Production, Management, and the Environment II

591 Global impact of improving feed efficiency and technology transfer efficacy. Robin R. White*[1,3], Todd J. Applegate[2], Gary L. Cromwell[3], Donald C. Beitz[4], Michael L. Galyean[5], Mary Beth Hall[6], Phillip S. Miller[7], Jack Odle[8], William P. Weiss[9], and Mark D. Hanigan[1], *[1]National Animal Nutrition Program, Virginia Tech, Blacksburg, VA, [2]Purdue University, West Lafayette, IN, [3]University of Kentucky, Lexington, KY, [4]Iowa State University, Ames, IA, [5]Texas Tech University, Lubbock, TX, [6]USDA/ARS, Madison, WI, [7]University of Nebraska, Lincoln, NE, [8]North Carolina State University, Raleigh, NC, [9]The Ohio State University, Columbus, OH.*

Providing protein for the expanding population is an imperative challenge to which animal nutrition research is vital. The objective of this work was to model how improving livestock feed efficiency and adoption of agricultural technologies would affect the number of people's annual protein requirements that could be met from a constant feed base. Global production data from FAOStat and occupation statistics from World Bank were collected to estimate the meat, milk and eggs (food) produced by an average farmer. Increasing feed efficiency was modeled as a % reduction in the feed required to produce 1 kg of food. Technology transfer efficiency was also accounted for. Net improvement in food produced was modeled as the sum of food produced from the proportion of farmers adopting the technology and food produced from the proportion of farmers not adopting the technology. Conversion of meat live weight to retail weight was based on dressing percentages (sheep/goat, 50%; beef, 63%; pork 70%) and a 50% conversion of dressed to retail weight. Retail milk and eggs were assumed 90% of produced weights. Protein production was calculated based on protein content. Meat protein (125 g/kg to 183 g/kg) and milk or egg protein (33 g/kg to 126 g/kg) varied by species. Protein produced by the system was divided by an average human's protein requirement (45 g/d) multiplied by 365 d. Assuming a 30% efficiency in technology transfer, a 34% improvement in feed efficiency would be required to meet the protein needs of an additional 0.5×10^9 people. A myriad of combinations of improved feed efficiency and improved technology transfer could result in sufficient protein to feed 2×10^9 people. In general, feed efficiency improvements of over 50% were required and technology transfer efficiencies between 50 and 70% greatly improved practicality of meeting the protein requirements of 2×10^9 billion people. Both biological research aimed at improving feed efficiency, and social research aimed at understanding factors influencing technology adoption rates will be required to improve global food security. Supported by USDA NIFA and State Agricultural Experiment Stations.

Key Words: food security, nutrition, feed efficiency

592 Nutrient cycling on dairy farms: Status and opportunities. Andrew Henderson[1], Ying Wang*[2], Karin Veltmank[3], and Olivier Jolliet[3], *[1]University of Texas, Houston, TX, [2]Innovation Center for US Dairy, Rosemont, IL, [3]University of Michigan, Ann Arbor, MI.*

Nutrient management represents both a challenge and opportunity to dairy and other livestock industries. Current practices may lead to lost nutrients from feed, manure, and commercial fertilizers, possibly impairing water bodies or affecting air quality. These losses may have direct economic implications for dairy farms, via possible phosphorus supply shortages [Van Vuuren et al., 2010. Glob. Environ. Change 20:428–439] or future nutrient regulation (for eutrophication or greenhouse gases). Losses also present an opportunity for improvement, if farmers can take advantage of nutrient cycling. Using a combination of literature meta-analysis and case study modeling, this research outlines and estimates the potential scale of improved nutrient cycling on dairy farm. For the meta-analysis, we compiled ~300 research articles for nutrient flows on dairy farms. We cataloged the variety of nitrogen, phosphorus, and potassium flows crossing the farm boundary (e.g., purchased feed) and internal to the farm (e.g., manure application to crops). Some flows had large coefficients of variation (CV), such as total excretion of nitrogen (CV = 2.3, n = 43) and total intake of nitrogen (CV = 2.7, n = 94). To complement this analysis, we compared modeled nutrient flows on a commercial dairy farm, using the process-based models Integrated Farm System Model [IFSM; Rotz et al., 2014; The Integrated Farm System Model (IFSM): Reference Manual Version 4.1, USDA] and ManureDNDC [Manure De-Nitrification De-Composition; Li et al., 2012. Nutr. Cycl. Agroecosys. 93:163-200]. Field N_2O emissions differed between the models (3.8–11.3 t of N_2O/yr), but other emissions predicted P and N losses to (ground)water through leaching, run-off and erosion are comparable across models. Whole-farm ammonia emissions are comparable across models (87.6 – 122.1 t NH_3/yr). The variation among farms, in the literature and modeled, represents a potential for improvement. This study compares and contrasts these variations, identifying the magnitude of potential nutrient cycling efficiencies on farm.

