Optimal Time to Replace Switchgrass Stand with a More Productive Variety

Choolwe Haankuku
Research Assistant
Oklahoma State University
Department of Agricultural Economics
Email: Email: choolwe.haankuku@okstate.edu
Phone Number: (405) 744-6156

Francis Epplin
Professor and Jean & Pasty Neustadt chair
Oklahoma State University
Department of Agricultural Economics
Email: Email: f.epplin@okstate.edu
Phone Number: (405) 744-6156

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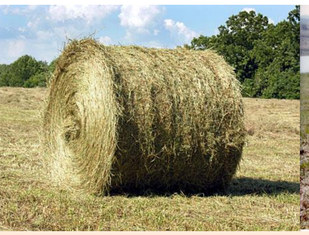
Introduction

Technology is being developed that could be used to produce biobased products from various lignocellulosic feedstock sources. The U.S. Department of Energy selected switchgrass as a model perennial grass for producing lignocellulosic feedstock . Switchgrass is well adapted to the U.S. and has potential to produce high biomass yield on marginal land.

Research is ongoing to develop hardy cultivars of switchgrass with enhanced biomass yield potential. Prior studies report that traditional breeding techniques can increase yield performance of switchgrass up to 20-30% compared to existing varieties (McLaughlin and Kszos 2005). Since switchgrass is a perennial, an established switchgrass stand is intended to be harvested once per year over many years. However, as agronomists develop improved cultivars with higher biomass yield potential, eventually it may be more economical for producers to destroy an existing stand with either mechanical or chemical means, forgo a year of production, and reseed the field with a more productive cultivar. The question as to whether or not an existing stand should be replaced with an alternative cultivar will depend on a number of factors.

Objective

The objective of the study was to determine if and when an existing stand of switchgrass (Defender) should be optimally replaced with a new cultivar (Challenger). The study also sought to determine the sensitivity of findings with respect to the discount rate, establishment cost of a new cultivar, and the planning horizon.



Contact Information

Choolwe Haankuku
Email: choolwe.haankuku@okstate.edu
Phone Number: (405) 744-6156

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Methods

Yield data from a randomized field experiment conducted from 1994 to 2000 in Haskell and Chickasha, Oklahoma (Fuentes and Taliaferro 2002) were used to represent average yields for the defender.

The study assumed a constant and a declining future yield scenario and consequently expected net revenue. The expected net revenue is:

$$ER_t = P.y - C_m - C_h(y) - C_\tau(y)$$

ER_t is expected net revenue, P is the biomass price, y is the biomass yield Mg ha-1, C_m is the maintenance cost, $C_h(y)$ is the harvest cost and $C_\tau(y)$ is the delivery cost both as a function of yield.
The yield increment by the challenger that would be necessary to replace the defender is modelled as:

$$\min_{1+\theta} Diff = [NPV^C(1+\theta) - NPV^D]$$
$$\text{s.t} \quad NPV^C = NPV^D$$

where
$E(NPV^C) = \sum_{t=1}^{s} ER_t\,(1+\theta) * (1+r)^{-t} - K$ is expected NPV of the challenger as a function of yield increment θ, K is establishment cost , including cost to kill existing crop and cost of one year yield loss (zero revenue) of the first year, r is discount rate, s is stand cycle length in years.
$E(NPV^D) = \sum_{t=1}^{s} ER_t * (1+r)^{-t}$ is expected NPV of the defender.

The defender should be kept an additional year if the expected net return of the defender is greater than the annualized return from the challenger (Perrin, 1972).

Results

Table 1. Optimal years to retain existing switchgrass before replacing with new cultivar

Item	Challenger Yield increment	
	10%	20%
	Number of years	
Base†	6	0††
Discount rate 2.5%	3	0
Discount rate 10%	NS (6) ‡	4
10 year planning horizon	NS (9)	6
40 year planning horizon	2	0
Double establishment cost	NS (9)	NS (9)
Biomass price $40§	-	-
Biomass price $60	4	0

† Base includes 5% discount rate, 20 year planning horizon, $50Mg-1 feedstock price
††zero means defender is replaced immediately
‡ Not significantly large enough yield increment by challenger and number of years before defender net returns become negative
§At price $40 Mg-1, NPV<0 for both the defender and challenger

Results

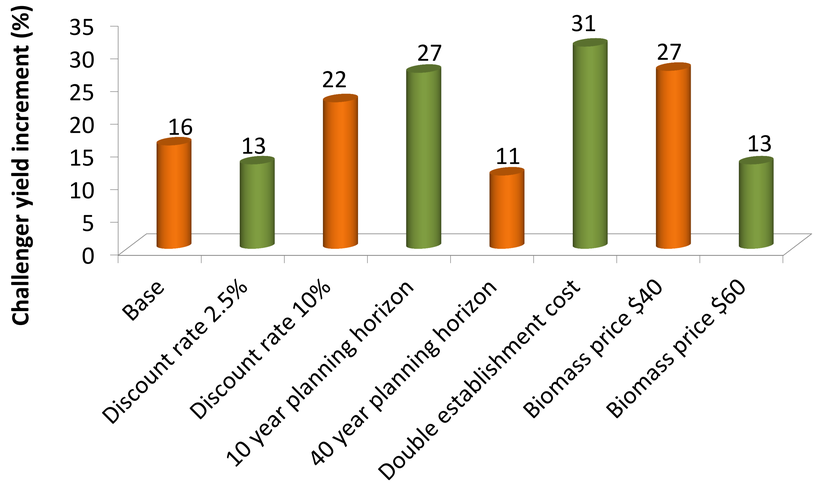

Figure1. Challenger yield increment (%) to replace Switchgrass

Conclusion

- Based on the assumed input and biomass prices, discount rate (5%) and planning horizon (20 years), it would be optimal to replace the existing switchgrass stand if the new cultivar produces 16% (Figure 1) greater biomass yield than the defender for the constant yield scenario.
- When establishment costs increase or if the planning horizon is shorter, a higher yield from the challenger would be required to justify replacement. Contrary, increasing the biomass price reduces the yield increment necessary to make a switching decision.
- For the base declining yield scenario, the optimal length of stand is 6 years (Table1) if the challenger yield increment is 10% and immediate replacement if yield increment is 20%. A lower biomass price produced negative returns and is not economically viable .
- Additional research would be required to develop the switchgrass replacement model using future yield estimates from robust econometric models.

References

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