A NEW TOOL FOR ESTIMATING PHOSPHOURS LOSS FROM CATTLE BARNYARDS AND OUTDOOR LOTS

Peter Vadas[1], Laura Good[2], John Panuska[2], Dennis Busch[3], and Rebecca Larson[4]

Introduction

Agricultural nutrient management continues to be an important area of research and policy due to concerns of phosphorus (P) loss in runoff and water quality impacts. For dairy and beef farms, outdoor cattle lots (feedlots, barnyards, exercise lots, over-wintering lots) can be significant sources of P loss (Koelsch et al., 2006). There is a need to assess P loss from lots, especially relative to other farm areas (cropland, pastures), to see if alternative lot management is needed and cost-effective. Computer models can be effective tools to help quantify P loss from cattle lots. Despite quite a bit of physical monitoring research on P loss from lots since the 1970's, there has been little development of models to predict P loss from these areas. To our knowledge, the only two examples of runoff and P loss models for cattle lots are in the AGNPS model (Young et al., 1989) and the APEX model (Gassman et al., 2010; Williams et al., 2006). Barnyard runoff models such as BARNY in Wisconsin and MinnFarm in Minnesota use the same approach as AGNPS. Both AGNPS and APEX have had only minimal testing for P loss from lots (Kizil et al., 2006; Williams et al., 2006), so it is not clear if they are reliable across a range of cattle lot managements, conditions, and locations. Our objectives were to:

1. Develop a relatively simple, annual model to estimate P loss in runoff from cattle lots
2. Test the model with data available in the published literature
3. Compare the new model to BARNY and MinnFarm.

The name of our new model is **APLE-Lots**. A flow chart of **APLE-Lots** is shown in Figure 1. The goal of the model is to estimate annual dissolved and solids-bound P loss from lots. **APLE-Lots** is intended to be user-friendly and does not require extensive input data to operate. All data are input directly into a spreadsheet (available to download at: http://www.ars.usda.gov/Services/docs.htm?docid=25452). User-input data include:

- Soil test P for earthen lots
- Area of the lot
- Annual precipitation for the lot location
- Number and type of cattle in the lot, including beef cattle and calves, dairy lactating and dry cows, and dairy heifers and calves.
- Number of days between lot cleanouts.
- Surface type (paved or earthen), and the % vegetative cover for earthen lots.

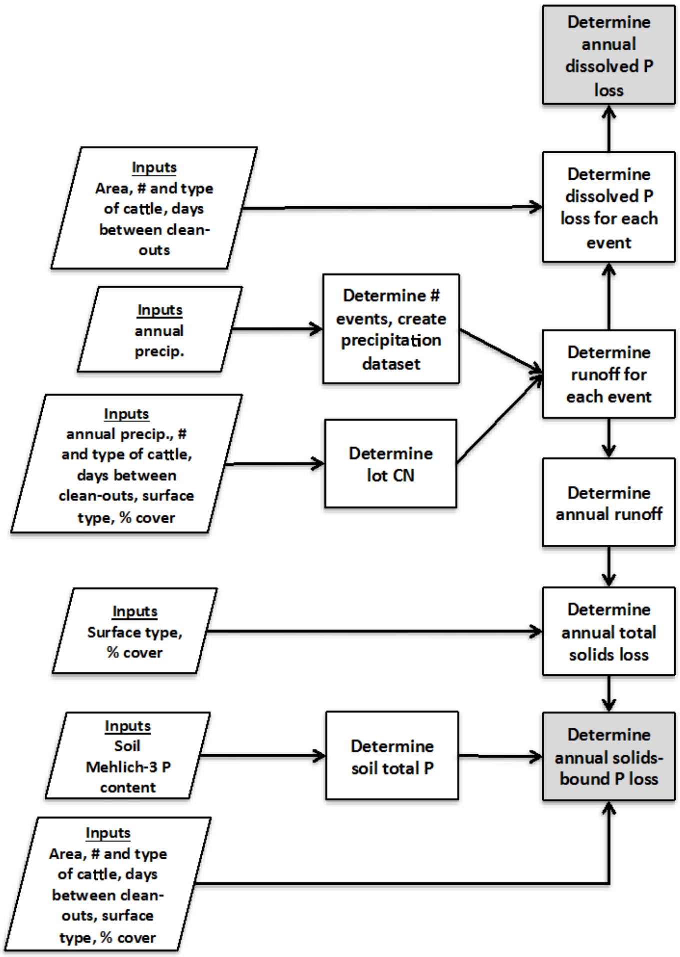

Figure 1. Flow chart of the **APLE-Lots** model.