Key Words: dairy, nutrient cycling, environmental impact

593 Comparing climate impacts of grass-finished beef production strategies in the upper Midwest using a partial life cycle analysis. Jason E. Rowntree*[1], Rebecca Ryals[2], Marcia S. DeLonge[3], Marilia B. Chiavegato[4], W. Richard Teague[5], and Peter Byck[6], *[1]Michigan State University, East Lansing, MI, [2]University of Hawaii, Honolulu, HI, [3]Union of Concerned Scientists, Washington, DC, [4]University of São Paulo, Piracicaba, São Paulo, Brazil, [5]Texas A&M Agrilife Research, Vernon, TX, [6]Arizona State University, Tempe, AZ.*

Cattle grazing management strategies can vary widely and have important effects on ecosystem carbon storage, greenhouse gas (GHG) emissions and land requirements. Existing GHG life cycle assessments of beef production often lack refined details about grazing strategies and their associated impacts on ecosystem carbon and greenhouse gas dynamics. A partial life cycle analysis was conducted on an upper Midwest grass finishing beef production system that compared 2 different grazing management strategies. The approaches were: 1) a non-irrigated, high-density grazing system stocked at 1.0 AU/ha (100,000 kg LW/ha; SysA) and 2) an irrigated, low-density grazing system stocked at 2.5 AU/ha (30,000 kg LW/ha; SysB). Our life cycle boundary only included the grass-finishing portion of beef production. Steers were born in April, weaned in November, backgrounded for 6 mo and grazed until slaughter in November, the following year, with an average age at slaughter of 19 mo and a 295 kg HCW. We included GHG associated with enteric methane (CH_4), soil nitrous oxide and CH_4 emissions, alfalfa and mineral supplementation and farm energy use. We used 2 years of on-farm corrected data for soil and enteric emissions and animal performance from Lake City Research Center, Lake City, MI. The assumed boundaries for potential soil C loss or gain ranged from an emission of 3 Mg C/ha/yr to a positive sink of 3 Mg C/ha/yr. Enteric CH_4 emissions had the largest effect on overall GHG flux and this varied by year and grazing system. In years 2012 and 2013, enteric CH_4 was 89 and 49% of the overall flux for SysA compared with 72 and 65% for SysB, respectively. Both systems are net GHG sources when soil

C sequestration is excluded. When soil C sequestration is considered, each grazing strategy has potential to be an overall sink. These results indicate SysA and SysB would have to sequester up to 1.0 and 2.0 Mg C/ha/yr to have a net zero GHG footprint, respectively.

Key Words: grass-finished, methane, carbon

594 Predicting methane emission of dairy cows using fatty acids and volatile and non-volatile metabolites in milk. Sanne van Gastelen*[1,2], Elsa C. Antunes-Fernandes[1,3], Kasper A. Hettinga[3], and Jan Dijkstra[2], [1]*Top Institute Food and Nutrition, Wageningen, the Netherlands,* [2]*Animal Nutrition Group, Wageningen University, Wageningen, the Netherlands,* [3]*Food Quality Design Group, Wageningen University, Wageningen, the Netherlands.*

