# NE1024: Whole Farm Dairy and Beef Systems for Environmental Quality

# Final Report

**Objective 1: Enhance cropping, grazing, and feeding management systems to improve animal nutrient utilization and reduce nutrient excretion.** (Muck, ARS, WI; Fick, Cornell; Dou, U Penn; Kohn, UMD; Knowlton, VaTech; Harrison, WA; Combs, WI; Mohtar, Purdue; Rotz, ARS, PA; Sanderson, ARS, PA; Felton, WVa)

**1a. Effects of forage conservation strategies on losses and nutrient availability**

Research was conducted to understand how bacterial silage inoculants improve rate of gain in growing cattle and milk production in lactating cattle (ARS, WI). A series of ruminal *in vitro* trials with laboratory-scale silages made with and without various silage inoculants found that some inoculants are capable of increasing ruminal microbial biomass production. This suggests that animal production responses to inoculated silages may be due to improved nitrogen use efficiency. A lactating cow trial was performed comparing untreated alfalfa silage with alfalfa silage treated with a *Lactobacillus plantarum* inoculant that had shown positive effects in previous *in vitro* trials. Cows on the inoculated silage produced more milk and had reduced milk urea nitrogen, suggesting improved nitrogen use efficiency. Analyses to estimate microbial protein production in the trial have not been completed to confirm these results.

The presence of a polyphenol oxidase (PPO) system in grasses that could protect crop proteins during ensiling was studied (ARS, WI). No grass was found to contain significant levels of both the polyphenol oxidase and appropriate polyphenol substrates for the enzyme. Orchard grass, which contains PPO, was ensiled with different levels of conditioning and with and without addition of chlorogenic acid, a substrate of PPO. The addition of chlorogenic acid did not reduce the amount of proteolysis during ensiling except in the treatments with the highest level of conditioning. Silages made with mixtures of two grasses, one with PPO and one with a polyphenol substrate, also demonstrated little protection of protein during ensiling except with high levels of conditioning.

A study was conducted to look at the relationship between dairy manure application to a grass field and nitrates in ground water (WA). Data indicated an initial increase in soil nitrate and shallow ground water nitrate associated with soil tillage. The 1-ft soil nitrate levels ranged from ~ 5 to 60 ppm and varied by year. Grass nitrogen yields ranged from ~ 159 to 209 kg per growing season. Shallow ground water nitrate increased in the first 5 months to ~ 30 mg/liter, and decreased steadily to less than 10 mg/liter two years later. Managing the organic nitrogen in soil appears to play a major role in the concentrations of nitrate in shallow ground water.

A further study was initiated to look at the relationship between dairy manure application to a grass field, reseeding management, and nitrates in ground water (WA). Management evaluations were conventional and minimum tillage. Data indicated an initial increase in soil nitrate associated with conventional tillage. The 1-ft soil nitrate levels increased to 60 ppm in the conventionally tilled soil. Managing the organic nitrogen in soil appears to play a major role in the concentrations of nitrate in shallow ground water. A study was conducted to evaluate the agronomic value of nutrients from anaerobically digested (AD) and non-AD manure for grass growth. The data from year one indicated that AD and non-AD manure support grass growth equally when applied at equal amounts of total nitrogen.

A process to remove P from liquid dairy manure from manure after anaerobic digestion treatment was refined. Results indicate that as much as 80% of P can be removed. Struvite (Mg-N-P) that has been extracted from liquid dairy manure was shown to be a good source of nutrients for growth of corn and alfalfa.

**1b. Herd Nutrient Utilization Strategies**

Previous attempts to correlate near-infrared reflectance spectroscopy (NIRS) spectral data with measures of *in vitro* NDF digestibility (ivNDFD) have yielded mixed results. The ability of NIRS to predict a nutrient parameter depends highly on the precision of the laboratory technique used as a reference procedure. A study determined if acceptable NIRS calibration equations for 24, 30, and 48 h NDF digestion measurements could be developed from a more precise *in vitro* NDF digestibility reference procedure. A set of 122 grasses and legumes were digested *in vitro* using the Goeser et al. (2008) ivNDFD technique. Following ivNDFD analysis, ground forage samples were scanned on a near-infrared reflectance spectrophotometer and spectral data was related to 24, 30, and 48 h NDF digestibility (NDFD, % of NDF) and digestible NDF (dNDF, % of DM) measurements as well as NDF (% of DM). The coefficient of determination (R2), the standard error of calibration (SEC), the standard error of cross validation (SECV) of the 48 h NDFD calibration indicated improved precision relative to prior research, and no comparison could be made for earlier time points. The R2, SEC, and SECV values of dNDF calibrations were also improved relative to prior research. The universal calibration equations developed are capable of precisely predicting 24, 30, and 48 h ivNDFD rapidly for a broad range of grass and legume samples.

Animal work was conducted to refine the P requirements of lactating cows, growing heifers, and pre-weaned calves (VaTech). Initially research focused on early lactation cows, evaluating the impact of dietary Ca on bone P resorption and replenishment throughout lactation. We found that, contrary to our expectations, dietary Ca concentration had no effect on P retention or bone metabolism. However, first lactation cows had more active bone metabolism through the 140 d study. There was a switch from net bone resorption to formation after 35 d of lactation regardless of dietary Ca concentration. This information will help refine dietary mineral recommendations for dairy cows and ultimately reduce P excretion into the environment.

Research on nutrient excretion and efficiency of nutrient utilization by growing heifers studied the effect of dietary forage content and byproduct utilization in bred heifers (VaTech). Heifers limit-fed the low forage ration excreted three times as much urine and more total manure compared to those fed high forage and by-product rations. Excretion of nitrogen and phosphorus were not affected by diet. The current ASABE beef equations that predict manure DM excretion rather than wet manure excretion were better predictors of manure excretion observed in this study than were the dairy equations.

Research evaluating the effect of varying milk replacers in pre-weaned calves was completed (VaTech). We found that calves fed a standard milk replacer ate more grain than heifers fed more nutrient-dense diets, but had poorest gain and greatest feces excretion. Addition of protein to standard milk replacer improved calf growth and nutrient retention; few additional benefits were observed with added fat. Compared to predicted values for mature cows, we calculate that 12,000 to 17,000 heifers would produce quantities of manure or manure nutrients similar to a concentrated animal feeding unit of 700 mature dairy cows.

Intensive feed management practices were implemented on collaborator farms in Virginia to improve whole farm nutrient balance. Practices included improved forage quality, more frequent feed analysis, implementation of feed mixing and delivery tracking software, and reduced overfeeding. As part of this project, we implemented an incentive payment program to reduce overfeeding of dietary P, with 200 farms enrolled in the project. Of farms completing 12 months of sampling, about half earned incentive payments because their dietary P approached targets.

