ASSESSING THE BENEFITS AND COSTS OF COVER CROPPING IN PA USING A MODEL-BASED APPROACH

Pennsylvania is literally losing tons of soil and nutrients every year from its watersheds. Cover crops have the potential to reduce this problem and help meet the EPA Total Maximum Daily Load (TMDL) goals, enhance local water quality and protect the Chesapeake Bay. This document summarizes potential benefits of utilizing cover cropping as a best management practice (BMP) for various types of dairy operations in Mifflin County, Pennsylvania. A model-based approach was used to estimate the costs to these farms and the impact on sediment and nutrient losses. While the model was developed on the basis of farm types typically found in Mifflin County, the results are applicable across much of Pennsylvania and the mid-Atlantic region.

WHAT ARE COVER CROPS?

A cover crop is defined as a close-growing species that is planted to provide soil improvements and protection from erosion between periods of normal crop production. They can also provide weed suppression and habitat for mutually beneficial organisms. Performing an important role in modern agriculture, cover crops often increase row crop productivity (corn grain and soybeans) by improving the soil's physical, biological, and chemical properties (Fageria et al. 2007). Winter cereal cover crops such as wheat or rye are commonly planted in rotation with row crops in an effort to reduce nutrient and sediment losses. In short, planting cover crops can be an effective approach to protecting and enhancing soil health and long-term profitability.

FIGURE 1: EXAMPLE OF A COVER CROP IN A DOUBLE-CROP ROTATION WITH CORN

HOW DO COVER CROPS PROTECT SOIL AND WATER?

Cover crops provide both protective vegetative cover and roots that protect and enhance the soil in many ways. The vegetation protects the soil from raindrop impact, reducing erosion and nutrient runoff. The cover crop helps to keep the soil cool during the hot summer months. Root tunnels formed from the cover crop allow row crops to extend their roots deeper into the soil, adding organic matter and nutrients to the soil. Legume species, such as crimson clover, are also used as cover crops for their ability to convert inert nitrogen gas into plant available nitrogen. Their use is beneficial on soils where there is a nitrogen deficiency because they reduce the need for added fertilizer or manure. Cover crops also aid in promoting soil and water health by reducing runoff, erosion, and nutrient loss by providing ground cover to what would otherwise be vulnerable, bare soil.

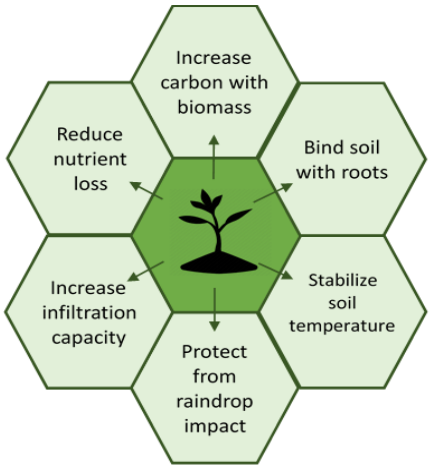

FIGURE 2: SOIL BENEFITS PROVIDED BY COVER CROPS

MODEL SCENARIO DETAILS

The Integrated Farm System Model (IFSM version 4.5) (Rotz et al. 2015) is a farm-scale model that connects the major physical, chemical and biological processes in a farm operation. The user can assess the whole-farm impact of management and technology changes. Four dairy operations representative of Mifflin County were simulated using IFSM over 26 years (daily weather data for Lewistown, PA from 1990-2015), with results given as average annual values. The four dairy operations we simulated were: confined housing for 150 animals, semi-confined housing for 100 animals, grazing system with 50 animals, and an Amish dairy with 35 animals. The size of the operation reflects the number of mature cows and includes both lactating and dry Holstein cows. Production of replacement heifers was also included on the farm with between 0.2 to 0.4 heifers produced per cow varying by farm type.

Farm-level, environmental and economic impacts of cover cropping were evaluated using two IFSM simulation scenarios on each of the four farm types. **Scenario 1:** corn silage (*Zea mays* with a maturity index of 115-120 days) fields were left untouched after harvest and provided little to no ground cover (tillage and manure treatments varied by farm type). **Scenario 2:** a cereal rye (*Secale cereal L.*) cover crop was planted (at a rate of 2 bu/ac) into all corn silage fields, immediately after the September corn-silage harvest, and was mechanically killed in the spring just prior to corn planting and left on the soil surface to decompose. Cereal rye was modeled with a seed cost of $24 per acre.

FIGURE 3: COMPARISON OF A COVER CROP (LEFT) VS. BARE SOIL (RIGHT)

The IFSM results showed reductions in all three parameters we analyzed – nitrogen (N) runoff, sediment bound phosphorus (P) loss, and sediment loss with the use of a cover crop (scenario 2) (Figure 4). Farms with less grassland and more land in row-crop production observed greater benefits and larger reductions with the use of a cover crop, while farms with more land as perennial grassland (semi-confined 100 and grazing 50) achieved smaller nutrient and sediment loss reductions. While the tillage systems and land use (Table 1) varied by farm type, the goal of the research is to observe the changes within a farm system due to the addition of a cover crop.

