

Reductions in phosphorus loading in the Sunrise River watershed from selected agricultural best management practices (BMPs)

Issue and Approach

Agricultural land occupies only 21% of the Sunrise River watershed but delivers 55% of the phosphorus load from uplands to receiving waters, i.e., streams, lakes, and wetlands (Table 1). Too much phosphorus in these waters can degrade water quality because of excessive algal growth. Estimating agricultural nonpoint loads of phosphorus is complicated by the many factors that affect the runoff response of the watershed to rainfall and snowmelt. These factors include not only soil type, topography, and vegetative cover, but also agricultural practices such as crop rotations, tillage, and applications of manure and inorganic fertilizer. To help account for these factors, a computerized watershed model was constructed for the Sunrise River watershed with the Soil and Water Assessment Tool (SWAT).

Agriculture in the Sunrise River Watershed

Agriculture in the Sunrise River watershed is dominated by a simple grain corn and soybean rotation (CS), accounting for about 85% of the tilled land in the model (Table 1). The remaining tilled area was simulated as a six-year silage corn and alfalfa rotation (CA). Tillage was modeled as chisel plowing in the fall for heavier soils and in the spring on sandier soils, followed by disking just prior to planting. All tilled rotations received inorganic fertilizer, which was adjusted downward if manure was also applied. In the model, livestock was simulated as adult beef cattle, dairy cows, and horses. Populations of these species were adjusted slightly above reported numbers to account for less common livestock such as hogs, sheep, buffalo, and red deer. About half (44%) of the CA rotations received all of the dairy manure, applied either seasonally (spring and fall) or by daily hauling at two selected rates (low and high). About half of the beef and horse manure was spread on grass hay fields in the spring to dispose of winter accumulation. The remainder was spread by grazing for 169 days per year, at a density of one animal unit per three acres. Soil-test phosphorus (STP) from fields in the watershed was variable but averaged about 40 parts per million (ppm). In the model, STP was simulated at three levels (20, 40, and 60 ppm) to account for some of this variability.

Table 1. Relative areas and total phosphorus loads for selected land uses in the Sunrise River watershed.

Land Use	Area (%)	TP load (%)
Agriculture	21%	55%
<i>CS rotation</i>	11%	44%
<i>CA rotation</i>	2%	7%
<i>Hay, Pasture</i>	8%	4%
Developed	16%	27%
Other	63%	17%

NOTES: TP, total phosphorus;
CS, grain corn-soybean rotation;
CA, silage corn-alfalfa rotation.

Which lands yield the most phosphorus?

Figure 1 summarizes phosphorus yields (annual load from a unit area) from different crop types and rotations. Values shown are model averages from the dominant soils (hydrologic soil groups A and B) and slopes (<10%) in the watershed. Values would be larger for denser or wetter soils (groups C and D) and steeper slopes, but these are not common.

Of all the crops, silage corn had the highest phosphorus yield at over 4 kg/ha (Figure 1; see right-hand scale for equivalent values as lb/acre). This large value was influenced by a few modeled areas where

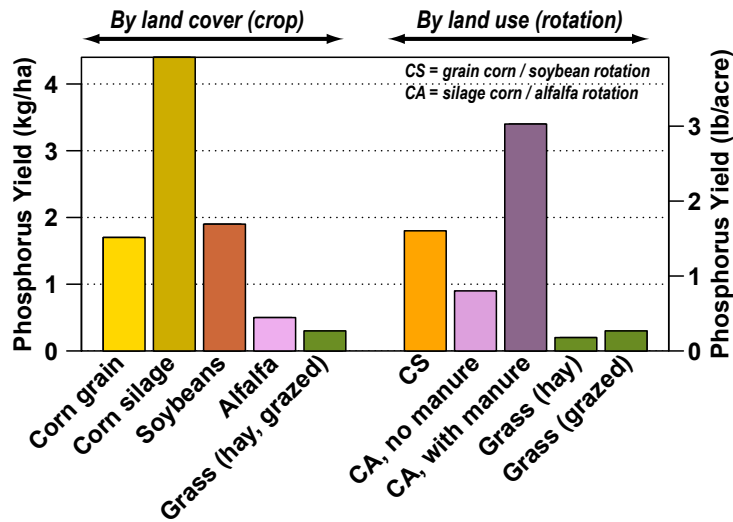


Figure 1. Phosphorus yields for selected crops and agricultural rotations in the Sunrise River watershed.

heavier soils intersected with large daily-haul applications of dairy manure. Corn grain and soybeans were about equal at well above 1 kg/ha, whereas alfalfa and grassland (either hay or grazed) were well below 1 kg/ha.

Phosphorus yields from rotations reflect combinations of those from individual crops (Figure 1). The CA rotations receiving manure had the highest yields at over 3 kg/ha, but CA rotations receiving only inorganic fertilizer during the corn years had much lower yields, below 1 kg/ha and about half that from a CS rotation. Agricultural grasslands, here pastures and hay fields receiving manure, had very low phosphorus yields, mostly because the model allows much greater infiltration, and hence less runoff, on grasslands than on tilled fields.

