Modeling Cellulosic Bioenergy Feedstock Supply

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Introduction

Cellulosic bioenergy feedstock production analyses often include simple breakeven comparisons of production alternatives versus current cropping practices, ignoring effects of spatial and temporal production variability and transportation costs. While this approach provides a rough estimate of potential biomass feedstock costs, it can lead to erroneous conclusions about the production practices that are likely occur. This is particularly important when evaluating potential environmental impacts of bioenergy feedstock production, since these impacts are closely tied to production practices. Consider the production alternatives for a single location illustrated in Figure 1. As biomass price increases, the profit maximizing cropping practice changes from a corn-soybean rotation with no feedstock harvest, to corn-soybean rotation harvesting corn stover, to a corn-spring wheat-soybean rotation harvesting corn stover and wheat straw, to continuous corn harvesting corn stover. Differences in transportation costs shift these curves left or right, so that fields with identical productivity may result in different profit maximizing practices given the same plant-gate biomass price due to differences in transportation costs. Differences in productivity can change the slopes of individual curves or shift them upward or downward, again leading to differences in profit maximizing practices for a given biomass price. The objective of this analysis was to evaluate potential biofeedstock supply, production practices, and environmental impacts for a bioenergy plant in West Central Minnesota.

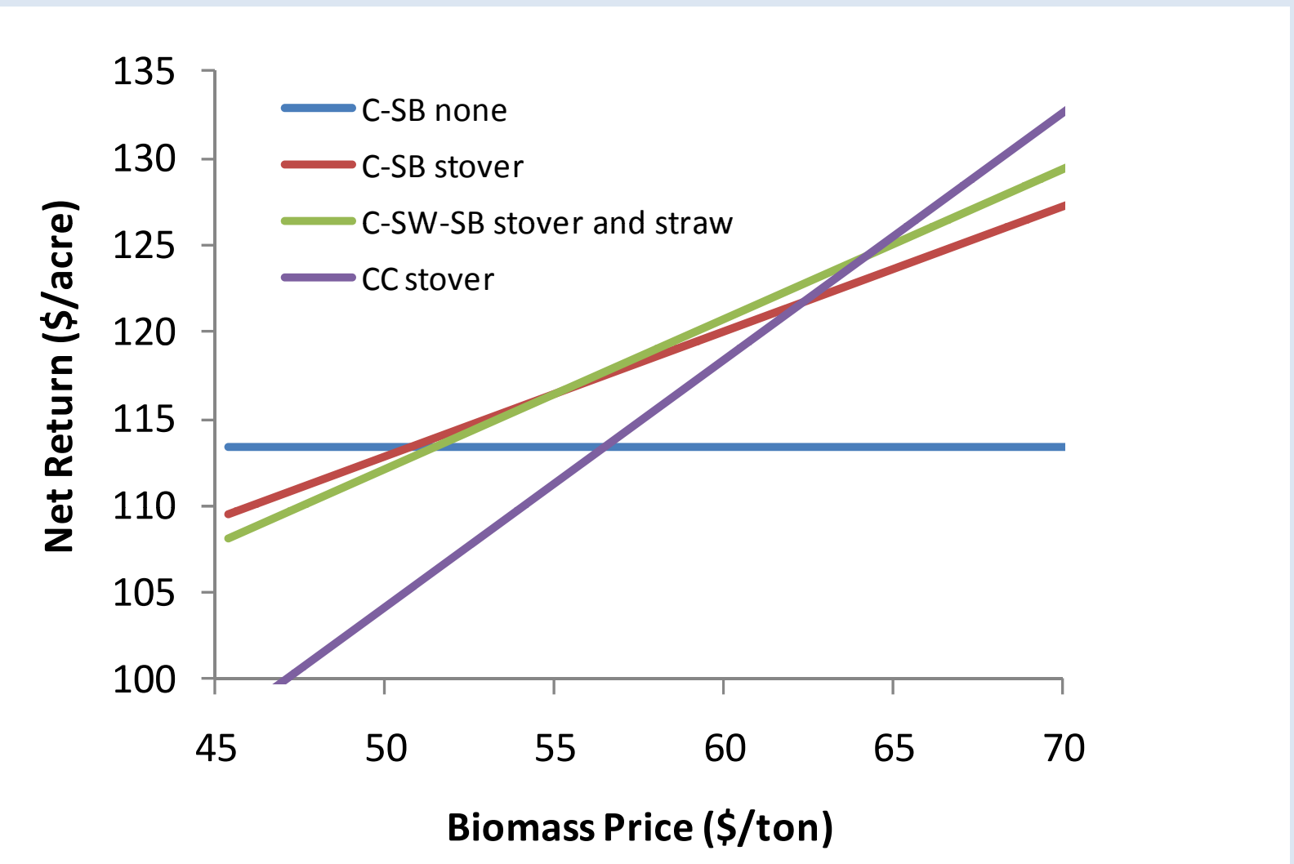