The objective of this study was to develop prediction equations for methane (CH4) emission of dairy cows using fatty acids (FA), volatile metabolites, and non-volatile metabolites in milk. Data from a randomized block design experiment with 32 multiparous Holstein Friesian cows and 4 diets was used. All diets had a roughage:concentrate ratio of 80:20 based on dry matter. Roughage consisted of grass silage only, corn silage only, or mixtures of both silages. Methane emission was measured in climate respiration chambers, and expressed per unit dry matter intake (DMI) and per unit fat- and protein-corrected milk (FPCM). Milk samples were analyzed for FA by gas chromatography, volatile metabolites by gas chromatography-mass spectrometry, and non-volatile metabolites by nuclear magnetic resonance. A multivariate model was developed using a stepwise procedure with selection of FA, volatile, and non-volatile metabolites. Only variables with $P < 0.05$ entered the model, and variables with $P < 0.10$ were retained in the final model. Multivariate analysis, using only FA (g/100g total FA), resulted in equations: CH4 (g/kg DMI) = 29.5 (±1.33) – 2.13 (±0.98) × C18:2n-6 – 5.37 (±1.31) × total CLA (adjusted R2 = 0.53), and CH4 (g/kg FPCM) = 11.7 (±2.13) + 42.7 (±7.55) × C15:0iso – 9.88 (±3.23) × C17:0 (adjusted $R^2 = 0.51$). Multivariate analysis, using FA, volatile metabolites (peak area) and non-volatile metabolites (area change), resulted in equations: CH4 (g/kg DMI) = 28.6 (±0.97) – 6.33 (±1.00) × total CLA – 6.21 (±1.65) × N-acetyl sugar + 2.46 (±0.83) × choline (adjusted R2 = 0.69), and CH4 (g/kg FPCM) = 7.2 (±2.32) + 1.23 × 10–6 (5.26 × 10–7) × 3-nonanone + 22.1 (±5.69) × C15:0iso – 205.1 (±66.21) × uridine diphosphate hexose + 62.7 (±28.17) × Unknown (adjusted R2 = 0.68). The potential of milk FA only to predict CH4 emissions was moderate. Including volatile and non-volatile metabolites enhanced the predictive power, suggesting that these metabolites, in combination with milk FA, hold potential to predict CH4 emission of dairy cows.

Key Words: methane emission, milk fatty acids, milk volatile and non-volatile metabolites

595 Methane prediction equations for beef cattle fed low forage diet. Paul Escobar-Bahamondes*[1,2], Masahito Oba[1], and Karen A. Beauchemin[2], [1]*University of Alberta, Edmonton, AB, Canada,* [2]*Agriculture and Agri-Food Canada, Lethbridge, AB, Canada.*

The goal of this study was to develop equations to predict CH_4 emissions from beef cattle fed low forage diets (≤20% DM basis) and compare their predictions with IPCC 2006. A dietary forage ≤20% DM database was constructed with treatment means from 17 beef studies published between 2000 and 2014. Criteria for inclusion in the database were: intake, diet composition and enteric CH_4 production. To overcome the limited size of the database (n = 34) each study was resampled 1,000 times using a Monte Carlo technique to create a new virtual data set. Outliers were excluded by Mahalanobis procedure. Three steps were used to obtain new equations: 1) variables associated with CH_4 production were detected by Principal Component Analysis, 2) stepwise forward multiple regression was used with the original database to obtain prediction equations with study included as a random effect using the Mixed procedure, and 3) stepwise forward regression and K-fold cross validation (n = 5) was used with the Monte Carlo data set (n = 34,000). Observed-predicted values were used to evaluate model performance using the concordance correlation (r_c) and root mean square prediction error (RMSPE, g/d). Statistical analysis was performed using JMP v.11. The best-fit equation using the original database was: CH_4 (g/d) = −26.4(±20.17) + 0.21(±0.04) × BW(kg) + 38.1(±11.83) × CP(kg/d) - 70.5(±25.48) × fat^2(kg/d) + 10.1(±5.12) × $(NDF\text{-}ADF)^3$(kg/d) with $P < 0.05$, r_c: 0.91 and RMSPE: 13.74; where BW = body weight, CP = crude protein, NDF = neutral detergent fiber, and ADF = acid detergent fiber. The best-fit Monte Carlo equation was: CH_4 (g/d) = −10.1(±0.62) + 0.21(±0.001) × BW(kg) + 0.36(±0.003) × DMI^2(kg/d) - 69.2(±1.65) × fat^3(kg/d) + 13.0(±0.45) × (CP/NDF) - 4.9(±0.07) × (starch/NDF) with $P < 0.001$, r_c: 0.92 and RMSPE: 12.6 where DMI = dry matter intake. These new prediction equations had greater r_c and lower RMSPE than IPCC 2006 (r_c:0.29; RMSPE:43.2), indicating greater prediction accuracy. Using the Monte Carlo equation data set improved accuracy of prediction compared with the original equation database. Both equations specifically developed for cattle fed low forage diets increase the accuracy of predicting CH_4 emissions compared with IPCC (2006).