TABLE 1: TILLAGE SYSTEM AND ACREAGE OF TILLED LAND USE BY FARM TYPE

	Tillage System	Tillable Area (acre)				
Farm Type		**Corn**	**Grass**	**Alfalfa**	**Total**	**% Grassland**
Confined 150	Disk + Cultivator	222	74	74	371	20%
Semi-Confined 100	No Till	62	89	37	188	47%
Grazing 50	Full Till	12	74	32	119	62%
Amish 35	Full Till	18	12	17	48	26%

MODEL RESULTS

Of the parameters we analyzed, sediment loss was impacted the most by cover crops. Operations that maximized row crop production (confined 150 and Amish 35) saw reductions in erosion ranging from 44 - 62 percent, while operations that utilized more land for perennial grassland saw reductions ranging from 23 – 30 percent (smaller reductions were due to lower initial loss rates).

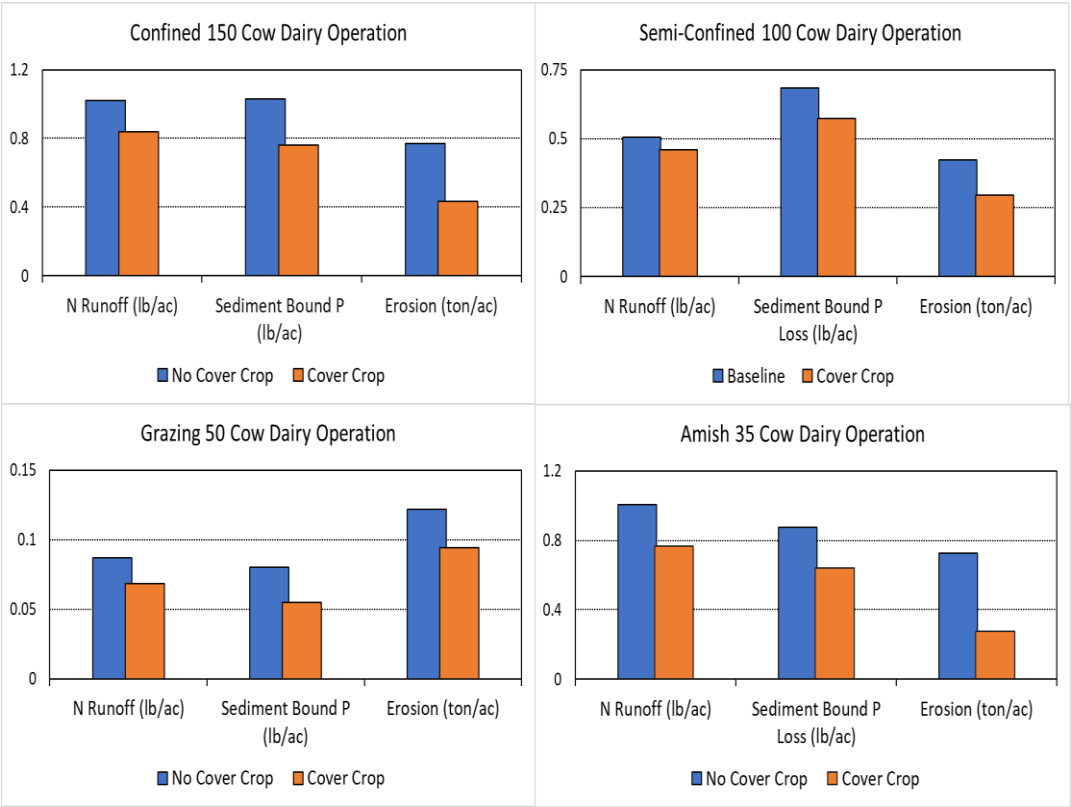

FIGURE 4: ANALYSIS OF N, P AND EROSION LOSS WITH AND WITHOUT THE USE OF COVER CROPS

To summarize these results, operations that heavily use row crop production will see greater benefits with the addition of cover cropping as the initial rates of N, P and sediment loss will be greater than operations that keep their tillable land in perennial grass rotation.

It is important to consider the effects cover crops have on the corn silage yields. Figure 5 shows the comparison of corn silage yields before and after the use of cover crop for each farm type. Changes in yields were less than six percent, with three of the farms seeing a one to five percent increase in yield.