Figure 1. Illustration of impacts of biomass price on net returns for four cropping alternatives: Corn-soybean rotation with no residue harvested for bionergy (C-S none), corn-soybean rotation with corn stover harvest (C-S stover), corn-spring wheat-soybean rotation with corn stover and wheat straw harvest (C-SW-SB stover and straw), and continuous corn with corn stover harvest (CC stover).

Methods

Bioenergy feedstock supply was estimated for a bioenergy plant located at the University of Minnesota, Morris (UMM). For this analysis, potential biomass supplies from crop residues only were evavluated. Three crop rotation were included: continuous corn (CC), corn-soybean (C-SB), corn-spring wheat-soybean (C-SW-SB). Four residue harvest scenarios were evaluate: no residue harvest (none), corn stover harvest (stover), wheat straw harvest (straw), and both corn stover and wheat straw harvest (stover and staw). Enterprise budgets were constructed based on field research conducted at the Swan Lake Research Farm near Morris, and using 2000 prices. The EPIC model was used to simulate crop yields and environmental impacts for each of 186 SSURGO soil map units within Stevens and Pope Counties. EPIC was calibrated using field research yields. Crop fields were delineated using the 2007 cropland data layer (NASS). Road network base maps were obtained from MN Department of Transportation. Transportation costs were calculated using in-field and on-road unit cost estimates with ArcGIS Cost Path Analysis on a 56 meter grid. Net returns were calculated for each field using 20-year average EPIC simulation results and transportation costs aggregated to the field level for $1/ton plant-gate biomass price increments ranging from $42-$63/ton.