Key Words: methane, beef cattle, equation

596 Evaluating extant empirical models for predicting enteric methane emissions from lactating dairy cows. J. A. D. R. N. Appuhamy* and E. Kebreab, *Department of Animal Science, University of California, Davis, CA.*

Empirical models are widely used to estimate enteric methane (CH_4) emissions from dairy cows worldwide. The objective of this study was to evaluate extant models for predicting CH_4 emissions from dairy cows using literature data. Thirty-nine extant models developed based on dairy cow data were evaluated using measurements from 47 studies published after 2000. The data containing dietary, production and animal information included 50, 83, and 41 enteric CH_4 measurements of lactating dairy cows from North America (NA), Europe (EU), and Australia and New Zealand (AUNZ), respectively. The models were evaluated using root mean square prediction error (RMSPE), concordance correlation coefficient, and Nash-Sutcliffe efficiency statistics. An index including equally weighted statistics was used to rank the models within each region. For NA, the 5 top ranked models were those by Hristov et al. (2013), Moe and Tyrrell (1979), Ellis et al. (2007), Moraes et al. (2014), and Moate et al. (2011) [Ref 1–5, respectively, in Table 1] and had RMSPE 15–17% of the average observed value. The majority of the best performing models in NA were developed on data from NA cows. A completely different Set of models performed best on both EU (RMSPE = 11–13%) and AUNZ (RMSPE = 11–15%) data. The best performing models were those by FAO (2010), IPCC (1997), Storlien et al. (2014), Yan et al. (2000), and Nielsen et al. (2014) [Ref I–V respectively in Table 1]. Regional origin and perhaps diet type of the data on which models have been developed need to be considered when selecting a model to predict CH_4 emissions successfully.

Table 1 (Abstr. 596). Top ranked models for predicting enteric CH_4 (MJ/cow/d) emissions[1]

NA	Ref	EU and AUNZ	Ref
= [2.54 + 19.14 × DMI] × 0.05565	1	(0.0975 – 0.0005 × DMd) × GEI	I
= 3.14 + 0.51 × NSC + 1.74 × HC + 2.65 × C	2	0.065 × GEI	II
= 4.08 + 0.068 × MEI	3	1.47 + 1.28 × DMI	III
= –9.311 + 0.042 × GEI + 0.094 × NDF% – 0.381 × FA% + 0.008 × BW + 1.621 × MilkF	4	3.234 + 0.0547 × GEI	IV
= [exp(3.15 – 0.0035 × FA)] × DMI × 0.05565	5	1.26 × DMI	V

[1]DMI, NSC, HC = hemicellulose, C =cellulose (all in kg/d), FA and FA%= dietary fat (g/kg of DM and % of DM), DMd = diet DM digestibility (%), GEI and MEI = gross and metabolizable energy intake (MJ/d), NDF% (% of DM), BW (kg), MilkF = milk fat %.

597 Comparison between the GreenFeed system and the sulfur hexafluoride tracer technique for measuring enteric methane emissions from dairy cows. Joonpyo Oh*[1], Fabio Giallongo[1], Tyler Frederick[1], Mike T. Harper[1], Holley Weeks[1], Antonio F. Branco[2], Alexander N. Hristov[1], William J. Price[3], Peter J. Moate[4], Matthew H. Deighton[4], S. Richard O. Williams[4], Maik Kindermann[5], and Stephane Duval[6], *[1]The Pennsylvania State University, University Park, PA, [2]Universidade Estadual de Maringá, Maringá, Paraná, Brazil, [3]University of Idaho, Moscow, ID, [4]Agriculture Research Division, Ellinbank Centre, Ellinbank, Victoria, Australia, [5]DSM Nutritional Products, Base, Switzerland, [6]DSM Nutritional Products France, Saint Louis Cedex, France.*