Comparison of P forms in feces of two dairy farms feeding different amount of P. Fecal samples were obtained from two commercial dairy farms. Farm 1 had 283 milk cows producing 69 lb milk/c/d with diet P concentration of 0.50%; Farm 2 had 93 cows producing 69.3 lb milk/c/d with diet P concentration of 0.37%. Conventional fecal analysis results: (i) fecal total P concentration was 11.30 g/kg for farm 1 and 4.17 g/kg for farm 2. (ii) fecal water soluble P was 3.98 g/kg on farm 1 and 1.46 g/kg on farm 2.

A comparison of P extractability (or recovery) from feces by different extractants was made. Water extracted 35% of the total P; an acid extractant 100 mM Na acetate, pH 5.0 plus 20 mg Na dithionite/ml had a recovery of 84-100%; an alkaline extractant 0.025 M NaOH with 50 mM EDTA had a recovery of 80-100%. Liquid state $^{31}$P nuclear magnetic resonance spectroscopy (31P-NMR) results: (i) Water is not an effective extractant

as several important P forms (phosphonate, IHP i.e., phytic acid, pyrophosphate, and polyphosphate) were missing in water extracts of samples from both farms. (ii) The slightly acid extractant NaAc performed equally well or even better than the traditional NaOH+EDTA extractant. Numerically, the amounts of orthophosphate, IHP, diesters, and polyphosphate were similar in the two extracts, whereas NaAc extracts had higher amounts of other monoesters and pyrophosphate as compared to the NaOH+EDTA extracts. (iii) Both NaAc and NaOH appeared to cause degradation of DNA and other diesters as there were greater amounts of these P compounds in the water extracts. (iv) The vast majority of total P in dairy feces existed as orthophosphate. Furthermore, orthophosphate accounted for a higher proportion of total P in the sample from Farm 1 (82 and 85%) than Farm 2 (64 and 72%).

Sixty-six Pennsylania dairy farms were monitored for a one to three year period to assess protein and P feeding practices in lactating cows (U Penn). The goal of the project was to work with nutritionists to encourage reduction in protein and P feeding. Total mixed rations and grab fecal samples from 8 high producing lactating cows were collected quarterly from the farms. Monthly DHIA records were collected, when farms were on DHIA. Farms were classified as to CP and P feeding practices based on initial TMR sampling. Production was not different for the farms by CP and P status on initial samples. When farms were classified by TMR CP concentration, CP was the only constituent of the TMR that was significantly different based on the classification status. Similarly when farms were classified by TMR phosphorus, only the P content was significantly different by classification. It was the goal of the project to see if herds with high CP and P concentrations would reduce these over time. In most cases, herds only slightly reduced CP and P from excess values. Herds already feeding low concentrations of CP and P continued to do so. Preliminary analysis shows that production and reproduction were not different with CP and P concentrations.

With the support of Chesapeake Bay Foundation as well as National Fish and Wildlife Foundation grants, more intensive collaboration was carried out with a number of dairy producers in the Chesapeake Bay watershed (U Penn). The overall purpose was to help producers improve farm productivity while reducing environmental footprint. Outcomes of this experience are as follows: (i) It is logical and achievable to improve farm productivity while reducing potential nutrient losses at the same time. Fine-tuned rations helped producers lower feed cost ($1,000 every three days in one case, $3,000 per month on another) and increase milk yield while reducing urine-N. Urine-N is most susceptible to environmental loss. (ii) Increases in rumen available CHO, in particular starch availability, can also reduce the herd bulk tank MUN and thus decrease potential N loss. (iii) Veterinarians can play a pivotal role in helping producers maintain good animal health and reproductive programs, which contribute to the bottom line of financial viability and success. (iv) Dietary TMR analysis alone may not reveal the whole picture of nutrient feeding levels; fecal P testing can be a useful tool for monitoring if P is overfed. (v) Concerted efforts are needed among all farm service providing personnel, e.g. feed company reps, agronomists, veterinarians, and producers themselves to help achieve the ultimate goal of enhanced production efficiency and environmental stewardship.

Limit feeding was examined as a strategy for heifer raising (WI). The objectives included 1) measurement of manure excretion, rumen volume, feed efficiency, 2) examination of the effects of replacing 5% DM by supplementing an ionophore while limit feeding, 3) evaluatuation of potential carryover effects of limit feeding on lactation DMI, rumen volume, and milk yield. Ninety-six Holstein heifers (400 ± 6 kg, 15.2 ± .1 mo), including 9 heifers fit with ruminal cannula, were fed one of three dietary treatments for 180 ± 8 d in a randomized replicated pen design. Treatment diets included: control (C100) fed to a fixed bunk score, (L85) fed at 85% of C100 intake, and L85 containing an ionophore (I), 325 mg/hd/d of lasalocid, fed at 80% of C100 intake (L80 + I). The C100 and L85 diets were formulated and fed to achieve isonitrogenous and isocaloric intakes and L80 + I was fed as an alternative limit feeding strategy to investigate whether an ionophore could replace dietary DM. Treatment diets were fed as a TMR (1x/d) and heifers were evaluated for growth, rumen function, blood and manure excretion parameters. Heifers fed L85 and L80+ I consumed less DM and NDF when compared to heifers fed C100. Heifers fed C100 had lower ADG (0.81 vs 0.96, 0.89 kg/d), and higher feed: gain ratios (13.0 vs 9.1, 9.3 kg/kg) as compared to heifers fed L85 or L80 + I. No differences in rumen pH, NH3-N, and VFA were observed between C100, L85 or L80 + I fed heifers. Digesta volume, weight and density were unaffected by limit feeding and limit feeding did not result in

carryover rumen volume effects when heifers were fed a common high fiber diet post trial. Ionophore supplementation (L80 + I) appeared effective as a limit feeding strategy in replacing 5% of the dietary DM, as no appreciable differences in heifer growth, rumen function or nutrient excretion were observed between heifers fed L85 and L80 + I. During the lactation phase of the trial no differences were observed among treatments for dystocia index, calf BW or 7 d postpartum cow BW. Lactation BW, DMI and feed efficiency did not differ between treatments at 45 and 90 DIM. Milk production and milk components were also not different between cows fed C100, L85 or L80 + I as heifers. Rumen digesta volume and density measurements were 76.2, 99.1 and 66.1 L for C100, L85 and L80 + I, respectively, at 45 DIM. However, by 90 DIM all cows had similar rumen digesta volume, suggesting effects of limit feeding on rumen capacity were mitigated by 90 DIM. Limit feeding or limit feeding in combination with supplementing an ionophore, improved heifer growth, increased feed efficiency during the growth phase and did not have detrimental effects on rumen function. Limit feeding heifers did not result in any deleterious carryover effects during lactation.