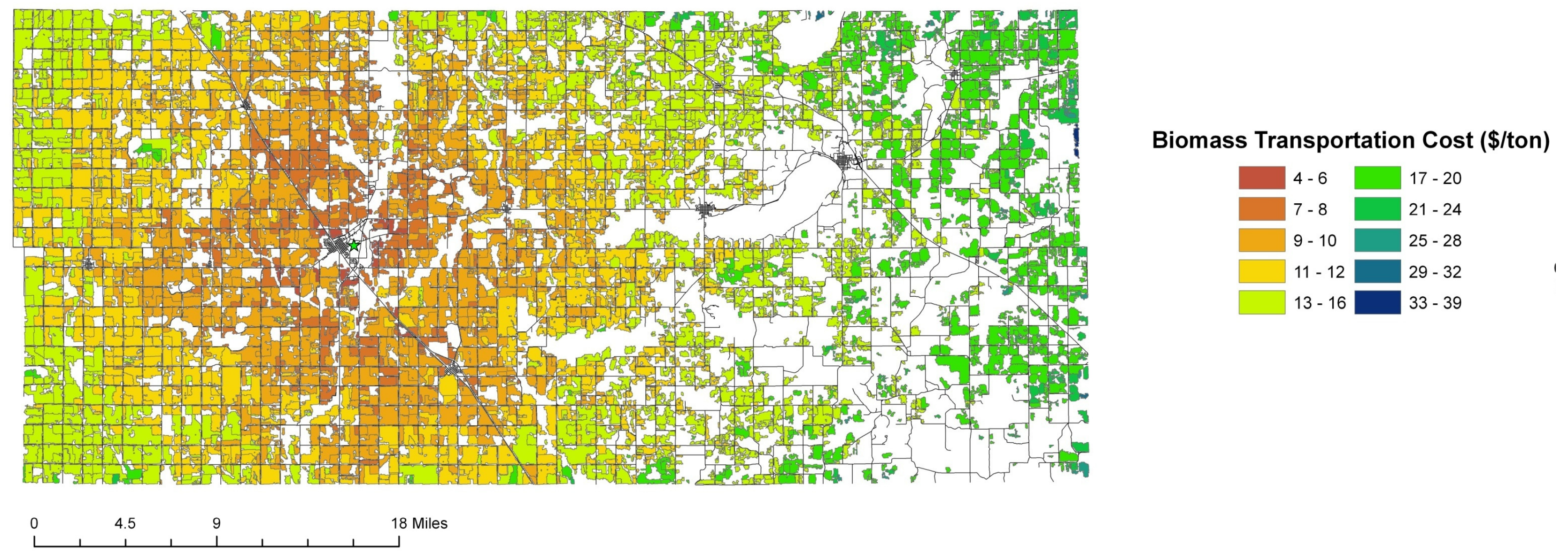

Figure 2. Biomass transportation costs from Stevens and Pope county Minnesota crop fields to the UMM gasification plant.

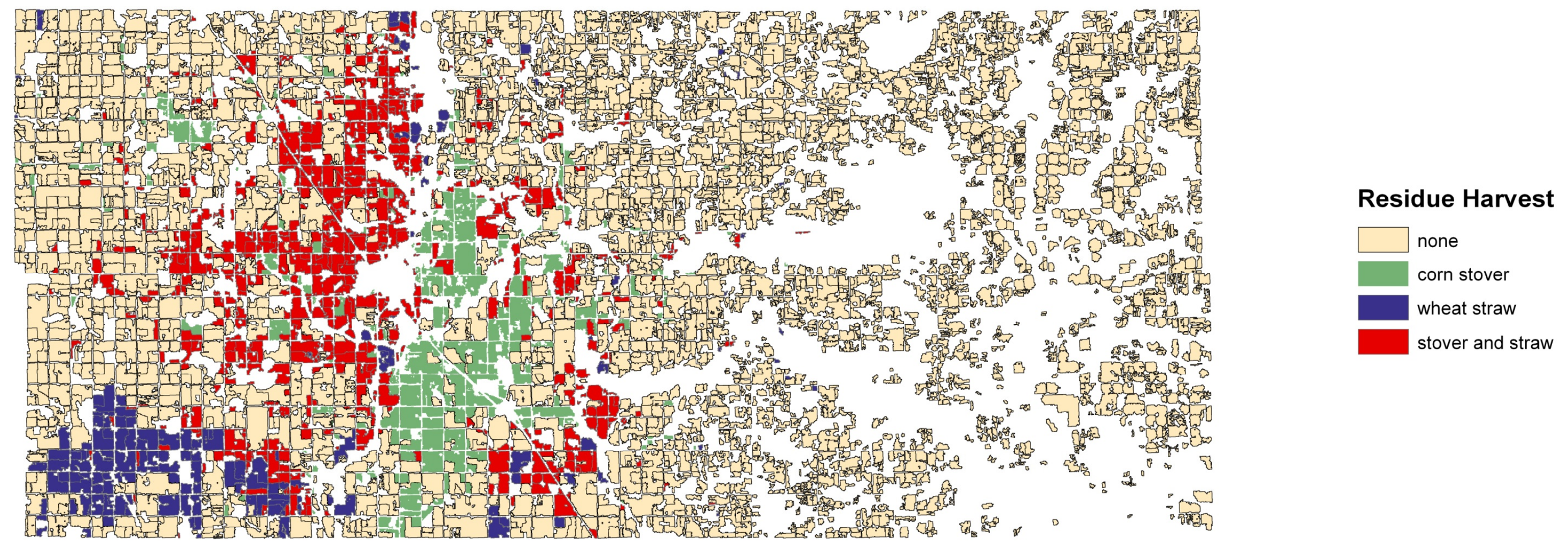

Figure 3. Profit maximizing residue harvest practices given a $51/ton UMM plant-gate biomass price.

