Nutrient management in energy crop production: Replacement costs of macro and micro nutrient

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Abstract

The on-site loss of nutrients due to biomass removal creates additional costs for ethanol production however this aspect has not been properly incorporated in economic analyses of biomass production and processing. This study investigates costs of on-site nutrient losses in switchgrass fields in Tennessee. The replacement cost methodology was applied to measure on-site cost of nutrient losses due to biomass removal and was based on the costs of replacing nutrients removed from the production site. The estimated costs for total on-site nutrient loss due to biomass removal show a substantial loss of nutrients in switchgrass fields. The loss of major nutrients from biomass removal represents the major part of on-site economic costs. A declining trend of nutrient costs per Mg of harvested biomass was observed with increasing in harvesting time. The internalization of on-site costs of nutrient losses is possible by adopting an appropriate harvest schedule for switchgrass.

Key Words: Julian day, nutrients, replacement costs, simulation, switchgrass

Introduction

There are three major impacts of nutrient losses namely; on-site effects, off-site consequences and inter-generational impacts. On-site effects of nutrient removal are measured in terms of impact on crop productivity; because the nutrient losses affect the future crop yield and economic costs for producers.

In switchgrass, nutrient removal depends on fertilizer application rates and the harvest system (Guretzky et al., 2011; Haque et al., 2009.

Kering et al. (2013) found that two-cut harvest systems remove more nitrogen as compared to a one-cut system. Accordingly, single harvest technique can result reduced total biomass but it also minimize the amount of nutrients removed in the harvested biomass. Cahill et al. (2014) suggested that nutrient removal with the biomass is a factor to be considered in decision making in biomass harvesting.

In order to motivate farmers, to enhance the likelihood of farmers producing switchgrass, they must be provided with information on the nutrient losses due to harvesting and the cost and benefits of different harvest timing.

Objective

Considering the above issues, the major objective of this study is to assess on-site costs of nutrient removal in switchgrass cultivation.

Methodology

The replacement cost approach which includes the cost of physical removal of nutrients from biomass was used for the study (Maynard et al., 1986). The replacement costs method is widely used to measure the cost of replacing nutrients with purchased inputs. The replacement cost was calculated by considering details about how much it costs to replace the removed nutrients with chemical fertilizer, and maintain a given level of productivity in switchgrass fields.

The primary data source includes biomass samples collected and tested from switchgrass fields (see de Koff and Allison, 2015) in Nashville, Tennessee.

- The samples were collected for the period of June 06 - November 02 in two year period (Julian day 157 to 306, 158 to 307, respectively).
- The samples were measured for concentration (g/kg) of macro (N, P, K) and secondary (Ca, Mg and S) nutrients.
- Estimated yield was calculated by taking the yield identified by Boyer et al. (2010) (12.72 Mg/ha) for a similar situation in Milan, TN and relating it to the dry weight samples collected by de Koff and Allison (2015). Therefore, the sample harvested on Nov. 2 was estimated to have the same yield as that of Boyer et al. (2010) and all other estimated yields shown were related to it by the dry weight measurements identified in de Koff and Allison (2015).

In this study, the nutrient removal from the switchgrass was calculated and the replacement cost of nutrients was determined based on nutrient prices.

- The nutrient prices were estimated based on market prices of fertilizer based on Farmer's Cooperative Association Inc.
- Price of N, P and K was calculated based on fertilizer mixtures of 46-0-0, 18-46-0 and 0-0-60, respectively.
- Prices of micronutrients were based on various fertilizer mixtures (ammonium sulfate, potassium magnesium sulfate, magnesium sulfate, magnesium oxide, dolomite, calcium nitrate, calcium carbonate, gypsum, single superphosphate and triple superphosphate) and their chemical properties.

We used the percentage of each nutrient in fertilizer mixtures to estimate the value of specific nutrient. Based on the data, we used pert distribution to crate probability distribution curves for quantity of macro and secondary nutrient removal from a hectare of switchgrass land and also for distribution of unit costs of nutrients.

The Monte Carlo simulation was performed using Risk analysis Software (@Risk) to analyze the distribution of nutrient losses and economic value of nutrient loss from switchgrass fields.

Results and Discussion

The mean yearly costs of total nutrient removal from switchgrass biomass in year 1 was \$117.41/ha with 90% probability range of distribution from \$100.4 - \$136.4/ha (Fig 1). The total distribution range of nutrition removal costs was \$82.9 - \$176.7/ha.

Other than the quantity of nitrogen, the price of N, P, Ca and K have the greatest effect on nutritional removal costs from switchgrass biomass (Fig 2).