Corn zein and starch can to be difficult to extract from feed samples during the rinsing phase of NDF assays (WI). Zein is soluble in 70% ethanol, and corn starch can be degraded to soluble disaccharides with amylase. Research was carried out to determine if pretreating feed samples with ethanol or amylase affects estimates of NDF or in vitro NDF digestibility (NDFD). Pre-rinsing Ankom F-57 forage bags with acetone was also tested for effects on estimates of NDF and NDFD. An alfalfa silage sample and a mixture of 70% alfalfa silage (the same alfalfa) and 30% corn grain were dried (60 C) and ground (1mm). Feed samples (0.5 g) were weighed into Ankom F-57 forage fiber bags. Half the bags had been pre-rinsed in acetone and dried at 100 C prior to adding sample. Both sets of bags were then sealed and pretreated as follows: untreated (control), bags containing feed sample were rinsed with 70% ethanol prior to NDF analysis and in vitro NDF digestion (ETOH), bags and feed were treated with an amylase hot water rinse prior to NDF analysis and in vitro NDF digestion (AMYLASE), or bags with feed were pre-rinsed with 70% ethanol and then pretreated with amylase prior to in vitro digestion (ETOH-AMYLASE). NDF concentration of the alfalfa (43.1% of DM) or the mix of alfalfa and corn grain (35.7% of DM) were not affected by acetone pre-treatment of the empty Ankom bags, or the ETOH, AMYLASE, or ETOH-AMYLASE pretreatments. Estimates of in vitro NDF digestibility (% of NDF) were higher from samples incubated in bags that had been pretreated with acetone (alfalfa; 28.6 v 30.9, $P<0.1$, alfalfa-corn mix; 21.1 v 26.8, $P<0.05$)) than in bags that had not been pretreated. The 24 h ivNDFD for control alfalfa bags (29.7% of NDF) significantly increased ($P<0.01$) when bags with feed were pretreated with ETOH (36.8% of NDF), AMYLASE (36.3% of NDF) or ETOH-AMYLASE (38.9% of NDF). The ivNDFD values from control bags containing the alfalfa-corn mixture (23.9% of NDF) were also lower than from sample within bags that had been pretreated with ETOH (35.6 % of NDF), AMYLASE (38.5% of NDF) or ETOH-AMYLASE (37.6% of NDF). Acetone pretreatment of Ankom F-57 bags had little effect on estimates of NDF in either sample but did influence the estimate of 24 h in vitro NDFD. Pretreatment of the alfalfa or the alfalfa-corn mixture with ethanol, amylase or a sequential treatment of ethanol and amylase did not affect estimates of NDF. Estimates of in vitro NDF digestibility were elevated when samples were pretreated with amylase, ethanol or the sequential combination of ethanol and amylase.

**1c. Dynamics (species, competition, compatibility, grazing height, sward density) of mixed pasture systems to improve animal and pasture productivity**

A trial compared milk yields of cows grazing either a perennial pasture type (kura clover/reed canary grass, (KRC)), or a short lived annual pasture (white clover/Italian ryegrass, WRG)) when managed by management intensive grazing (WI). Twenty-eight primiparous Holstein cows (89 DIM and, 535 kg BW), were randomly assigned to one of four-2.4 hectare paddocks. Two of the pastures were established with kura clover (*Trifolium ambiguum* Bieb, cv. Endura.) and low alkaloid reed canarygrass (*Phalaris arundinacea* L, cv.Palaton) in 1999. The KRC pastures contained approximately 50% reed canarygrass and 50% kura clover at initiation of this experiment in 2007. The other two pastures were seeded in the spring of 2007 with a mixture of white clover (*Trifolium repens* L. cv Kopu II) and Italian Ryegrass (*Lolium perenne* ssp. Multiflorum, cv Feast II). All pastures were managed to offer cows approximately 30 kg of forage DM per day. The daily grazing area was estimated according to the pasture availability and the number of cows in

each paddock. Cows were allowed to graze approximately 20 h/d and were milked twice daily. Supplemental concentrate was provided daily after each milking (7.2 kg/cow/d). Pastures were initially stocked with 7 cows per paddock, but as the summer progressed and pasture growth declined, cows from each of the paddocks were removed to keep pasture availability constant and assure adequate supply of pasture. Pasture intake was estimated by difference in yield estimates from pasture quadrats clipped at a 5 cm stubble height before and after grazing. Pastures quality was high throughout the trial (41 +/- 1.6%, NDF, and 18 +/- 0.5%, CP). Milk yield/cow/d tended lower for JH than H (27.0, 29.8 kg/d, respectively $p < 0.07$) and 3.5% FCM was lower for JH than H ( 28.0, 30.0 kg/d respectively, $p < 0.01$). Milk fat percentage was similar for JH and H (3.6+/- 0.1%). Fat corrected milk yield by paddock was higher for H than JH (1349, 1187 kg 3.5%FCM/paddock/week respectively, $p<0.05$). Pasture DMI did not differ by breed (1133 kg DM/paddock/d). Grazing Holstein primiparous cows produced more milk from high quality pasture than Jersey-Holstein crossbreds. Breed did not affect pasture intake. The advantage was due to the higher production per cow of the Holsteins than the Jersey-Holstein crossbreds.

Models integrating farming systems utilizing ruminant livestock must consider that the rumen is a dynamic biological system within the entire farm system (WVa). Rumen microorganisms are responsible for the majority of rumen activity and require nutrients in a synchronized fashion for maximal production and minimal nutrient loss. Previous reports demonstrate that diurnal changes in rumen activity exist and are influenced by things such as but not limited to basal diet and supplements as well as animal grazing activity. Grazing beef and dairy cattle consume their pasture-based diets in non-equally spaced meals and at differing rates throughout the day. Carbohydrates and protein within these diets are composed of many different fractions that have varying rates of digestibility and availability. Given the above information, it is conceivable that there are times within a day that a loss of synchrony between supplies of carbohydrates and nitrogen can occur and ultimately effect nutrient excretion. The effects of time of supplementing a fat enriched protein supplement on diurnal rumen activity and nutrient digestion were investigated in-vivo and supplemental fat, protein or fat and protein were investigated in-vitro. In the in-vivo experiment, lambs were fed poor quality, low protein orchard grass hay at 0600h for all treatments and supplemented at 0600h (AM), 1800h (PM), or one half of daily allotment at both times (AP). There were treatment x time interactions ($P < 0.001$) on rumen VFA and $NH_3$ concentrations and pH. Liquid passage rates did not differ ($P = 0.56$) between treatments while PM lambs had a slower solids passage rate ($P = 0.04$) than the AM and AP lambs. Treatments did not significantly affect hay intake, nitrogen retention or overall nutrient digestibility although PM lambs followed a slower passage rate with numerically less hay intake and numerically greater diet digestibility. In the in-vitro experiment, single-flow continuous culture fermenters were used in a generalized completely randomized block designed experiment in which 3 experimental supplements were tested across 3 experimental runs at 3 supplementation times to fermenters receiving fall-harvested cool season pasture regrowth (17% CP). Fermenters were fed 50 g/d dietary DM. Supplements were soybean oil (SO; 3% daily dietary DM), soybean meal (SBM; 7% daily dietary DM) and soybean oil with soybean meal (SBOM; 3 and 7% daily dietary DM, respectively) and were delivered to the fermenters at either AM, PM, or AP or not at all (C). There were treatment x time interactions ($P < 0.05$) for diurnal pH and $NH_3$ as both the SO and SBOM supplemented in the AM resulted in a more neutral pH and lower $NH_3$ concentrations at 6 and 3 h proceeding the morning feeding at 0600 compared to other treatments. No interactions ($P > 0.05$) of treatment x time were observed for VFA production; however, effect of supplement did influence overall nutrient digestibility and VFA concentrations. Based on these results the time of supplementation can affect diurnal fermentation in-vivo and in-vitro but not to a similar degree. These results indicate that timing of supplement delivery may affect animal nutrient excretion and should be considered in any models utilizing supplements.