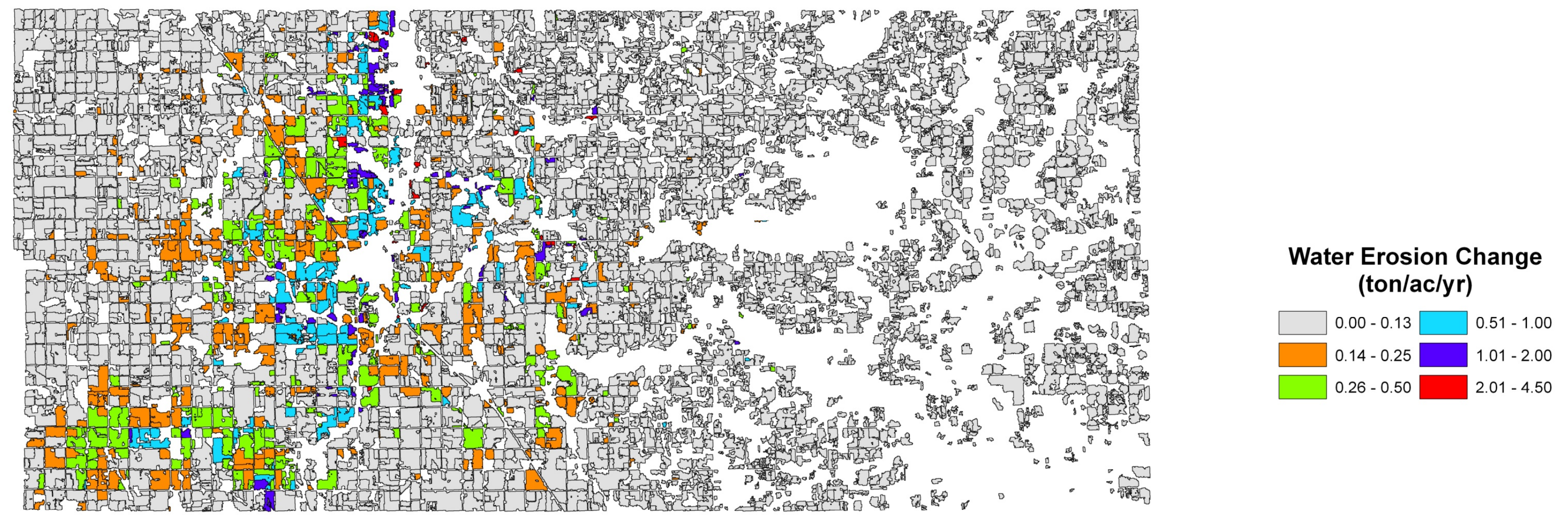

Figure 4. Change in soil erosion rates due to water for the profit maximizing cropping practices given a $51/ton UMM plant-gate biomass price relative to the baseline profit maximizing rotation with no residue harvest.

Results

Estimated biomass transportation costs ranged from $4/ton to $39/ton from fields within Stevens and Pope counties to the UMM plant (Figure 2). These costs include in-field transportation costs, loading onto a truck at field edge, and trucking to the UMM plant. Profit maximizing residue harvest practices vary spatially as influenced by both soil productivity and transportation costs (Figure 3). Fields where wheat straw harvest , or both corn stover and wheat straw harvest was optimal were generally in a C-SW-SB rotation in the baseline, while fields where corn stover harvest was optimal were generally in a C-S rotation. These baseline differences reflect differences in soil productivity. Differences in optimum harvest practices also result in differing impacts on soil erosion levels, with higher soil erosion levels occurring on fields where both stover and straw harvest were optimal (Figure 4). Also, note that there are greater incentives for higher harvest rates where transportation costs are low. Since a local highway parallels the river that flows near Morris this could lead to higher erosion rates near the river. Estimated biomass supply for UMM plant-gate prices ranging from $42-63/ton are shown in Figure 5. At a price of $51/ton an annual average of over 75,000 tons of biomass could be profitably produced, however this would result in an additional 40,000 tons of soil erosion if offsetting conservation practices were not implemented. As the biomass price increases, there are economic incentives to harvest higher amounts resulting in accelerated erosion rates.