The objective of this study was to compare 2 commonly used techniques for measuring CH_4 emissions from ruminant animals, the GreenFeed (GF) system and the sulfur hexafluoride (SF_6) technique. The study was part of a larger experiment, in which a CH_4 inhibitor, 3-nitrooxypropanol (3NOP), fed at 4 application rates (0, 40, 60, and 80 mg/kg feed DM) decreased enteric CH_4 emission by 25 to 32% in a 12-wk experiment with 48 lactating Holstein cows. The larger experiment used a randomized block design and was conducted in 2 phases (Feb-May, phase 1 and Jun-Aug, phase 2), with 24 cows in each phase. Methane emissions using GF were measured during experimental wk 2, 6, 9, and 12. During each GF measurement, 8 spot samples of gas emissions were collected from each cow, staggered over a 3-d period (a total of 0.67 h/cow). Emission data using the SF_6 technique were collected for 3, 24 h periods (a total of 77 h/cow) during wk 2, 6 or 9, and 12. An outlier analysis removed 1 observation from the GF data set (1,271 observations) and 6 observations from the SF6 data set (451 observations). Methane yield data (g/kg DMI) were averaged per cow for the statistical analysis. The mean CH_4 yield, SD, lower and upper 95% CL, CV, and min and max values for the GF data set were (g CH_4/kg DMI or as indicated): 12.8, 3.63, 12.8 and 13.9, 27.2% (18.1 and 21.2%; control and 3NOP cows, respectively), and 6.7 and 26.4. For the SF6 data set these values were: 14.7, 5.60, 14.7 and 17.0, 35.3% (30.4 and 29.9%, control and 3NOP cows), and 7.2 and 36.5. Data were analyzed within experimental phase, sampling week, and treatment to compare CH_4 yield between GF and SF_6. The difference between the 2 methods (SF_6 – GF) within treatment was 1.9 to 4.1 g CH_4/kg DMI ($P < 0.001$ to 0.06) for phase 1 and 1.1 to 2.4 g/kg DMI ($P = 0.06$ to 0.38) for phase 2. In the conditions of this experiment, the SF_6 technique produced larger variability in CH_4 yield than the GF method. The difference between the 2 methods was not consistent over time, perhaps influenced by barn ventilation and background CH_4 and SF_6 concentrations.

Key Words: methane, GreenFeed, sulfur hexafluoride

598 Breed and lactation stage affect rumen methanogens in co-housed primiparous dairy cattle. L. M. Cersosimo*[1], M. Bainbridge[1], J. Kraft[1], and A.-D. G. Wright[2], *[1]University of Vermont, Burlington, VT, [2]University of Arizona, Tucson, AZ.*

Rumen methanogens are anaerobic, methane-producing archaea that decrease feed efficiency in dairy cattle and contribute to global warming. The objective of this study was to determine if breed or lactation stage affect the rumen methanogen diversity and density. Seven Holstein (H), 8 Jersey (J), and 7 Holstein-Jersey crossbreeds (X) were co-housed in a free stall on a total mixed ration, and whole rumen digesta samples were collected at 3, 93, 183, and 273 d in milk (DIM). To determine the methanogen diversity, the V1-V3 region of the 16S rRNA gene was amplified. Sequences were generated using Illumina MiSeq v.3 and all bioinformatics analyses were performed using Mothur. Real-time PCR amplified the methanogen-specific mcrA gene and the mcrA copy numbers per mL rumen digesta were calculated. Data were analyzed using PROC MIXED in SAS. The model included the effects of breed (B), lactation stage (LS), and B x LS. A total of 1,683,569 16S sequence reads were classified to species-level taxa by B and LS. The *Methanobrevibacter* (*Mbr.*) *smithii-gottschalkii-millerae-thaueri* and *Mbr. ruminantium-olleyae* clades did not differ. Notably, the mean % abundance of the species *Mbr. thaueri* differed ($P < 0.01$) by LS. At 93 DIM, *Mbr. thaueri* abundance was higher in J (35.0%) compared with both H (24.5%, $P < 0.05$) and X (19.4%, $P < 0.01$), while no significance was observed at 183 and 273 DIM, respectively. Differences by LS were seen in less abundant species (<5%), *Mbr. woesei* ($P < 0.001$), *gottschalkii* ($P < 0.05$), *millerae* ($P < 0.05$), and *Methanosphaera stadtmanae* ($P < 0.01$). The top operational taxonomic units (OTU) from a 2% cutoff were related to *Mbr. smithii*, *Mbr. thaueri*, *Mbr. ruminantium*, and *Mbr. millerae*. There were no differences in methanogen density, the number of OTUs (18–37 per breed), or Shannon and Inverse Simpson indices. Chao values differed by LS ($P < 0.01$). Our data suggest that LS may have had a greater effect on the methanogen diversity than B and that core rumen methanogens persist over a lactation period.

