Estimating the Impacts of Storage Dry Matter Losses on Switchgrass Production

James A. Larson[1*],
Daniel F. Mooney[1],
Burton C. English[1], and
Donald D. Tyler[2]

[1]Department of Agricultural and Resource Economics
2621 Morgan Circle, 302 Morgan Hall
The University of Tennessee
Knoxville, TN 37996
***Corresponding Author:**
E-mail: jlarson2@utk.edu
Phone: (865) 974-3716

[2]West Tennessee Research and Education Center
Department of Biosystems Engineering and Soil Sciences
605 Airways Blvd.
The University of Tennessee
Jackson, TN 38301

Poster prepared for presentation at the Agricultural & Applied Economics Association 2010 AAEA,CAES, & WAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010

Estimating the Impacts of Storage Dry Matter Losses On Switchgrass Production

James A. Larson[1]*, Daniel F. Mooney[1], Burton C. English[1], and Donald D. Tyler[2]

[1] Agricultural and Resource Economics, The University of Tennessee, Knoxville, TN

[2] Biosystems Engineering & Soil Sciences and West Tennessee Research & Education Center, The University of Tennessee, Jackson, TN

Introduction

Switchgrass is a potential energy crop and can be harvested using conventional hay equipment. Storage of bales for a year or more may be required to supply a biorefinery. Dry matter loss (DML) from weathering may be a significant factor in the optimal harvest and storage regime (Sanderson and Ward, Wiselogel et al.). Round bales are designed to shed water and can be stored with minimal protection. By contrast, rectangular bales have economies of size in harvest and storage, but may not withstand weathering. Information on switchgrass DML over time for alternate harvest and storage systems in the southeastern United States is currently limited.

Objectives

- Estimate DML for switchgrass as a function of harvest method, storage treatment, and time in storage.
- Calculate the cost to store switchgrass bales under alternate harvest and storage scenarios.
- Determine the economic optimal harvest and storage method as a function of biomass price and time in storage.

Conceptual Framework

The net return ($/dry ton, dt) equation used to evaluate the harvest and storage decision was:

$$NR_{ijt} = P \times Y(1 - DML_{ijt}) - SC_{ij} - FC,$$

where

- i = Harvest method (round vs. square bales)
- j = Storage treatment (covered vs. uncovered)
- t = Time in storage (days)
- NR = Net return to harvest & storage decision ($/dt)
- P = Biomass price ($/dt)
- Y = Yield at harvest (dt)
- DML = Dry matter loss during storage (proportion of Y)
- SC = Harvest and storage costs ($/dt)
- FC = Other production costs, assumed fixed ($/dt)

The breakeven biomass price equation used to compare harvest and storage systems as a function of time was:

$$P^{C,D} = (SC^D_{ij} - SC^C_{ij}) / (Y \times [DML^C_{ijt} - DML^D_{ijt}]),$$

where *D* denotes the *defender* harvest and storage system, *C* denotes the *challenger* system, and we assume $SC^C > SC^D$ and $DML^C < DML^D$ (i.e., the challenger system offers increased protection from weathering, but at a higher cost).

Data and Methods

Data on DML are from an experiment at Milan, TN. Round (5′×4′) and square (4′×4′×8′) bales arranged in a factorial combination with two storage cover and three storage surface treatments were compared at 110, 231, 327, 415, and 529 days after harvest. Storage covers were uncovered and covered with a polyurethane tarp. Storage surfaces were well-drained ground (round only), gravel pad, and wood pallet.

At each period, three replicates from each treatment combination were weighed, mechanically separated, and sampled based on visual estimates weathered areas (Fig 1-4). Dry bale weights were determined using percent moisture and the relative proportion of each weathered area. DML was calculated as dry bale weight at harvest minus dry bale at sampling divided by dry bale weight after harvest.

Fig 1. Removal from storage

Fig 2. Mechanical separation

Fig 3. Sampling process

Fig.4. Weathered area proportions

Savoie et al. indicated DML for stored biomass increases at a decreasing rate, then ceases when no organic material is left to oxidize. Therefore, the linear (LIN), quadratic plateau (QP) and Mitscherlich-Baule (MB) functional forms were used to model DML. The QP and MB forms impose diminishing DML and an asymptotic DML plateau and are hypothesized to have the best fit. The models were estimated using the NLIN and MIXED procedures in SAS and compared empirically using the J-test for non-nested functional forms (Davidson & McKinnon).