**Objective 2: To reduce environmental impacts of animal, manure, and cropping systems on nutrient flow, cycling, and transformation.** (Rotz, ARS Pa; Herbert, UMass; Dou, UPenn; Miller, UT; Harrison, WA; Powell, WI; Moreira, LA; Erickson, NE; Knowlton, VaTech)

Studies conducted under this objective encompassed feeding, pasture, and integrated practices management practices, evaluations of waste treatment systems, and whole farm modeling.

## FEED, GRAZING, AND INTEGRATED MANAGEMENT PRACTICES

### Surveys of management practices in dairies

With regulations pertaining to environmental impacts of animal agriculture, dairy farmers seek new ways to track and improve the management of nutrients contained in feed and manure. US Dairy Forage Research Center in collaboration with University of Wisconsin-Madison, Chinese Academy of Sciences, Australian Department of Primary Industries and dairy farmers developed methods to rapidly assess relationships between dairy feed nitrogen (N) and phosphorus (P) consumption, N and P secretions in milk, N and P excretions in manure, and how much manure is collected and land-applied. Feed and manure management data from 54 Wisconsin dairy farms was used to calculate feed N and P use efficiencies, and manure N and P excreted, collected and land-spread. There appears to be a range of diets that satisfy nutritional requirements of high-producing dairy cows and produce feces having different effects on plant available N, plant yield and N uptake. Information is being used to revise Wisconsin's Nutrient Management Curriculum and Wisconsin's Code 590 Nutrient Management Standards. The on-farm survey instruments have been requested, adapted and applied in Iowa, Ohio, Pennsylvania, Wisconsin, Australia and China (**Muck & Powell – ARS Wisconsin**).

In Louisiana, grazing is the primary method of feeding dairy cows. In a survey, dietary protein was reported to be closely monitored (reported crude protein averaged 16.1% of the diet dry matter basis) by the vast majority of farmers (70%) but only few displayed any knowledge of the phosphorus content in their cows' diets. Routine forage analysis should be encouraged to help producers establish a seasonal pattern of P contents in pastures, thus allowing for more accurate P feeding program. Finally, farmers and company nutritionists should be the focus of extension programs intended to inform on excess P effects on environment if farmers are expected to feed near recommended levels (**Moreira – Louisiana**).

### The influence of cow feeding on milk production, amount and forms of nutrients excreted in manure, and nutrient availability to crops when manure is land-applied

Dairy nutritionists and soil scientists at the US Dairy Forage Research Center and University of Wisconsin-Madison used lactation trials, manure-soil incubations and greenhouse trials to demonstrate that a variety of diets, including numerous forages and crude protein levels (CP), can satisfy the nutritional requirements of high-producing lactating dairy cows only marginal impact on milk production. Researchers used feces from dairy cows fed fourteen diets incubated in soils, and plant available N (PAN) and plant N uptake were determined. Feces from cows fed alfalfa silage (AS)-based diets generally produced higher levels of PAN than soils that received feces from corn silage (CS)-based diets. Application of feces from AS-based diets resulted in higher plant yield and N uptake than feces from CS-based diets. After application to soil, feces from high protein (HP) diets produced more PAN than feces from low protein (LP) diets. Feces from LP diets resulted in lower plant yield and N uptake than feces from HP diets (**Muck & Powell – ARS Wisconsin**).

In a follow-up study, Wisconsin researchers determined the impact of forage tannin on cows' N excretion; fecal fiber fractions and their N concentrations; and on PAN. Significantly ($P < 0.05$) higher concentrations of N were excreted in urine by cows fed low-tannin birdsfoot trefoil (LTBT) and red clover (RCL) than by cows fed alfalfa (ALF), or high-tannin birdsfoot trefoil (HTBT) silages. Cows fed RCL also had higher rates of urinary N excretion and lower rates of fecal N excretion than cows fed any of the other silages. Fecal N excretion rates were greatest for cows fed LTBT and HTBT, followed by ALF and RCL. Concentrations of neutral detergent fiber (NDF) in feces, of N in NDF (NDIN) and in acid detergent fiber (ADIN), and relative amounts of excreted NDIN and ADIN were significantly higher from cows fed HTBT than the other silages. Slurry (feces plus urine) from cows in this study were then applied (375 kg N ha-1) to field plots during spring only or spring plus fall. After spring application, slurry source did not significantly impact soil pH, and only periodically impacted concentrations of soil NH4-N and NO3-N. First year corn N uptake after spring application of ALF slurry was greater than corn N uptake after LBFT slurry application or in control

plots. Corn yield and N uptake were not significantly impacted by slurry types applied the previous fall. Second year residual ALF plots had 35% greater corn yield and 50% greater corn N uptake than control plots, followed by RCL, LTBT and HTBT plots, which had from 17% to 22% greater corn yield and 29% to 36% greater corn N uptake than control plots. Total N recovery was likewise highest in ALF plots followed by RCL and LBFT. Average residual N recovery by corn in spring slurry-amended plots ranged from 20% (ALF) to 13% (RCL and LTBT). Low impacts of slurry types on soil chemical properties and corn was likely due to several interactive factors, including low rainfall, high indigenous soil N availability, and high response variability associated with indirect estimates of slurry N recovery (**Muck & Powell – ARS Wisconsin**).

Pennsylvania researchers conducted an experiment to examine forms and bioavailabilty of P in cows' feces from two different dairying systems. Liquid state 31P nuclear magnetic resonance spectroscopy (31P-NMR) was used to identify phosphorus compounds present in water, dilute acid and NaOH-EDTA extracts of feed, forage and feces. Water was not an effective extractant as several important P forms (phosphonate, phytic acid, pyrophosphate, and polyphosphate) were missing in water extracts of samples from both farms. The slightly acid extractant NaAc performed equally well or even better than the traditional NaOH+EDTA extractant. Numerically, the amounts of orthophosphate, phytic acid, diesters, and polyphosphate were similar in the two extracts, whereas NaAc extracts had higher amounts of other monoesters and pyrophosphate as compared to the NaOH+EDTA extracts. Third, both NaAc and NaOH appeared to cause degradation of DNA and other diesters as there were greater amounts of these P compounds in the water extracts. The concentration of P in feces was generally proportional to that in feed; however, the feces of animals on pasture had higher P content than those fed TMR at the same P concentration. The vast majority of total P in dairy feces existed as orthophosphate. Water extractability of P decreased when fecal samples were dried; however this did not occur in extracts of dilute acid and NaOH-EDTA. Type of feed input and drying of feces had strong effects on changing the distribution of fecal P forms and on the potential impact of P on soils and surface water bodies. Although P availability in spring pasturage was greater than in Total Mixed Rations, the larger land area used for grazing, in combination with less diet supplementation with mineral P and reduced P chemical fertilization of pasture, was shown to reduce the potential for negative impacts of P in manure on agricultural land and associated water bodies (**Dou – Pennsylvania**).