Annual Runoff Estimation

APLE-Lots estimates annual runoff using the NRCS Curve Number (CN) approach. The method requires a dataset of annual precipitation events, for which runoff is estimated for each event and summed for annual runoff. For a precipitation dataset for a given location, the model estimates an appropriate number of precipitation events during a year and a precipitation amount for each event. As annual precipitation increases, both the number of annual events and the precipitation per event increase. For example, drier regions are less likely to have large events compared to wetter regions. In the model, a location with 100 cm of annual precipitation would have a maximum event size of 6.0 cm, whereas a location with 25 cm of annual precipitation would have a maximum event size of 3.3 cm.

With a precipitation dataset calculated, the model then determines a CN value to use to calculate runoff for each event. The model uses different relationships for different lot surfaces. The model allows the CN for only paved lots to increase up to a maximum of 99 based on the percentage of the lot covered by manure. For example, as lot coverage decreases due to low cattle density or frequent cleaning, CN can increase up to a maximum of 99. The increase is in direct proportion the percent of the total lot area covered. The logic is that paved lots with more manure have a more uneven surface that can hold water and thus have less runoff. Finally, research has shown that increasing vegetative cover can decrease runoff amounts. Accordingly for earthen lots, CN and runoff will decrease as vegetation increases.

Annual Total Solids Loss Estimation

The model estimates annual eroded solids loss from a cattle lot as a function of how much runoff water moves across the surface. For earthen lots, the model also allows total solids loss to fluctuate down to a minimal amount based on % vegetative cover of the lot. There is a non-linear relationship between runoff and total solids loss, which is logical because greater runoff volumes are likely due to a greater occurrence of larger storms, which may generate more sediment transport. The model adjusts solids loss for paved cattle lots that have manure consistently removed by cleaning because such lots have less manure on the surface and therefore less manure solids loss in runoff. For example, if a lot is cleaned once per week, and only 23% of the total lot area is covered in a week, annual solids loss is reduced by multiplying by 0.23.

Annual Solids-bound and Dissolved P Loss Estimation

In the model, annual solid P loss is determined by multiplying annual solids loss by solids P content. For paved or concrete lots, the dominant source of eroded solids is cattle manure; and the eroded solids P content is the same as manure P content. The model estimates manure P content based on information about the type and number of cattle on the lot, and cattle type, daily manure production, and manure P content. On earthen lots, both manure and soil are sources of solids P loss, and the P content of eroded solids is generally less than the P content of manure. Thus for earthen lots, the model assumes eroded solids is 30% from manure and 70% from soil. The model then calculates eroded solids P content based on manure P content, soil P content, and the 30/70 ratio. The model also allows this 30/70 ratio to fluctuate to account for the lot area covered by manure. For example, if manure covers 50% of the lot area, the ratio is 15/85. At 75% manure coverage, the ratio is 25.5/74.5.

For dissolved P loss estimation, the model estimates how much P is released from manure during a precipitation event. Then, an estimate is made of how much of that released P infiltrates into soil and how much is lost in runoff. The model then sums the estimates of runoff dissolved P for all runoff events in the precipitation dataset to estimate annual loss of dissolved P from manure on the lot surface.

Model Testing

We tested the model with lot runoff monitoring data from the scientific literature to see how well it estimates runoff, solids loss, and P loss. Figure 2 shows results for model testing for annual runoff, Figure 3 for annual solids loss, Figure 4 for annual total P loss, and Figure 5 for annual dissolved P loss.

