1. Studies showing benefits of vegetated buffers

Title: Integrated management of in-field, edge-of-field, and after-field buffers.
Author: Dabney, S.M., Moore, M.T., Locke, M.A. (USDA ARS)
Journal of the American Water Resources Association. 42(1): 15-24, 2006

Take-home message: Research from USDA's Ag Research Service shows that vegetative buffers such as filter strips, constructed wetlands, and contour buffer strips can retard, retain, and metabolize pollutants. Buffers restrict pollution by reducing drift, increasing sedimentation, increasing uptake by plants, and increasing microbial activity. Vegetated ditches and constructed wetlands can process pollutants in runoff.

Abstract: Conservation benefits are maximized when in-field and edge-of-field buffers are integrated with each other and with other conservation practices such as residue management and grade control structures. Buffers improve both surface and subsurface water quality. Soils under permanent buffer vegetation generally have higher organic carbon concentrations, higher infiltration capacities, and more active microbial populations than similar soils under annual cropping. Sediment can be trapped with rather narrow buffers but extensive buffers are better at transforming dissolved pollutants. Buffers improve surface runoff water quality most efficiently when flows through them are slow, shallow, and diffuse. Vegetative barriers, narrow strips of dense erect grass, can slow and spread out concentrated runoff. Subsurface processing is best on shallow soils that provide increased hydrologic contact between the groundwater plume and buffer vegetation. Vegetated ditches and constructed wetlands can act as "after-field" conservation buffers, processing pollutants that escape from fields. For these buffers to function efficiently, it is critical that in-field and edge-of-field practices limit peak runoff rate and sediment yield in order to maximize contact time with buffer vegetation and minimize the need for cleanout excavation that destroys vegetation and its processing capacity.

Title: Significant Escherichia coli Attenuation by Vegetative Buffers on Annual Grasslands
Authors: Kenneth W. Tate, Edward R. Atwill, James W. Bartolome and Glenn Nader (from UC Davis and the UC School of Veterinary Medicine)
J Environ Qual 35:795-805 (2006)

Take-home message: In 2006, UC Davis researchers tested the effectiveness of vegetated buffers at filtering E. coli in runoff from cattle grazing lands in California. They found that even narrow vegetative buffers can filter between 95% and 99.99% of total E. coli. These results support the assertion that grassland buffers are an effective method for reducing animal agricultural inputs of waterborne E. coli into surface waters.

Abstract: A study was conducted to estimate the retention efficiency of vegetative buffers for Escherichia coli deposited on grasslands in cattle fecal deposits and subject to natural rainfall-runoff conditions. The study was conducted on annual grasslands in California's northern Sierra Nevada foothills, a region with a distinct wet–dry season

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Mediterranean climate. We used 48, 2.0- by 3.0-m runoff plots to examine the efficacy of 0.1-, 1.1-, and 2.1-m buffers at three land slopes (5, 20, and 35%) and four dry vegetation matter levels (225, 560, 900, and 4500 kg/ha) across 27 rainfall-runoff events during two rainfall seasons. Buffer width treatments were implemented by placement of cattle fecal material containing known loads of E. coli 0.1, 1.1, or 2.1 m upslope of the plot runoff collector. Mean total runoff to total rainfall ratio per plot ranged from 0.014:1 to 0.019:1 and reflected the high infiltration capacity of these soils. Approximately 94.8 to 99.995% of total E. coli load applied to each plot appears to be either retained in the fecal pat and/or attenuated within 0.1 m downslope of the fecal pat, irrespective of the presence of a wider vegetated buffer. Relative to a 0.1-m buffer, we found 0.3 to 3.1 log10 reduction in E. coli discharge per additional meter of vegetative buffer across the range of residual dry vegetation matter levels, land slope, and rainfall and runoff conditions experienced during this project. Buffer efficiency was significantly reduced as runoff increased. These results support the assertion that grassland buffers are an effective method for reducing animal agricultural inputs of waterborne E. coli into surface waters.