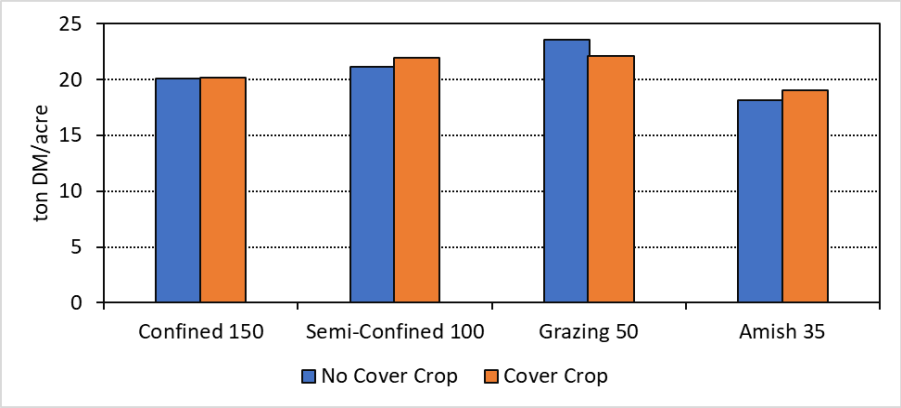

FIGURE 5: CORN SILAGE YIELD (TONS/ARE) COMPARISON BEFORE AND AFTER COVER CROPS ACROSS THE FOUR FARM TYPES

The slight increase in yields is likely attributed to the improved nutrient use as a result of the cover crop residue being mulched and left to decompose on the soil surface. The decomposition of the rye acts as a slow-release fertilizer, supplementing the corn's nutrient requirements.

WHAT DOES COVER CROPPING COST TO IMPLEMENT?

One important metric to consider is the cost of cover cropping per acre on a farm. The cover cropping costs represent the summation of labor, machinery repairs, fuel consumption, and seed purchased on a per acre basis. IFSM was used to generate annual average cover cropping costs (Table 2) over a 25-year period. The confined 150 cow operation saw a higher cover cropping cost compared to the other three farms due to larger and more expensive equipment being used. In general, costs may vary due to equipment size and condition, tillage methods, fuel prices, and labor costs.

TABLE 2: ANNUAL COSTS ASSOCIATED WITH COVER CROPPING ($/ACRE)

	Labor	Repairs	Fuel	Seed	Total
Confined 150	5.71	9.13	5.88	24.00	44.72
Semi-Confined 100	2.40	1.99	3.23	24.00	31.63
Grazing 50	2.67	2.22	3.76	24.00	32.65
Amish 35	0.00	3.93	4.54	24.00	32.47

ADDITIONAL BENEFITS

There are additional ecologically and economically benefits of cover crops, not represented by these model scenarios. In addition to improved nutrient use, cover crops can prevent weeds from germinating or becoming too large to control and can be utilized as a livestock forage in the case of double-cropping). (To double-crop, the producers plant a cover crop in the fall after row-crop harvest and remove the cover crop forage in the spring as silage). Cover crop can also be used to graze livestock thereby reducing purchased feed costs. There are also ecological benefits of cover crops that provide long-term benefits such as the continual addition of organic matter, drought resilience, improved nutrient use, and crop diversity – all of which help the producer improve soil and water quality over time, maintain productive soil and achieve higher yields in the long-run (Fageria et al. 2007).

PennState College of Agricultural Sciences

WATER for AGRICULTURE

SUMMARY

Cover cropping is a strategy that producers can use to conserve soil, nutrients and improve soil and water quality, and has been encouraged within the Chesapeake Bay Watershed to help meet the TMDL goals. The results from IFSM showed a reduction in N, P and sediment loss with cereal rye cover cropped on corn silage acreage. The cover crop caused minimal variability in production costs for all farm scenarios. The fluctuation in total production costs, either positive or negative, was less than two percent. There are additional benefits of cover crops not represented in the data shown, such as double-cropping corn silage and cereal rye to utilize the small grain forage as silage and thus reducing feed costs. There are long term benefits as well, that while not seen immediately, ultimately lead to healthier and more productive soils.

Developed by: **Ryan G. Barnes**, graduate student, Agricultural and Biological Engineering Department. Coauthors: Virginia Ishler, Walt Whitmer, C. Alan Rotz, Heather E. Preisendanz, Herschel A. Elliott, and John E. Watson, August 2020.

We would like to thank the Mifflin County Water for Agriculture Local Leadership Committee for its guidance and expertise in developing this fact sheet.

References:

N. K. Fageria , V. C. Baligar & B. A. Bailey (2005) Role of Cover Crops in Improving Soil and Row Crop Productivity, *Communications in Soil Science and Plant Analysis*, 36:19-20, 2733-2757

Rotz, C.A., M.S. Corson, D.S. Chianese, F. Montes, S.D. Hafner, H.F. Bonifacio, C.U. Coiner 2018. The Integrated Farm System Model. USDA-Agricultural Resource Service, Pasture Systems & Watershed Management Research Unit, University Park, PA, 16802.

This work is supported by the Agriculture and Food Research Initiative (AFRI) Water for Agriculture grant no. 2017-68007-26584/project accession no. 1013079 and project accession no. 1004448 from the USDA National Institute of Food and Agriculture. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.