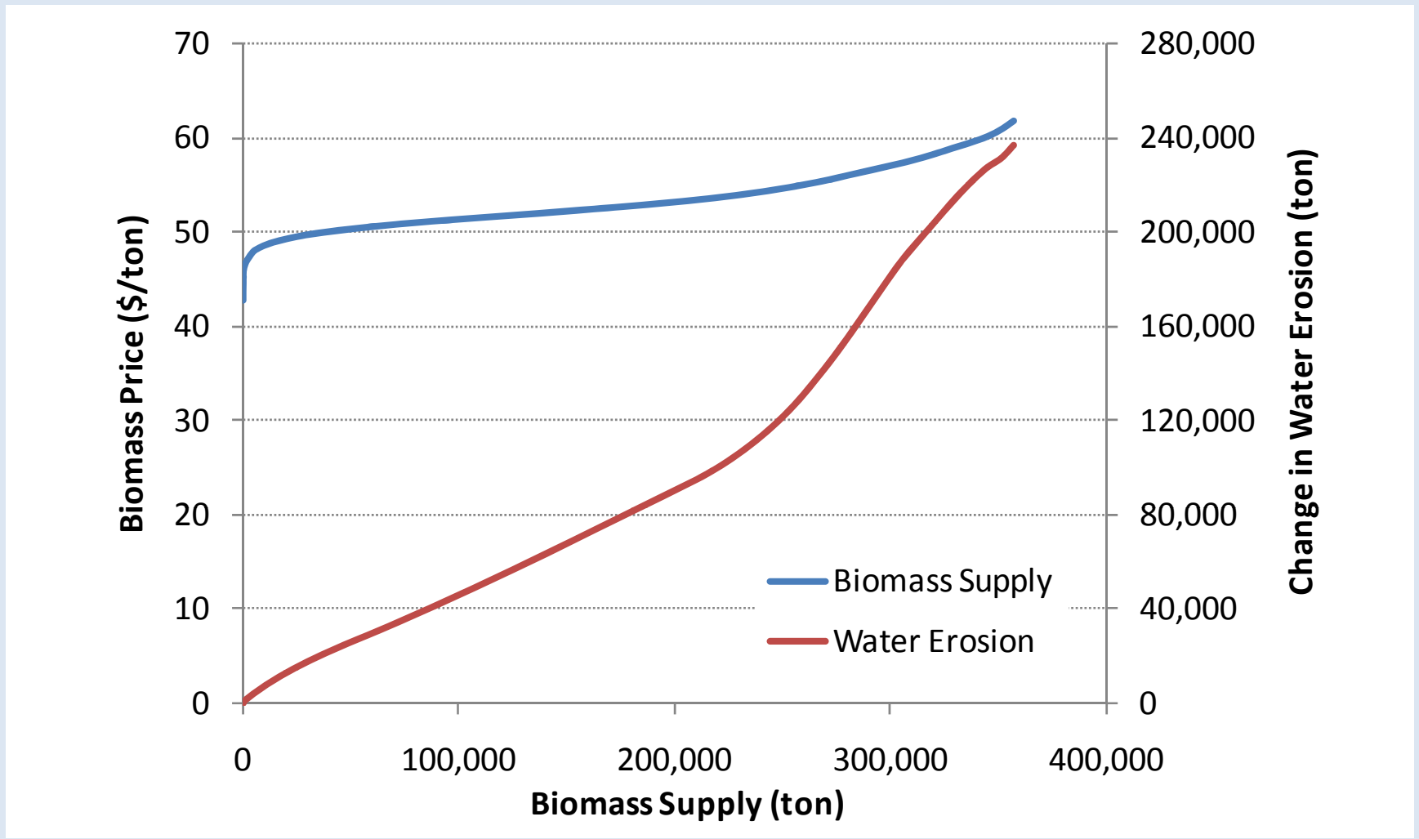

Figure 5. Estimated biomass supply and associated change in total annual water erosion within Stevens and Pope counties, Minnesota based on maximizing average annual net returns at the field level. Biomass supply reflects price at the UMM plant gate.

Conclusion

In evaluating biofeedstock supplies, it is important to include spatial characteristics, including transportation costs and variations in soil productivity, in order to understand potential effects of bioenergy production on production practices and the environment. Inclusion of spatial information allow identification of the range of practices likely to be adopted, and, important for determining environmental fate, the locations of these practices. Although this analysis only evaluated use of annual crop residues, this effect could be particularly important in evaluating perennial biofuel crops such as switchgrass. Just as spatial variation in productivity can lead to variation in optimum production practices, it is anticipated that temporal variablity could have similar impacts. This is a planned area for future analysis. The analytical approach used in this example can be used to evaluate potential biomass supplies and environmental impacts for other cellulosic bioenergy facilities.

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