The same researchers assessed the impact of long-term manure application on soil P functional groups using 31P NMR in 10 soils receiving agricultural wastes including dairy, swine, poultry manure, or spent mushroom compost for 8-10 years. Soil total P increased by 3 to 5 folds. Much of the increases were inorganic orthophosphate. Among the organic P, phosphate-monoesters dominate, mostly as phytic acid. Despite the presence of considerable amounts of phosphate-monoesters in animal manures as reported earlier, evidence was unclear about the accumulation of phosphate-monoesters in the soils receiving 8-10 years of manure applications. Phosphate-diesters that are typically present in animal manures were not detected in most of the soils, manured or untreated (**Dou – Pennsylvania**).

Wisconsin researchers compared two dairy heifer management practices on manure N capture and recycling through crops: the conventional practice of barn manure collection and land application, and corralling heifers directly on cropland. Heifers were kept in a barn for two (B2) or four (B4) days and manure was hauled to fields, or heifers were corralled directly on cropland for two (C2) or four (C4) days. Four successive manure application seasons, spring-summer (SS), fall-winter (FW), summer (S) and winter (W) were evaluated over two years. Each application was followed by three-year crop rotations: SS and S by wheat (Triticum spp. L.), sudangrass (Sorghum bicolor (L.) Moench), winter rye (Secale cereale L.), corn (Zea mays L.), winter rye, and corn; and FW and W by corn, winter rye, corn, winter rye, and corn. Corralling resulted in 50 to 65% greater N applications than barn manure. In-barn N losses (% of excreted manure N, ExN) were greater from B4 (30%) than B2 (20%). Apparent N recovery of applied manure N (ANR) by wheat ranged from 13% to 25% at the lower (B2 and C2) application rates and 8% to 14% at the higher (B4 and C4) rates. First-year corn following FW had ANR of 13 to 32% at the lower (B2 and C2) application rates and 9 to 20% of applied N at the higher (B4 and C4) rates. As a percent of ExN, ANR over the 3 yr rotation from C2 was 50%, B2 35%, C4 30% and B4 22% (**Muck & Powell – ARS Wisconsin**).

**Protocols for emission research**

Dairy barns are thought to emit large amounts of ammonia and other gases, which can have detrimental effects on human health and natural ecosystems. In the U.S., relatively little is known about ammonia emissions from dairy barns. Scientists at the US Dairy Forage Research Center, the University of Wisconsin-Madison, and the Institute of Grasslands and Environmental Research in the UK designed and converted a conventional tie-stall dairy barn into four chambers to evaluate at a production-scale, ammonia emissions from dairy cows fed different diets, from different bedding types, etc. Initial trials revealed that reduced dietary crude protein content decreased total manure nitrogen (N) excretion, the proportion of N excreted in urine, and ammonia emissions from dairy barns and after manure land application. Increasing the content of condensed tannins in the forage legume component of the diet decreased the proportion of N excreted in urine and resulted in proportionally lower ammonia emissions from a barn floor. The ability of beddings to separate urine and feces, and the relative absorbance of beddings were the most important factors influencing ammonia emissions from dairy barn floors. Ammonia emissions were least from sand and pine shavings and greatest from chopped newspaper, recycled manure solids and chopped corn fodder. Initial results of chamber calibrations and large-scale trials revealed that the chambers can provide precise data on ammonia emissions, data which can be used to develop ammonia emission factors for tie-stall dairy barns in the Midwest USA (**Muck & Powell – ARS Wisconsin**).

A study was conducted at the Pioneer system research farm, University of Wisconsin, Platteville. The 78-cow lactating herd was divided in two groups, each being allocated to either a recommended diet (REC) with 16.7 ± 1.3 % crude protein (dry matter basis) or an excess crude protein diet containing 18.2 ± 1.5%. Feeding excess dietary crude protein did not affect dry matter intake, milk production or milk composition. Wet manure excretion was higher when corn silage became unavailable and alfalfa silage was the only forage source in the diet (75 vs. 87kg/d per cow, respectively). On average N loss was 110 g/d per lactating cow, but ranged from 64 g/d to 178 g/d with no clear seasonal pattern. Milk urea N was weakly related with N volatilization; however there was a strong linear association between milk urea N, manure N excretion and dietary crude protein. A 27% reduction in N emission (93 vs. 127 g/d per cow) was observed by decreasing protein a merely 8.3% from 18% (**Wattiaux – ARS Wisconsin**).

**Nutrient cycling under grazing management**

Feed is one of the greatest costs a livestock producer faces. Grazing systems that extend the grazing season beyond the standard growing season, such as deferred or stockpiled grazing, reduce the need for harvested feed resulting in great reductions in machinery and labor costs. However, with the economic benefits of extending the grazing season come additional environmental concerns. Plant growth is minimal in the late fall and early spring which severely limits utilization of nutrients in the animal waste. In addition, snow melt and early spring rainfall events may "flush" many of the nutrients past the root zone. This study examined nutrient cycling in a management intensive grazing system, a deferred grazing system, and a mechanically harvested pasture.

Tall fescue paddocks (12 meters x 24 meters) at the Intermountain West Pasture Facility located near Lewiston, Utah were utilized for this study. Tall fescue is a cool-season grass that is noted for its high yield production. Three grazing treatments: no grazing (NG), standard management intensive grazing (MIG), deferred grazing (DG) were assigned in strip plots with six replications. The NG plots were mechanically harvested. The MIG plots were grazed for 24 hours, approximately every 6 weeks. The DG plots were grazed the same as the MIG plots; with the last grazing event for the season being delayed until early winter. Plots were watered every two weeks applying an average of 10 cm per set as need. Bulk densities were taken to a depth of 30 cm at the beginning and end of each grazing season to assess soil compaction. Complete soil profile samples (to a depth of 150 cm) were collected at the beginning and end of each grazing season to monitor any nutrient movement and buildup for each treatment. The soil samples were analyzed for N, P, and K at seven depths (0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm, 90-120 cm, 120-150 cm, and 150 - 180 cm). Leachate samples were collected using zero-tension lysimeters, 38.1 cm in diameter and 111.8 cm in length. Samples were collected bi-weekly during the grazing season, and as often as possible during the winter

months. Samples were be analyzed for nitrite and nitrate nitrogen utilizing a cadmium reduction method. Inorganic dissolved phosphorus was determined colorimetrically using an ascorbic acid method. Ammonia volatilization was measured after grazing events using dynamic chambers.