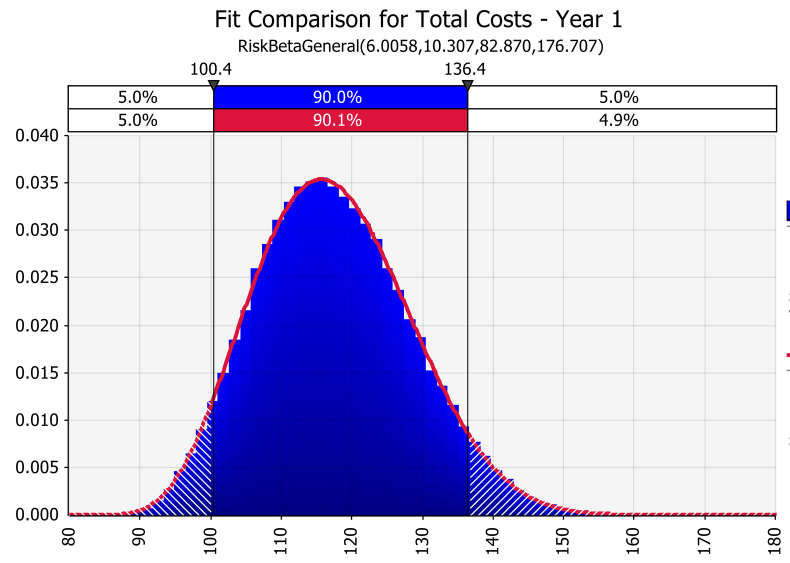

Figure 1. Distribution of total costs of nutrition from switchgrass biomass in year 1

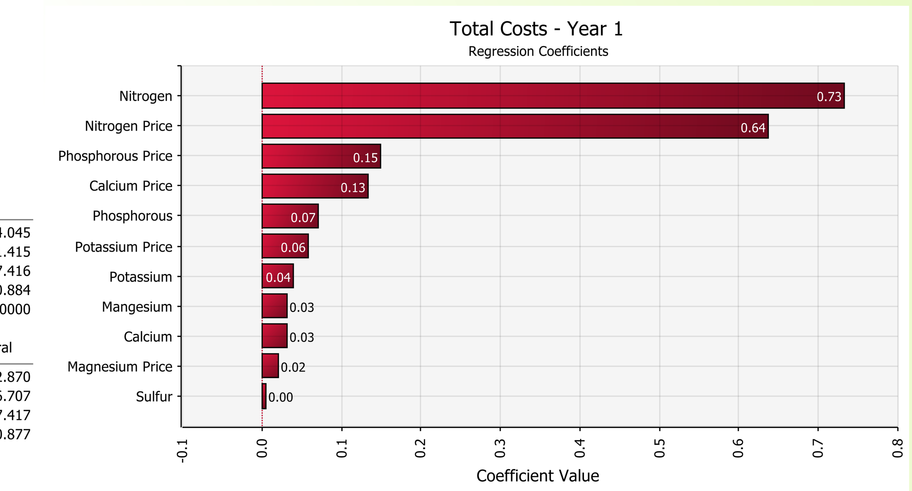

Figure 2. Regression coefficients and mapped values

The mean yearly costs of total nutrient removal from the switchgrass biomass in year 2 wass \$91.2/ha with 90% probability range of distribution from \$81.70 - \$101.10/ha (Fig 3). The total distribution range of nutrition removal costs was \$59 - \$145.60/ha. Other than the quantity of nitrogen, the price of N, P, K have large effects on nutritional removal costs from switchgrass biomass (Fig 4).

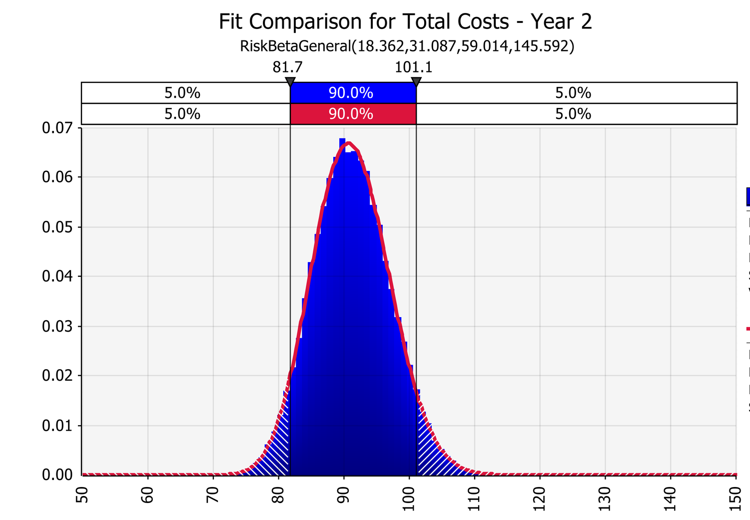

Figure 3. Distribution of total costs of nutrition replacement from harvested switchgrass biomass in year 2.