Title: Microbial water quality improvement by small scale on-site subsurface wetland treatment.
Authors: Nokes RL, Gerba CP, Karpiscak MM. (Department of Soil, Water and Environmental Science, University of Arizona)
J Environ Sci Health A Tox Hazard Subst Environ Eng. 2003 Sep;38(9):1849-55.

Take-home message: Researchers from the University of Arizona show that large and small-scale constructed wetlands can reduce levels of fecal coliform and other pathogens in water by up to 97%. A similar study (Hench et al, 2003) showed that constructed wetlands can reduce Salmonella levels in runoff by 93-96%.

Abstract for Nokes et al: It has been demonstrated that large constructed wetlands used for domestic wastewater treatment are useful in the reduction of enteric microorganisms. This study evaluated the ability of three small-scale, on-site subsurface wetlands with different vegetation densities to remove total coliforms, fecal coliforms, coliphage, Giardia and Cryptosporidium. These wetlands were found to be equally efficient in the removal of enteric bacteria and coliphage as larger constructed wetlands. Giardia and Cryptosporidium were usually undetectable after passage of the wastewater through the subsurface wetlands. Coliphage removal increased with increasing vegetation density.

2. Studies showing benefits of well-managed soil with high microbial activity

Title: Potential Uptake of *Escherichia coli* O157:H7 from Organic Manure into Crisphead Lettuce
Authors: Gro S. Johannessen, Gunnar B. Bengtsson, Berit T. Heier, Sylvia Bredholt, Yngvild Wasteson, and Liv Marit Rørvik
APPLIED AND ENVIRONMENTAL MICROBIOLOGY, May 2005, p. 2221–2225 Vol. 71, No. 5

Take-home message: E. coli outbreaks on fresh produce have raised concerns that the use of manure as fertilizer may lead to contamination of crops. However, a number of studies show that the beneficial soil microbes present in soil that has been amended with manure actually suppress the growth of pathogenic E. coli. In one Norwegian study, crisphead lettuce was planted in organic soil amended with E. coli-contaminated manure. The study found that E. coli 0157:H7 was not taken up by the lettuce roots and was not found in the edible parts of the lettuce after harvest. Beneficial microbes were found to be present in the organic soil on the lettuce roots. The researchers concluded that these beneficial organisms compete with and reduce the presence of pathogenic bacteria in the soil.

Abstract: To investigate the potential transfer of *Escherichia coli* O157:H7 from contaminated manure to fresh produce, lettuce seedlings were transplanted into soil fertilized with bovine manure which had been inoculated with approximately 104 CFU g_1 *E. coli* O157:H7. The lettuce was grown for approximately 50 days in beds in climate-controlled rooms in a greenhouse. As the bacterium was not detected in the edible parts of the lettuce, the outer leaves of the lettuce, or the lettuce roots at harvest it was concluded that transmission of *E. coli* O157:H7 from contaminated soil to lettuce did not occur. The pathogen persisted in the soil for at least 8 weeks after fertilizing but was not detected after 12 weeks. Indigenous *E. coli* was detected only sporadically on the lettuce at harvest, and enterococci were not detected at all. The numbers of enterococci declined more rapidly than those of *E. coli* in the soil. *Pseudomonas fluorescens*, which inhibited growth of *E. coli* O157:H7 in vitro, was isolated from the rhizosphere.

Title: Survival of genetically marked Escherichia coli O157:H7 in soil as affected by soil microbial community shifts.
Authors: van Elsas JD, Hill P, Chronakova A, Grekova M, et al (Department of Microbial Ecology, Centre for Ecological and Evolutionary Studies, University of Groningen, Haren, The Netherlands)
ISME Journal (multidisciplinary journal of microbial ecology). 2007 Jul 1(3):204-14.

Take-home message: A number of studies show that well-managed soil, such as that encouraged by organic production systems, can suppress pathogenic organisms. For example, a 2007 study in The Netherlands showed that soil with less biological complexity offers greater opportunities for invading microbial species, including E. coli 0157:H7, to establish and persist. More biodiverse soils may suppress pathogens because beneficial microbes compete with pathogenic microbes for resources.