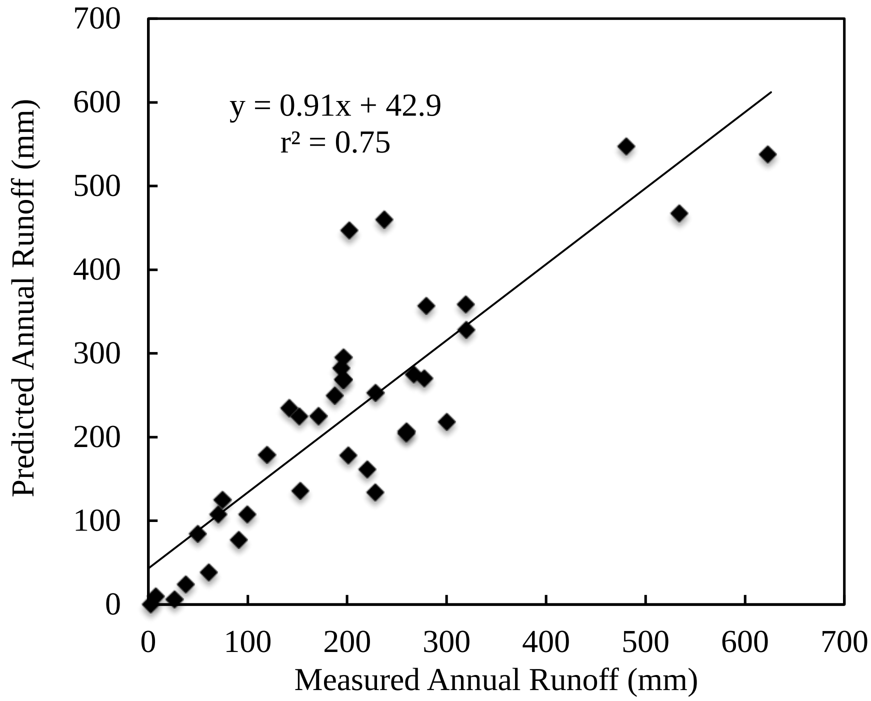

Figure 2. Data from 12 studies showing the relationship between measured annual runoff from cattle lots and predicted runoff using the new model.

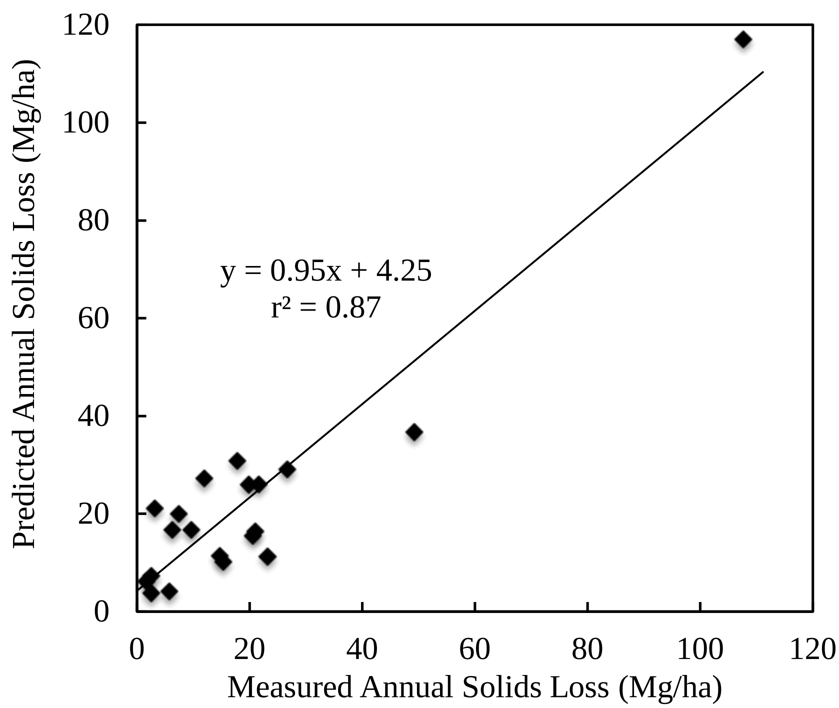

Figure 3. Data from 5 studies showing the relationship between measured annual total solids loss from cattle lots and predicted solids loss using the new model.