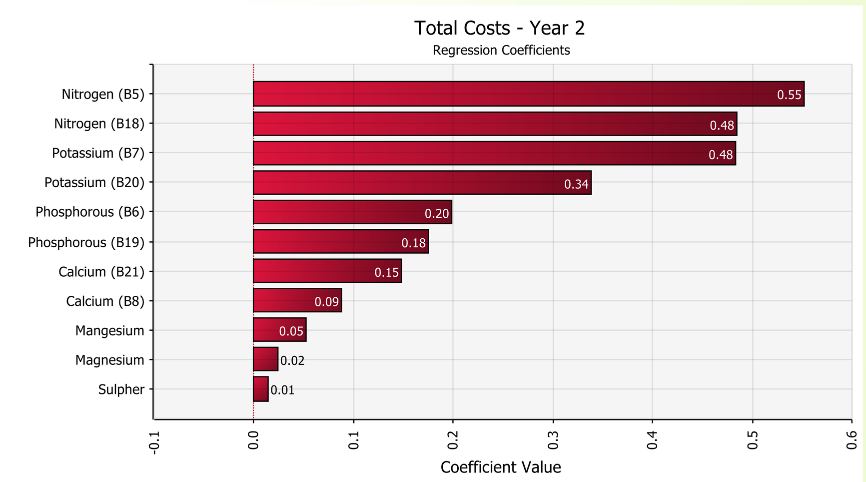

Figure 4. Regression coefficients and mapped values

Total nutrient replacement costs declined for biomass harvested between Julian day 150 to 200 and 250 to 300 (Fig 5). The harvested biomass yield in various harvesting schedules is in the range between 7.58 -14.36 Mg/ha (std 2.04). The lowest nutrient costs (\$195/ha yr^{-1}) was associated with a biomass yield of 12.99 Mg/ha on Nov. 2nd (Julian day 306). The highest yield of 14.36 Mg/ha was associated with nutrient costs of \$346/ ha yr^{-1} on August 22nd (Julian day 234).

Comparison of biomass yield and replacement costs shows additional costs of nutrients of \$151/ha yr^{-1} for 1.37 Mg (\$110/Mg) of yield. There is a sharp drop of nutrient costs of harvested biomass between 157-206th Julian day \$51 to \$23/Mg) and becomes constant between 227- 277 Julian day (\$24 to \$22). The late harvesting of Julian days 227 to 306 shows lowest cost per Mg of biomass (Fig. 6).

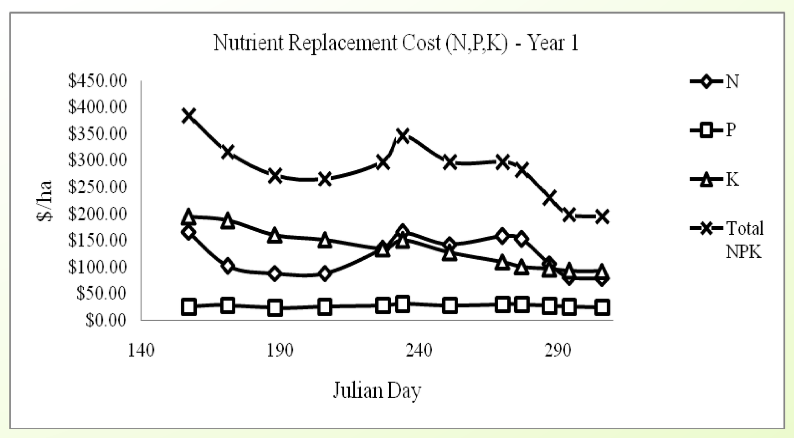

Figure 5. .Major nutrient replacement costs in Year 1

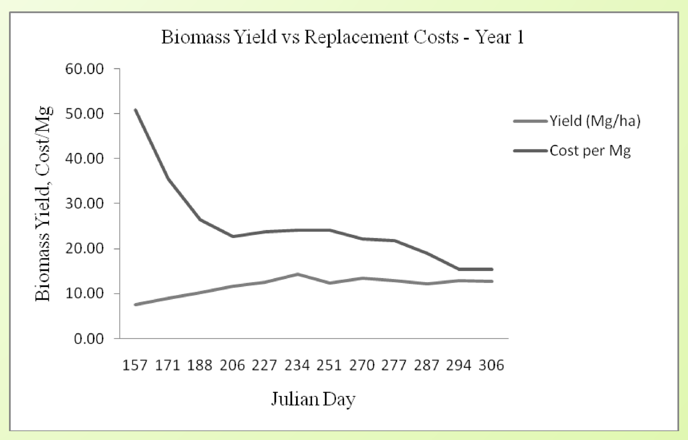

Figure 6. Nutrient replacement costs per Mg of biomass yield in different harvesting schedules in 2011

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