Compaction effects from grazing were evident after the first year, and continued throughout the study. Initial results indicate that nitrate leaching was heavily influenced by the amount and timing of fertilization and irrigation events; however, no significant differences were observed for phosphorus. Ammonia volatilization was highly variable with no significant differences being observed (**Miller – Utah**).

## MANURE HANDLING MANAGEMENT

### Manure handling and treatment methods

Virginia researchers focused on implementing advanced wastewater treatment techniques on dairy farms to generate designer manures targeted to better meet crop nutrient needs. Approaches used include enhanced biological P removal (EBPR), struvite crystallization, and deammonification (nitritation coupled with denitrification), in combination with physical and chemical nutrient removal systems. Significant ammonia removal was achieved in deammonification reactors, and significant P removal in EBPR reactors. Combinations of polymers with aluminum sulfate, aluminum chloride, ferric chloride or ferric sulfate were evaluated for their effectiveness in removing P from dairy manure. Greater than 90% P removal in research scale reactors, and 80% removal of P were achieved in a full scale test with a combination of aluminum chloride and a high molecular weight polymer. Results of the work with chemical treatment of manure, and reviews reporting on EBPR and deammonification were published (**Knowlton – Virginia**).

The LSU AgCenter Animal Waste and Nutrient Management Team evaluated technologies and management practices to optimize wastewater treatment at the Southeast Research Station Dairy Wastewater Treatment Evaluation System (DWTES). DWTES is a replicated system of wastewater treatment lagoons consisting of anaerobic/facultative lagoon (ANL), followed by aerobic lagoon (AEL), and constructed wetlands (WLD). The contribution of each additional stage after ANLs was compared to the effluent from previous stage and the overall system treatment effectiveness was quantified. Emerging plants (Pickerel weed - *Pontederia cordata*) were also evaluated in the constructed wetlands. The addition of AEL and WLDs to a single ANL significantly contributed to improve the system's effluent. More than 18 water quality characteristics were evaluated, 11 of which decreased 50% or more, including suspended solids (95%), oxygen demand, nitrogen, *E. coli* and phosphorus (**Moreira – Louisiana**).

An attempt to replace AEL with WLDs resulted in poor performance of the 2-stage system (ANL-WLD) particularly for the breakdown of organic nitrogen. Other water quality characteristics were less affected but suggested WLDs surface area merely replaced that of the AEL (**Moreira – Louisiana**).

Plant species (3 cool-season, and 5 warm-season) growth on artificial floating islands (Floating Islands Environmental Solutions, Baton Rouge, LA) was evaluated in each treatment-stage over 2 years (4 growing seasons). In the first cool season, ryegrass (*Lolium multiflorum*) outperformed rye (*Secale cereale*) and oats (*Avena sativa*) by nearly 100% in yield (6.4 g dry matter/day/m2 of island), in nitrogen uptake (0.22 g/day/m2 of island) and in phosphorus uptake (0.03 g/day/m2 of island). Samples from the 3 subsequent seasons are being processed for laboratory analyses (**Moreira – Louisiana**).

Wastewater flow rates (in litters per minute: 19.7 – H; 6.8 – M; and 1.5 – L) into each of the six constructed wetlands were evaluated. Concentrations of most characteristics analyzed (solids, nitrogen, ammonia, phosphorus, *E. coli*) sharply decreased from H and M treatments to L wetlands effluents. Counts of *E. coli* decreased by 2 orders of magnitude in wetlands at low flow rates. Pollutants (solids, sulfate, phosphorus, nitrogen, ammonia, oxygen demand) averaged 80% lower (ranging from 53% for phosphorus to 95% for suspended solids) in L wetlands' effluents than their concentrations in fresh wastewater (**Moreira – Louisiana**).

**Pathogen survival in dairy manure and manured soils**

It was been observed that much *E. coli* found in the system's effluent can originate from wildlife. DNA fingerprinting was also able to document that some *E. coli* strains can survive in the system much longer than others (**Achberger – Louisiana**).

A study to investigate the environmental fate of E. coli O157:H7 and Salmonella Newport was carried out by Pennsylvania researchers. A preliminary trial was conducted using environmental sentinel chambers containing manure-soil mixtures inoculated with either E. coli O157 or Salmonella Newport and buried in an agricultural field. Salmonella Newport had a consistent slow decline over 90 days, total counts declined by approx. four orders of magnitude from initial inoculated concentrations; environmental data (soil temperature and moisture) will be examined to establish correlations between soil conditions and time trends in pathogen die-off. For E. coli O157, the introduced pathogen remained at inoculation concentrations through three weeks but was not detected thereafter. Absence of E. coli O157 was confirmed by PCR analysis. The short-duration presence of E. coli O157 was apparently due to low inherent survivability in the soil system and to competition with native soil and manure microorganisms (**Dou – Pennsylvania**).

**Manure application management**

High farm costs for feed and fertilizer significantly impact profitability of dairy farms. A system approach in production of corn silage with efficient cycling of nutrients can reduce input costs and reduce nutrient loss to the environment. With a focus on early planting with early maturing hybrids can achieve an earlier harvest time of corn enabling timely planting of cover crops for increased end-of-season nitrogen accumulation. More than 100 lbs N/ac can be accumulated if the winter rye cover crop was planted in early September. Achieving an early planting date for cover crops is difficult for farmers who commonly are harvesting corn and spreading manure into mid to late September. Massachusetts research indicated that early corn hybrids had similar yield on average to late season hybrids. A new research approach was to harvest corn and plant cover crops by mid September, and then spread manure later when temperatures are cooler. Colder fall temperatures significantly reduced the rate of ammonia volatility from surface applied manure (**Herbert – Massachusetts**).

Another work by Virginia researchers evaluated the relative risk of P losses from fescue pasture following application of manures (dairy slurry, swine slurry, beef solids, and poultry litter) or commercial fertilizer. Cropland-derived coefficients in the Virginia P Index were generally appropriate for pasture in soils typical of the Shenandoah Valley, but reduction in their magnitude and a differentiation between liquid and solid manures may be warranted. In more complex process-based models, inclusion of season and rainfall duration may be appropriate, to reflect the greater runoff risk during longer rain events and from wet fields early after manure application (**Knowlton – Virginia**).