Key Words: archaea, diversity, *Mbr. thaueri*

599 Aerodynamic design of a TMR feed bin to measure gaseous emissions from cattle. Scott Zimmerman*[1], John Roche[2], and Pat Zimmerman[1], *[1]C-Lock Inc., Rapid City, SD, [2]Dairy NZ, Hamilton, New Zealand.*

The need to measure methane (CH_4) and carbon dioxide (CO_2) emissions from cattle in production environments is increasing. Previously, CH_4 and CO_2 emissions have been accurately measured for short-term repeated periods using a supplemental feeding station (GreenFeed, C-Lock Inc.). Considering the interest in residual feed intake, there is an opportunity to combine the measurement of feed intake with the

measurement of CH_4, by incorporating this technology into a TMR-feeder. To do this effectively, it is necessary to design a feed bin that has desirable airflow characteristics, that ensure a high capture of emitted gasses and produces a fast response time to emitted gasses. The purpose of this study was to design a TMR feeder with optimal airflow characteristics. A TMR bin, 92 × 92 × 81 cm was constructed (dead-volume = 710 L). An opening for the cow's head of 30 × 6 cm was made and the lid was sealed. Bin dimensions enabled adequate TMR to be offered, while allowing the cow to reach all corners. Airflow was extracted from the bin at a rate of 45 L/s using a fan. From the outlet gas, CO_2 concentrations were measured. Artificial smoke was used to visualize flow patterns inside the TMR bin and results were recorded on video. Separately, CO_2 gas was injected into the TMR bin at 7 g/min until the system reached equilibrium, at which point the CO_2 was removed. The T-90 equilibrium time of CO_2 disappearance was analyzed. Three gas extraction methods were tested: (m1) a 10-cm-diameter circular outlet, (m2) a manifold with 36 evenly spaced 1.27-cm-diameter holes in only the upper half of the bin, (m3) a manifold with 72 evenly spaced 1.27-cm-diameter holes throughout the bin. There was no observed sample loss from the head opening with any outlet configuration. However, m2 and m3 produced a significantly longer T-90 equilibrium time compared with m1 (24, 33, and 66 s, respectively). The multiple air outlets in m2 and m3 produced improved airflow characteristics. Although m3 produced the fastest equilibrium time, the air holes at the bottom of the bin could become plugged with TMR; therefore, manifold 2 is likely the optimal option. In conclusion, a well-designed TMR bin can produce acceptable airflow characteristics for the measurement of gaseous emissions from cattle while they are feeding.

Key Words: methane, emissions, cattle

600 Predicting nitrogen excretion from lactating dairy cattle.
Kristan F. Reed*[1], Luis E. Moraes[1], Alexa Johnson[1], David P. Casper[2], and Ermias Kebreab[1], [1]*University of California, Davis, Davis, CA,* [2]*South Dakota State University, Brookings, SD.*

A genetic algorithm was implemented to select models to predict fecal, urinary, and total manure nitrogen (N) excretion by lactating dairy cows. Akaike's Information Criterion was used as the criteria for model selection. Data for model development consisted of 1,047 indirect calorimetry observations on lactating cows collected at the USDA's Energy and Metabolism laboratory from 1963 to 1995. Two tiers of model classes based on model input requirements were developed resulting in 6 models. Tier 1 selects a single covariate model to estimate N excretion and the Tier 2 selects models from many potential dietary and animal covariates including BW, DIM, CP, NDF, ash content, and proportion of concentrate in the diet. Animal and study were designated as cross-classified random effects and the final selected mixed models were fit using restricted maximum likelihood in R statistical software with the lme4 package. The root mean square prediction error (RMSPE) was used to evaluate the models in 3 ways: (1) K-fold cross validation based on all data, (2) evaluation with the most recent 6 years of data, and (3) evaluation with N balance data collected from literature published from 1996 to 2014. The number of published studies reporting covariates required for tier 2 models was not sufficient for model evaluation. Results listed in Table 1 for tier 1 models show better prediction for total manure N and fecal N compared with urinary N excretion. Tier 2 models had lower RMSPE than Tier 1 models across all forms of excretion.

Table 1 (Abstr. 600). Model selection and evaluation reported in the RMSPE (% mean N excretion); parameter estimates with standard errors in parentheses

Model estimates	USDA cross-validation	USDA 1990-1995	Literature data 1995-2014
UN = 12.0(5.80) + 0.333(0.0106) × NI	23.7	12.7	23.8
FN = −18.5(3.59) + 10.1(0.169) × DMI	12.6	18.2	16.2
TN = 20.3(4.72) + 0.654(0.00926) × NI	9.80	8.14	10.8

UN = urine nitrogen, FN = fecal nitrogen, TN = total manure nitrogen, NI = nitrogen intake (g/d).