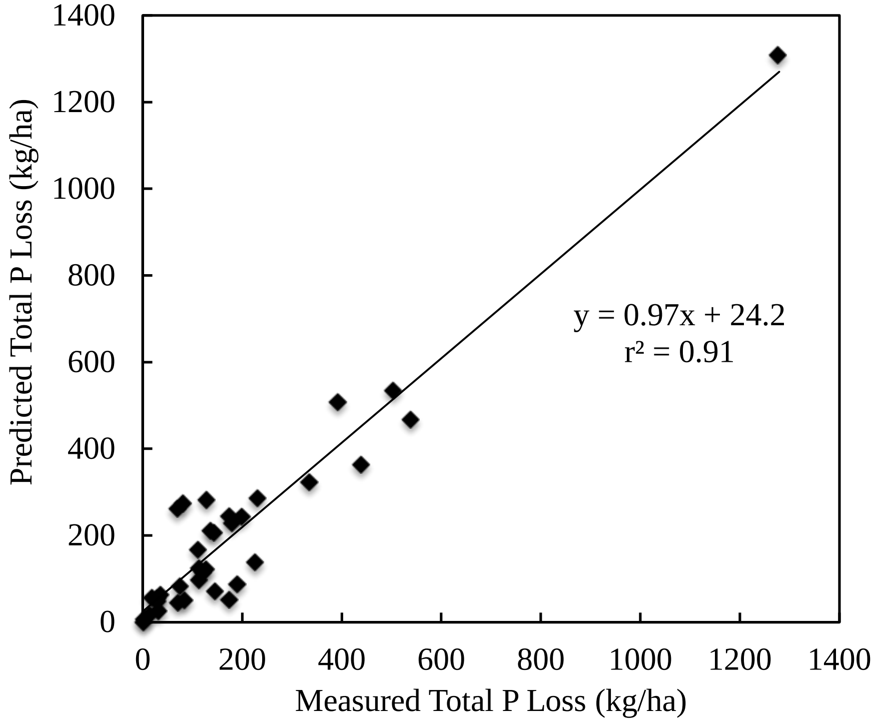

Figure 4. Data from 12 studies showing the relationship between measured annual total P loss from cattle lots and predicted total P loss using the new model.

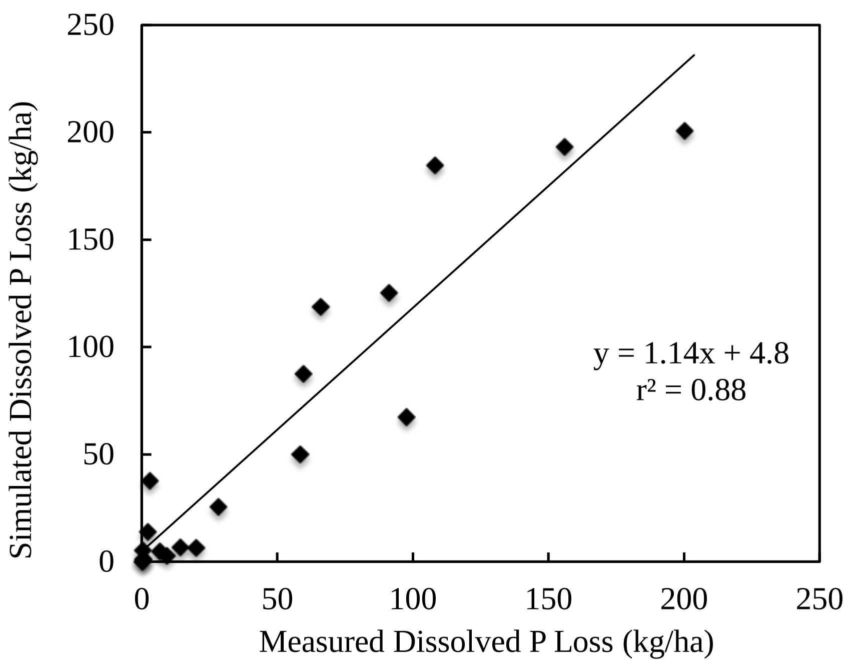

Figure 5. Data from 12 studies showing the relationship between measured annual dissolved P loss from cattle lots and predicted dissolved P loss using the new model.

Model Comparison with BARNY and MinnFarm

We compared the performance of BARNY and MinnFarm with that of our new barnyard and feedlot P runoff model using data from the same 12 studies cited above that measured total P loss from barnyards and feedlots (Table 1).

Table 1. Regression results for measured and predicted total P loss (kg ha^{-1}) from barnyards and feedlots for the BARNY and MinnFarm models.

Model	Regression Equation	r^2
BARNY	Predicted TP = 0.42 (Measured TP) + 56.19	0.73
MinnFarm	Predicted TP = 0.40 (Measured TP) + 41.32	0.71

Results for both models were similar, which is expected since they are based on the same prediction approach. The regression between measured and predicted P loss was strong for both models, suggesting that the models can reasonably simulate the relative difference in P loss between different types of lots, managements, and runoff amounts. However, the regressions were not as strong as our new lot P model (r^2 of 0.91), the slopes of the regression equations were significantly less than 1.0, and while the intercepts were not significantly different from 0.0, they were greater than the intercept for our new P runoff model (Figure 4). Based on the data used, results show that BARNY and MinnFarm over-predicted at low observed rates of P loss, and under-predicted at high rates of P loss. These trends are because BARNY and MinnFarm use a constant concentration of runoff total P (85 mg/L) to estimate total P loss. This constant under-predicts at high rates of P loss, and over-predicts at low rates of loss. In contrast, our new lot P runoff model predicted lot P loss more reliably across a wide range of measured loss rates. Thus, the new model provided a more robust, dynamic simulation of P loss for a variety of lot types, lot management, and climate.

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