**Economics of manure handling and treatment**

The cost benefit of wastewater recycling from commercial lagoons was evaluated for dairy farms in Louisiana. Because of high dilution rates, lagoon wastewater recycling in most grazing Louisiana dairies were deemed uneconomical, even with the 75% cost-sharing offered by local USDA-NRCS programs (**Westra – Louisiana).**

**Modeling**

The Integrated Farm System Model (IFSM) has been continually updated and tested in several studies. Simulation was used to evaluate forage management options on a typical farm in the mid Atlantic region, which included 100 cows and 200 acres of cropland on a Hagerstown silt loam soil. The base farm produced 100 acres each of alfalfa and corn with the alfalfa harvested as silage using a four cutting strategy and most of the corn harvested as silage. These crops supplied all of the forage and a portion of the grain needed to meet the nutrient requirements of the herd. Alternative cropping systems included 1) half of the alfalfa was replaced with grass, same amount of corn silage, 2) more corn with 70% of the forage from corn silage and 30% from alfalfa, and 3) inclusion of rye double-cropped with corn where 18% of the forage came from rye silage with a little over 50 and 30% from corn and alfalfa silages. The production and use of more corn

silage, particularly when double-cropped with rye silage, reduced nutrient losses from the farm with relatively small effects on farm profit. Use of a three-cutting strategy for alfalfa production with longer regrowth periods between harvests reduced farm profit by $80/cow. Genetic improvement of alfalfa for a 10% increase in fiber digestibility provided up to a $76/cow increase in farm profit. Increasing the cutting height in corn silage harvest improved forage quality, but provided a net loss in profit of $12/cow. Mechanical processing provided a more economical means of improving corn silage quality where an assumed 2% increase in milk production increased profit by $42/cow per year (**Rotz – ARS Pennsylvania**).

Manure Application Methods: Field measurements and a farm simulation model were used to compare the environmental and economic impacts of using alternative manure application methods on dairy farms. The IFSM was able to represent the corn silage production, water balance, volatile ammonia N loss, nitrate N leaching loss, and P runoff losses measured in field plots with manure application treatments of no manure application, broadcast application without incorporation, broadcast application with tillage incorporation, band application with aeration, shallow disk injection, and high pressure injection. Measured and simulated results showed that incorporation of manure below the soil surface through tillage or injection reduced ammonia N losses but tended to increase nitrate leaching losses. Effects of the manure application strategy on P losses were less clear, but there was a trend toward less surface runoff loss of P with injection of manure and greater loss of sediment bound P when tillage was used to incorporate manure. Whole-farm simulation of each of the manure application strategies on a representative dairy farm in central Pennsylvania indicated that reductions in ammonia N loss and runoff loss of P can be obtained with the use of shallow disk injection without adversely affecting farm profitability. Use of broadcast application with tillage incorporation, band application with aeration, or high pressure injection reduced average annual farm net return by $34, $22, and $30/cow, respectively compared to broadcast application of manure without incorporation. Additional benefits such as odor reduction may also be obtained, which may help justify the additional production cost even when no direct economic benefit is received (**Rotz – ARS Pennsylvania**).

Silage VOC Emissions: Volatile organic compounds (VOCs) from agricultural sources are believed to be an important contributor to tropospheric ozone in some areas. Limited data on VOC emissions from silage suggest that silage is a major source. Ethanol is the most abundant VOC emitted from corn silage, and thus was used as a representative compound to characterize the pattern of emission over time and to quantify the effect of air velocity and temperature on emission rates. Ethanol emission was measured from corn silage samples, removed intact from a bunker silo, over a range in air velocity (0.05, 0.5, and 5 m s-1) and temperature (5, 20, and 35°C) using a wind tunnel system. Ethanol flux ranged from 2.3 g m-2 h-1 to 220 g m-2 h-1 and 12 h cumulative emission ranged from 7.4 g m-2 to 270 g m-2. Ethanol flux was highly dependent on exposure time declining rapidly over the first hour and then more slowly for the duration of the 12 h trials. Cumulative emission increased by a factor of 3 with a 30°C increase in temperature and by a factor of 9 with a 100-fold increase in air velocity. Process-based models were developed to represent VOC transfer within and from silage during storage and feeding. These models were based upon well-established theory for mass transport processes in porous media with parameters determined from silage properties using relationships developed for soils. Preliminary results indicate that VOC emission by advective flow of silage gas is generally insignificant compared to emission by surface convection and diffusion from within silage. VOC emissions are dependent upon silage properties, temperature, wind speed, and exposure duration, which have implications for measuring, predicting, and controlling VOC emissions from silage. Emissions appear to be co-limited by convection and diffusion; therefore, the EPA-style emission isolation flux chamber previously used to measure VOC emissions from silage does not represent field conditions (**Rotz – ARS Pennsylvania**).

**Extension**

An NRCS CIG grant was awarded to a team of land grant universities and lead by WSU to develop the infrastructure to implement the Feed Management 592 practice standard for NRCS. Tools in the form of assessment tools, checklists, and a feed management template were developed for the species of beef, dairy, swine, and poultry. Training workshops have been held for both nutritionists and technical service providers (nutrient management planners). A tool named Feed Nutrient Management Planner Economics (FNMP$)

was refined to include beef management practices associated with composting of manure from feedlots. An online survey was conducted from users of the whole farm balance education tool (WFBNET) and it's value in education related to whole farm nutrient balance. Information will be used to revise the tool in 2007 (**Harrison – Washington**).

**Objective 3: Refine, evaluate, and apply integrated quantitative models of dairy and beef farms to predict profitability and nutrient losses to the environment.** (Rotz, ARS, PA; Rayburn, WV, Karsten UPenn; Grabber, WI; Moriera, LA; Mohtahr, Purdue; Randhir, UMass)

The following studies were completed to refine, evaluate, and apply the Integrated Farm System Model. Work was done to develop and integrate component models for predicting ammonia emissions, greenhouse gas emissions, and the carbon footprint of farm production systems. The whole farm model was then used to evaluate grass-based organic dairy production systems, the environmental impact of grazing-based farms, and management effects on the carbon footprint of dairy production systems.

**Ammonia Emissions Model**

Ammonia emissions from animal feeding operations are an important concern due to their potential adverse effects on animal and human health and the environment. Emissions occur from manure surfaces on the barn floor, during storage, and following field application. Based upon theoretical principles and associated published information on ammonia emission, relationships were refined for modeling the dissociation constant, Henrys law constant and mass transfer coefficient to better predict ammonia loss from manure surfaces. Theoretical inconsistencies in widely used expressions for the dissociation constant and mass transfer coefficient were observed. Refined expressions were developed that relate these parameters to the temperature, pH, and ionic strength of the ammonium containing material, and the velocity of air flowing over the material. These expressions were tested by comparing predicted ammonia emission rates against values measured in controlled laboratory experiments for buffered ammonium-water solutions and dairy cattle manure. Experimental results compared well to values predicted using these theoretical expressions derived from ammonia volatilization literature. These process-level relationships were incorporated in the Integrated Farm Systems Model providing a software tool to quantify management effects on ammonia emissions from farms (**Rotz – ARS Pennsylvania**).

**Greenhouse Gas Emissions Model**

Concern over greenhouse gas emissions and their potential impact on global climate has grown rapidly in the US over the past couple years. Livestock agriculture is recognized as an important emitter of these gases, but little quantitative data exist on emission rates and the effect of management on these emissions. Simple process-level relationships were integrated in the development of a comprehensive model for predicting all important sinks and emission sources to determine a whole-farm carbon balance and an estimate of the net farm emission of greenhouse gas. Relationships were used to track carbon dioxide, methane, and nitrous oxide flows during crop production, from the animals, and from manure on the barn floor, during storage and following land application. These relationships were added to the Integrated Farm System Model to predict net greenhouse gas emissions along with nitrogen and phosphorus losses and the overall performance and economics of farm production systems (**Rotz – ARS Pennsylvania**).