Abstract: A loamy sand soil sampled from a species-rich permanent grassland at a long-term experimental site (Wildekamp, Bennekom, The Netherlands) was used to construct soil microcosms in which the microbial community compositions had been modified by fumigation at different intensities (depths). As expected, increasing depth of fumigation was shown to result in progressively increasing effects on the microbiological soil parameters, as determined by cultivation-based as well as cultivation-independent (PCR-DGGE, PLFA) methods. Both at 7 and at 60 days after fumigation, shifts in the bacterial, fungal and protozoan communities were noted, indicating that altered community compositions had emerged following a transition phase. At the level of bacteria culturable on plates, an increase of the prevalence of bacterial r-strategists was noted at 7 days followed by a decline at 60 days, which also hinted at the effectiveness of the

fumigation treatments. The survival of a non-toxigenic Escherichia coli O157:H7 derivative, strain T, was then assessed over 60 days in these microcosms, using detection via colony forming units counts as well as via PCR-DGGE. Both data sets were consistent with each other. Thus, a clear effect of fumigation depth on the survival of the invading strain T was noted, as a progressive increase of depth coincided with a progressively enhanced inoculant survival rate. As fumigation depth was presumably inversely related to community complexity, this was consistent with the hypothesis that soil systems with reduced biological complexity offer enhanced opportunities for invading microbial species to establish and persist. The significance of this finding is discussed in the light of the ongoing discussion about the complexity-invasiveness relationship within microbial communities, in particular regarding the opportunities of pathogens to persist.

Title: Effects of cattle feeding regimen and soil management type on the fate of Escherichia coli O157:H7 and salmonella enterica serovar typhimurium in manure, manure-amended soil, and lettuce.

Amanda Gonzalez Exhibit #117

Authors: Franz E, van Diepeningen AD, de Vos OJ, van Bruggen AH (Department of Plant Sciences, Wageningen University and Research Center, The Netherlands.)
Appl Environ Microbiol. Oct;71(10):6165-74, 2005

Take-home message: In 2005, researchers in the Netherlands tested the survival of E. coli 0157:H7 added to manure from grass-fed cows and those fed a mixture of grass and corn silage. This manure was added to organic and conventional soils. E. coli levels declined fastest in the manure from grass-fed cows that had been mixed with organic soil; the slowest rate of decline was in manure from cows fed the grass/corn silage mixture that had been mixed with conventional soil. The researchers found that cattle diet and soil management are important factors affecting the survival of human pathogens in the environment.

Abstract: Survival of the green fluorescent protein-transformed human pathogens Escherichia coli O157:H7 and Salmonella enterica serovar Typhimurium was studied in a laboratory-simulated lettuce production chain. Dairy cows were fed three different roughage types: high-digestible grass silage plus maize silage (6:4), low-digestible grass silage, and straw. Each was adjusted with supplemental concentrates to high and low crude protein levels. The pathogens were added to manure, which was subsequently mixed (after 56 and 28 days for E. coli O157:H7 and Salmonella serovar Typhimurium, respectively) with two pairs of organically and conventionally managed loamy and sandy soil. After another 14 days, iceberg lettuce seedlings were planted and then checked for pathogens after 21 days of growth. Survival data were fitted to a logistic decline function (exponential for E. coli O157:H7 in soil). Roughage type significantly influenced the rate of decline of E. coli O157:H7 in manure, with the fastest decline in manure from the pure straw diet and the slowest in manure from the diet of grass silage plus maize silage. Roughage type showed no effect on the rate of decline of Salmonella serovar Typhimurium, although decline was significantly faster in the manure derived from straw than in the manure from the diet of grass silage plus maize silage. The pH and fiber content of the manure were significant explanatory factors and were positively correlated with the rate of decline. With E. coli O157:H7 there was a trend of faster decline in

organic than in conventional soils. No pathogens were detected in the edible lettuce parts. The results indicate that cattle diet and soil management are important factors with respect to the survival of human pathogens in the environment.