to the fact that since passage of the Clean Water Act in 1970, point sources of pollution have accounted for progressively smaller portions of water quality problems in the nation. Agriculture now remains a key source of nonpoint source pollutants, chiefly sediment, nitrogen and phosphorus loads to downstream waters (USEPA, 2000). To reduce these losses, many best management practices (BMPs) have been proposed, including manure storage, handling and utilization, tillage and

* Corresponding author. Tel.: +1 515 294 6313; fax: +1 515 294 6336.
E-mail address: pwgassma@iastate.edu (P.W. Gassman).

0167-8809/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.agee.2006.03.030

land treatment, as well as livestock feed management and judicious use of inorganic fertilizers. The impacts of these practices depend on specific environmental characteristics in the area of concern and the practices already in place.

The National Pilot Project (NPP) on livestock and the environment was initiated in 1992 to help determine technologies, policies, practices, and institutional settings that could help alleviate potential adverse environmental impacts in livestock-dominated watersheds (Jones et al., 1993). Watersheds that were studied under the NPP include the upper north Bosque river watershed (UNBRW) in north central Texas (Pratt et al., 1997; Osei et al., 2000b, 2003a), the Lake Fork reservoir watershed (LFRW) in northeastern Texas (McNitt et al., 1999; Osei et al., 2003b), and the upper Maquoketa river watershed (UMRW) in northeastern Iowa (Keith et al., 2000; Gassman et al., 2002). The UMRW is an intensive livestock and cropland agriculture region located in the headwaters of the Maquoketa river basin. According to recent estimates the Maquoketa river contributed about 470,000 tonnes of sediment to the Mississippi river in 1997; in comparison, total sediment load in the Mississippi river as it entered Iowa was estimated at 1 million tonnes (Maquoketa River Alliance, 1998. Undocumented research report, Maquoketa, Iowa). Efforts undertaken to help reduce nutrient and sediment losses from the Maquoketa basin include field demonstrations, educational programs, manure calibration training, and other nutrient management promotions (Rodecap, 1999, 2000; Ingels, 2000). In recent years the UMRW received funding to assist producers to adopt nutrient management practices that have potential for water quality improvement.

In general, it is important to determine the efficacy of these practices in order to ensure more efficient use of resources and minimize adverse financial impacts on livestock operations. In lieu of costly monitoring efforts and field trials for each combination of BMPs, computer model simulations serve the useful role of informing stakeholders and policy makers of practices that may best serve the needs of their watersheds. In this study, computer model simulations were performed to assess a number of practices that have potential for sediment and/or nutrient loss reduction in the UMRW. These practices were developed with input from survey data from the watershed and other sources, which were obtained at the time of the study (1999–2001). The specific objectives were to: (1) evaluate the impact of structural BMPs on sediment and nutrient losses from UMRW cropland, and (2) assess the economic impacts of these practices on producer net returns.

2. Methods and materials

2.1. The study area

The UMRW (Fig. 1) drains 16,224 ha of predominantly intensely cropped farmland located in portions of Buchanan, Clayton, Fayette, and Delaware counties in northeast Iowa, at approximate coordinates of 42.6N latitude and 91.6W longitude. About 80% of the land area is cropland; forest, pasture, and conservation reserve program lands cover 9, 4, and 4.3% of the remaining land area, respectively (Keith et al., 2000). Corn (*Zea mays*) and soybean (*Glycine max*) production are dominant in the watershed, which together comprise about 67% of the cropland area. Other major crops in the watershed are alfalfa (*Medicago sativa*), oats (*Avena sativa*), and ryegrass (*Lolium perenne*). For this study, three major cropping rotations were identified on animal feeding operations in the watershed, namely, corn–soybean rotation (CS), continuous corn (CC), and corn–corn–oats–alfalfa–alfalfa (CCOAA). The Kenyon–Floyd–Clyde soil association comprises the dominant soil types in the watershed, which are characterized by relatively high organic carbon contents of 2.0–4.3% in the surface horizon. Average slopes in the subbasins comprising the watershed range from about 1% to slightly over 16%. Average annual precipitation is about 879 mm. Average monthly minimum temperatures range from −14.7 to 15.9 °C and the range of average monthly maximum temperatures is from −4.2 to 28.5 °C.

A total of 90 operations were identified as having one or more types of livestock in a survey of the UMRW (Osei et al., 2000a), with production focused primarily on swine, dairy cows, beef cattle, feeder cattle, and/or calves and heifers. The survey also revealed that most livestock producers were not taking adequate credit for the nutrient content of manure when it was applied to crops. Thus commercial fertilizer was applied to manured fields at rates close to those used for nonmanured cropland in many cases. Surface water monitoring at four sites (Fig. 1) showed elevated levels of nitrate-nitrogen (NO_3-N) and phosphate-phosphorus (PO_4-P), depending on the flow conditions (Baker et al., 1999). Tile drains have been extensively installed throughout the UMRW at a typical depth of about 1.2 m and are a key conduit of NO_3-N to the stream system.

2.2. Simulation methodology

Alternative practices for nutrient and sediment loss control were assessed using the Comprehensive Economic and Environmental Optimization Tool-Livestock and Poultry (CEEOT-LP), which was developed as part of the NPP (Osei et al., 2000c). The CEEOT-LP environmental component consists of two models, the field-scale Agricultural Policy Environmental eXtender (APEX) model (Williams, 2002; Williams and Izaurralde, 2006) and the watershed-scale Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998; Arnold and Fohrer, 2005). The other modeling component of CEEOT-LP is the Farm-level Economic Model (FEM) that is described by Osei et al. (2000c). A third CEEOT-LP component is a policy module, which embodies the process of determining alternative policy and practice scenarios to be simulated.