Key Words: dairy, nitrogen, prediction

601 Checks and balances: Evaluating reliability of dairy nutrient management data to better protect groundwater resources.
Christine Miller* and Deanne Meyer, *University of California, Davis, Davis, CA.*

To protect groundwater from further nitrate contamination, California regulations require dairy farmers to follow a strict nutrient management plan. The regulations require copious annual reporting of crop field management, farm infrastructure, and animal population. The data collected in these annual reports could be integral to evaluating and improving both farm practices and the regulations themselves. The objectives of this project were to (1) assess the reliability and accuracy of annual report data to allow the information to be used responsibly and (2) to suggest promising methods of improving data quality. Annual reports from 18 dairies were obtained to assess data reliability. Mass balance calculations were preformed to check the self-consistency of data within a facility. The results of mass balance calculations show that the annual reports do not account for a remarkably large percentage of the nutrients being produced on the farms. Literature suggests that over 60% of nitrogen (N) and 90% of phosphorus (P) should be recovered; however, a median of only 25% of both N and P in cattle manure was recovered based on annual reports. This could be due to many different causes including inaccurate nutrient sampling and analysis techniques or fraudulent reporting. It is likely that the sampling and analysis methods are a significant source of error because the accuracy of the majority of the protocols has not been assessed. The results of this study have led to projects that should improve data collection protocols in both the short and long-term. In the short term, online decision trees are being developed in collaboration with extension agents and consultants to help farmers self-assess their current data collection practices, and provide personalized suggestions for improvement. Suggestions are currently based on the recommendations of experts, but will be improved in the long term using a statistical modeling approach paried with field experiments to examine the uncertainty in each of the recommended protocols. With more reliable data, we can identify regulations and management practices that are more protective of groundwater quality.

Key Words: dairy waste management, nitrate leaching

602 Economic and environmental implications of wheat crop rotations on organic dairy farms. D. C. Abreu*[1,3], A. K. Hoshide[2], E. B. Mallory[2], A. S. Oliveira[1], R. J. Kersbergen[2], R. P. Lana[3], and C. P. Ghedini[4], [1]*Universidade Federal de Mato Grosso, Sinop, MT, Brazil,* [2]*University of Maine, Orono, ME,* [3]*Universidade Federal de Viçosa, Viçosa, MG, Brazil,* [4]*University of New Hampshire, Durham, NH.*

Our objective was to determine the sustainability for 8 crop rotation sequences of 3-yr rotations in a long-term (25-yr) well-managed organic dairy farm in Maine. A medium-sized organic dairy farm was simulated with the Integrated Farm System Model (version 3.6) to evaluate crop rotation (management) effects on crop performance, environmental impacts and profitability. The 9 cropping strategies included continuous ryegrass/red clover (continuous grass), corn harvested early followed by winter wheat (corn-wwheat-grass), corn followed by spring wheat (corn-swheat-grass), ryegrass/red clover rotated with winter wheat (grass-wwheat-grass), ryegrass/red clover in rotation with spring wheat (grass-swheat-grass), soybean rotated with both winter wheat (soybean-wwheat-grass) and spring wheat (soybean-swheat-grass), corn double cropped (corn-corn-grass) and soybean followed by corn (soybean-corn-grass). Wheat was harvested as a cash crop in all simulated years and sold at an organic premium price. All rotations were in long rotation with perennial ryegrass/red clover over the 3 yr period. When the continuous grass-based system was simulated, farm net return was higher ($742.15/cow). Under crop rotation, the option of growing and selling winter wheat instead of spring wheat improved farm profitability when the results were compared with other wheat cropping rotations. The higher winter wheat yields for soybean-wwheat-grass resulted in 7% more income from feed sales ($1,027) and 1% more in total revenue ($1,065). Also, winter wheat should be encouraged to reduce soil nutrient accumulation, particularly soybean replaced with cash crop wheat (soybean-wwheat-grass). Here the major reductions in nutrient flows were a 0.8 kg/ha/yr decrease in both P runoff and leachate losses and K accumulation (−17%); there was also a 4% reduction in water footprint (kg/kg FPCM). Use of corn harvested as silage in place of grass or/and soybean in the first year or winter/spring wheat in the second year provided relatively less profitability to the farm. In general, there were lower economic and more favorable environmental benefits to shifting land from continuous grass-based production to specified small grain cropping rotations.

Key Words: dairy, wheat, integrated farm system model