**Dairy Greenhouse Gas Model**

The Dairy Greenhouse Gas Model (DairyGHG) was developed to provide an easy to use software tool that estimates total net greenhouse gas emissions and the carbon footprint of a dairy production system. While the Integrated Farm System Model (IFSM) provides a sophisticated research tool, DairyGHG was designed to provide a simpler educational aid for more general use. DairyGHG uses a process-based model, similar to that in IFSM, to predict the primary GHG emissions from the production system, which include the net emission of carbon dioxide plus all emissions of methane and nitrous oxide. Secondary emissions are those occurring during the production of resources used including machinery, fuel, electricity, fertilizer, pesticides, plastic, and purchased animals. Emissions are predicted through a daily simulation of feed use and manure

handling where daily values of each gas are summed to obtain annual values. A carbon footprint is then calculated as the sum of both primary and secondary emissions in $CO_2$ equivalent units divided by the energy corrected milk produced. DairyGHG is available on the Internet at https://www.ars.usda.gov/Main/docs.htm?docid=17355. The model includes a fully integrated help system with a reference manual that documents the relationships used to predict emissions (**Rotz – ARS Pennsylvania**).

**Grass-Based Dairy Production Provides a Viable Option for Producing Organic Milk in Pennsylvania**

More intensive use of pasture and the transition to organic production are being used to reduce production costs and increase profitability of some small dairy farms in Pennsylvania. Farm simulation, supported by case study farm data, was used to compare the economic benefits and environmental impacts of two grazing-based production systems using either organic or conventional practices. Systems using all-grass production with managed rotational grazing and a spring calving herd maintained outdoors throughout the year had lower erosion and phosphorus losses, lower production costs, and up to $200/acre ($1.58 to 3.63/cwt of milk produced) greater net return compared to systems using crop production, supplemental grazing, random calving, and winter confinement. With either production approach, substantial economic benefit was found using organic practices, but this benefit was highly dependent upon the price difference between organic and conventional milk. Environmental concerns for organic production were (i) long-term accumulation of soil nutrients due to the use of imported poultry manure for crop fertilization, and (ii) greater soil erosion and runoff loss of phosphorus due to increased tillage for weed control in annual crops. The economic net benefit may encourage more grass-based dairy producers to transition to organic certification, so more attention must be given to identifying strategies that better utilize farm nutrients and reduce losses to the environment (**Rotz – ARS Pennsylvania; Karsten - Pennsylvania**).

**Grazing and the Environment**

Incorporating managed rotational grazing into a dairy farm can result in an array of environmental consequences. A comprehensive assessment of the environmental impacts of four management scenarios was conducted by simulating a 250-acre dairy farm typical of Pennsylvania with: 1) a confinement fed herd producing 22,000 lb of milk per cow per year; 2) a confinement fed herd producing 18,500 lb; 3) a confinement fed herd with summer grazing producing 18,500 lb; and, 4) a seasonal herd maintained outdoors producing 13,000 lb. Converting 75 acres of cropland to perennial grassland reduced erosion 24% and sediment-bound and soluble P runoff by 23 and 11%, respectively. Conversion to all perennial grassland reduced erosion 87% with sediment-bound and soluble P losses reduced 80 and 23%. Ammonia volatilization was reduced about 30% through grazing, but nitrate leaching loss increased up to 65%. Grazing systems reduced the net greenhouse gas emission by 8 to 14% and the C footprint by 9 to 20%. Including C sequestration further reduced the C footprint of an all grassland farm up to 80% during the transition from cropland. The environmental benefits of grass-based dairy production should be used to encourage greater adoption of managed rotational grazing in regions where this technology is well adapted (**Rotz – ARS Pennsylvania**).

**Carbon Footprint of Dairy Production Systems**

Dairy production, along with all other types of animal agriculture, is a recognized source of GHG emissions, but little information exists on the net emissions from our farms The Dairy Greenhouse Gas model (DairyGHG) was used to estimate the net GHG emission and C footprint of various production systems. The cradle-to-farm gate C footprint of commonly used production practices was found to vary from 0.37 to 0.69 kg $CO_2$ $kg^{-1}$ of ECM produced depending upon milk production level and the feeding and manure handling strategies used in the production system. In a comparison to previous studies, DairyGHG predicted C footprints similar to those reported when similar assumptions where used for feeding strategy, milk production, allocation between milk and animal co products, and sources of $CO_2$ and secondary emissions. Model-predicted C footprints were most sensitive to the relationships used to predict the $CH_4$ from enteric fermentation, moderately sensitive to those for $CH_4$, $N_2O$, and $CO_2$ emissions from long-term manure

storage, and mildly sensitive to those for the amount of fuel, electricity and inorganic fertilizer used on the farm (**Rotz – ARS Pennsylvania**).

**Objective 4 –Develop science-based tools and educational materials to promote environmental stewardship in US dairy and beef industries.** (Kohn, MD; Powell, ARS, WI; Combs, UW; Harrison, WA, Fick, Cornell).

The following science-based tools were developed to promote environmental stewardship in US dairy and beef industries. A fecal phosphorus test was developed by Dou et al at the University of Pennsylvania with collaborators in New York, Pennsylvania, Maryland and Virginia. Several projects contributed to developing and testing a procedures using milk urea nitrogen (MUN) to fine tune diets.

**Fecal P test for Assessing P Overfeeeding on Dairy Farms**

Data from studies in the early 2000's suggested most of 612 surveyed farms were overfeeding P. Investigators in PA used data from feeding trials in New York, Maryland and Virginia in which different levels of P were fed. Different methods to assess feeding levels from fecal samples were developed. Laboratory studies compared effects of pH, Ca, Mg, and sample handling (e.g. wet vs. dry samples) on solubility and ability to predict overfeeding of P from the soluble P fraction. A 0.1% HCl solution was used as the extractant.

A multi-state project was carried out to test the procedure in the field. It involved 90 farms in four states over a 3-year period. Fecal, urine and feed samples were collected quarterly to determine relationship between fecal P solubility fractions to P feeding level. The study also showed that production and reproduction were not different with different CP and P concentrations in the diets.

**Milk Urea Nitrogen**

Several studies were conducted to develop a method to use analysis of Milk Urea Nitrogen (MUN) to fine tune diets. Several studies in Maryland, Pennsylvania, Wisconsin and others established a strong relationship between MUN and urinary N excretion and dietary N concentration. Excess dietary protein is typically excreted in urine, and urine N excretion (g/d) is correlated with MUN concentration (g/dl). Target values for MUN were determined to range from 8 to 11 mg/dl depending on breed and production level. Herds in Maryland, Pennsylvania and Virginia with high or low MUN were offered assistance to understand reasons for the difference from targe values. Common reasons were substitution of feeds, load cell biases, inaccurate feed analysis, or lack of recent diet formulation