Agricultural BMPs to Reduce Phosphorus Loading

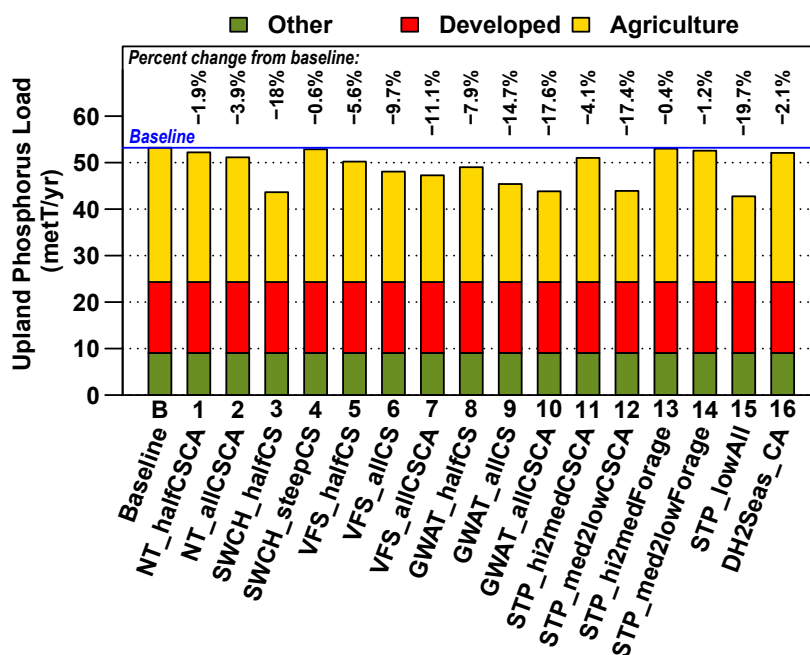
Agricultural practices have been changing to reduce losses of soil and nutrients from fields. Collectively these new methods are called best management practices, or BMPs. Selected BMPs were implemented in the SWAT model to estimate how much phosphorus loads were reduced from the baseline upland load of 53 metric tons/yr (Figure 2). Loads given here are those delivered from uplands to receiving waters, namely streams, lakes, and wetlands. Loads leaving the watershed (baseline of 22 metric tons/yr) are much less because much of the phosphorus entering wetlands or lakes is trapped.

- *No-till (NT)*: Scenarios 1 and 2 converted half, and then all, of the CS and CA rotations to no-till agriculture. Reductions in total phosphorus loads were modest, resulting from increased infiltration in the model, and transported phosphorus changed from mostly sediment-bound to dissolved.
- *Switchgrass (SWCH)*: Scenario 3 converted half the CS lands to perennial switchgrass, which received fertilizer but required no tillage. Phosphorus loads were substantially reduced by 18%. Scenario 4 replaced all CS lands on steep slopes with switchgrass, which is good management, but there were so few of these areas in the model that the result was inconsequential.
- *Vegetated filter strips (VFS)*: A VFS is a strip of grassland along the downhill edge of a field, here set to 2% of the field area. For a square 40-acre field, the strip would be about 25 ft wide (8 meters). About 75% of the field was assumed to form concentrated flow that bypasses the VFS. Adding a VFS to half or all CS lands (scenarios 5 and 6) resulted in substantial load reductions of about 6-10%. Adding VFSs to CA lands as well (scenario 7) resulted in little additional reduction, mostly because the area of CA lands is small.
- *Grassed waterways (GWAT)*: Grassed waterways were implemented as a 10-m wide strip of grassland with a length set to the square root of the field area, e.g., a single waterway down the middle of a square

field. Scenarios 8-10 implemented GWATs on half of CS land, all of CS land, and all of both CS and CA lands, respectively, and resulted in substantial reductions in phosphorus loads of 8-18%.

- *Soil-test phosphorus (STP) reductions:* STP can be lowered by reducing fertilizer additions of phosphorus below that removed by crop harvest and runoff. Scenario 11 reduced STP in the CS and CA lands with high STP (60 ppm) down to medium levels (40 ppm). The reduction in load (4%) was modest but useful because implementation required only 25% of the tilled lands, those with the highest STP. Scenario 12 reduced STP to 20 ppm in all CS land and 30 ppm in all CA land, thereby reducing phosphorus loads by a substantial 17%. Scenarios 13 and 14 reduced STP in grass hay fields and pasture (forage crops), first in those few grasslands with high (60 ppm) levels down to medium (40 ppm), and second in all grasslands down to 20 ppm. Load reductions were modest because such grasslands were not large contributors of phosphorus in the first place in the model. However, combining all these STP reductions (scenario 15) resulted in a nearly 20% reduction in phosphorus load.

- *Converting daily-haul (DH) manure applications to seasonal:* Seasonal applications of manure, if incorporated by chisel plowing, can reduce phosphorus loads compared to daily haul operations that spread some manure on frozen ground in early spring. Converting all daily haul operations on CA land to seasonal manure applications (scenario 16) resulted in only a modest phosphorus load reduction (2%), mostly because of the small area of these lands.



Conclusions

Even though the phosphorus load reduction from any one BMP may be modest, in aggregate the reductions could be substantial. Furthermore, the model could not include the entire range of large STP values or manure application rates that might be present in the watershed. Resource managers should expect to find such sites and to target them first for remediation.

Figure 2. Upland loads of phosphorus in the Sunrise River watershed under selected agricultural best management practices (BMPs).

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