The impacts of DML on switchgrass production were determined using the net return and breakeven equations. Predicted DML values for the functional form with the best fit were used. Budgeting procedure for calculating harvest and storage costs followed standard practices. See Larson et al. for additional details about storage materials, costs, and assumptions used.

Results

Table 1. J-test results for non-nested hypotheses , DML functional form

Bale harvest & storage method	Alternative Hypothesis (H_a)	Null Hypothesis (H_0) LIN	QP	MB
Round uncovered (RU)	LIN	---	n.s.	n.s.
	QP	n.s.	---	n.s.
	MB	**	*	---
Round covered (RC)	LIN	---	n.s.	n.s.
	QP	n.s.	---	n.s.
	MB	***	***	---
Square uncovered (SU)	LIN	---	n.s.	n.s.
	QP	*	---	n.s.
	MB	*	n.s.	---
Square covered (SC)	LIN	---	n.s.	n.s.
	QP	***	---	n.s.
	MB	***	n.s.	---

- ***= reject H_0 in favor of H_a at 0.01; **= reject at 0.05; *= reject at 0.10; and n.s. = not significant.
- Reject LIN in favor of MB for all harvest and storage methods. Also, reject QP in favor of MB for RU & RC.
- Fail to reject MB in favor of LIN or QP for all harvest and storage methods.
- MB model provides the best fit for DML estimation.
- This result is likely due to the fact that the MB model increases more rapidly than the QP model.

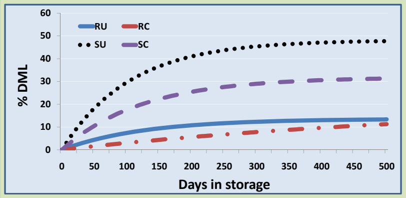

Fig. 5. Predicted DML based on the MB functional form

- DML increases at a decreasing rate as hypothesized.
- Round bales have lower DML than square bales.
- Storage cover has a noticable effect on DML.
- SU has highest DML, with a plateau of 46% DML at 436 days.
- RC has lowest DML, with 11% DML at 500 days.
- While DML for RU increases more rapidly than RC, DML estimates converge near 500 days.

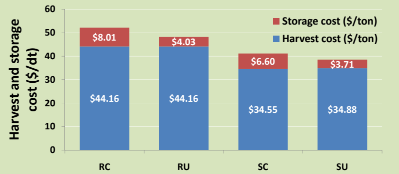

Fig. 6. Switchgrass bale harvest & storage costs

- Square bales offer economies in harvest over round bales due to higher throughput capacity.
- Square bales also offer economies in storage due to higher bale densities and a more stackable design.
- Pallets & tarps assigned 5yr useful life & zero salvage value, w/ 50% & 5% annual replacement, respectively.
- Cost analysis assumed bales were stacked in a pyramid design and placed on wooden pallets.

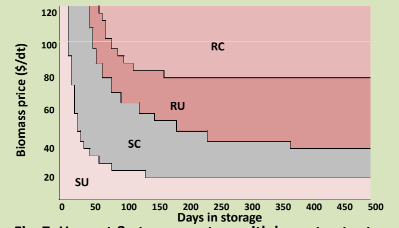

Fig. 7. Harvest & storage system with largest net return

- Higher biomass prices and longer storage periods favor more costly storage methods.
- SU bales are optimal for delivery directly after harvest or for short storage periods (<3 weeks).
- RC bales are optimal for long-term storage (>3 months) when biomass is highly valuable (>$80/dt).
- RU and SC bales are optimal for a range of medium- and long-term storage periods, with the choice between them depending on biomass price.

***Corresponding author:**

Dr. James A. Larson, Department of Agricultural and Resource Economics, 308 Morgan Hall, 2621 Morgan Circle, The University of Tennessee, Knoxville, TN 37996. E-mail: jlarson2@utk.edu, Phone: (865) 974-3716.

Literature cited:

- Davidson & McKinnon. 1981. *Econometrica* 49:781-793.
- Larson et al. 2010. *Agric. Finance Rev.*, forthcoming.
- Griffth et al. 1987. *Western J. of Agric. Econ.* 12:216-227.
- Sanderson & Ward. Unnumbered report, TAMU forage research, 1993.
- Savoie et al. ASABE Annual Meeting, Portland, OR, 2006.
- Wiselogel et al. *Biores. Technol.* 56(1996): 103-109.

Acknowledgements:

The authors thank Blake Brown & the Milan Research and Education Center field crew, Janet Gibson, and UT Ag Econ graduate students for their research assistance. They also thank the UT Switchgrass project for financial support.