Economic Analysis of Farm-Level Supply of Biomass Feedstocks for Energy Production under Alternative Contract Scenarios and Risk

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Introduction

- Considerable interest in the potential for on-farm production of cellulosic biomass for ethanol production (English et al, 2006).
- Perlack et al. (2005) estimates that more than a billion tons of cellulosic feedstock could be produced annually.
- Compared to other agricultural commodities, transportation costs from grower to processor for cellulosic feedstocks will be relatively high due to their bulkiness and low energy densities.
- This transportation cost factor will likely result in a more locally-grown market situation for biomass feedstock.

Introduction

- One possible alternative for supplying biomass to the processor is a vertically integrated system where the plant leases (or purchases) lands and directly manages the production, harvest, storage, and transportation of feedstocks (Epplin et al. 2007).
- Another alternative for the processing plant is to enter into long-term production and harvest contracts with individual farmers (Epplin et al., 2007).
- Given the high cost of constructing a processing facility, the processor likely will have an interest in providing contracts or other incentives to induce farmers to supply sufficient feedstocks to keep the plant operating at capacity.

Objective

- **Evaluate the potential risk and return tradeoffs of producing biomass feedstocks under alternative contractual arrangements with a processing facility given:**
  - **On-farm resources and contraints:**
    - **Soil types,**
    - **Labor, and**
    - **Planting and harvest times**
  - **Farmer risk aversion.**

Representative Crop Farm in Northwest Tennessee

- **Soils and Crop Area:**
  - The 2,400 acre farm was assumed to have three major soil types common to northwest Tennessee:
    - Collins (0% slope with no fragipan),
    - Memphis (1% slope with 42" depth to fragipan), and
    - Loring (3% slope with 30" depth to fragipan).
  - In general, the Collins and Memphis soils are the most productive and the Loring soil is the least productive.
  - The area of the farm in each soil type was determined using data from the USDA-NRCS soil survey database (USDA-NRCS, 2005).
    - 1,200 acres of Collins soils,
    - 528 acres of Loring soils, and
    - 672 acres of Memphis soils.
  - The major tillage practice in northwest Tennessee is no tillage and was used to simulate yields and estimate production costs for all crop activities on the farm (Tennessee Department of Agriculture, 2007).

Representative Crop Farm in Northwest Tennessee

- **Base crop production alternatives:**
  - Continuous corn,
  - Continuous soybeans,
  - Continuous winter wheat (grain or grain and straw bales),
  - Soybean-corn rotation, and
  - Soybean-corn-corn rotation,
  - Soybeans-wheat double-crop (grain or grain and straw bales).

Biomass Energy Crop Contract Scenarios

- **Representative farm was assumed to have the opportunity to provide biomass feedstocks to a local single-user facility that produces ethanol:**
  - Wheat straw,
  - Corn stover, and
  - Switchgrass.
- **Contract Alternatives:**
  - Spot Market Type Contract
  - Standard Marketing Contract
  - Acreage Contract
  - Gross Revenue Contract
  - Above contracts with and without a planting incentive for the perennial switchgrass, i.e., processor pays for seed costs.

Spot Market Contract (SPOT)

- Assumes processor purchased biomass based on current energy price equivalent.
- Straw and stover prices adjusted downward from the switchgrass price to account for lower energy content:
  - Wheat straw: Mean=$27.68/dt, std dev=$9.29/dt,
  - Corn stover: Mean $29.44/dt, std dev=$15.50/dt, and
  - Switchgrass: Mean $34.77/dt, std dev=$7.43/dt.
- The SPOT contract assumes that all of the output price, yield, and production cost risk from biomass production is borne by the farmer.

Standard Marketing Contract (STANDARD)

- Assumes processor pays the producer a guaranteed price on a proportion of expected production (Musser, Mapp, and Barry, 1984; Paulson and Babcock, 2007).
  - $30/dt-80/dt in $5/dt increments simulated for switchgrass.
- A penalty for production underage is assessed using the SPOT price.
- Production in excess of the guaranteed price proportion is sold at the SPOT price.
- With the STANDARD contract, a portion of the price risk on expected production is shifted from the producer to the processor.
- Yield and production cost risk from biomass production is borne by the farmer.

Acrerage Contract (ACREAGE)

- **Assumes processor provides a guaranteed annual price on the actual biomass produced in each year on the contracted biomass acreage (Paulson and Babcock, 2007).**
  - **$30/dt-80/dt in $5/dt increments simulated for switchgrass.**
- **Yield and production cost risk from biomass production is borne by the farmer.**

Gross Revenue Contract (REVENUE)

- Assumes processor provides a guaranteed annual gross revenue per acre from biomass based on a guaranteed contract price times expected yield per acre over the life of the contract (Garland, 2007).
  - $30/dt-80/dt in $5/dt increments simulated for switchgrass.
- Contract provides the greatest potential risk benefits to the farmer because all of the biomass price and yield risk is assumed by the processor.
- The gross revenue contract and the planting incentive are two potential switchgrass production incentives that are being consider for contract production for the pilot cellulosic ethanol plant being constructed in Vonore, TN, for Tennessee Biofuels Initiative (Garland, 2007).

Net Revenues

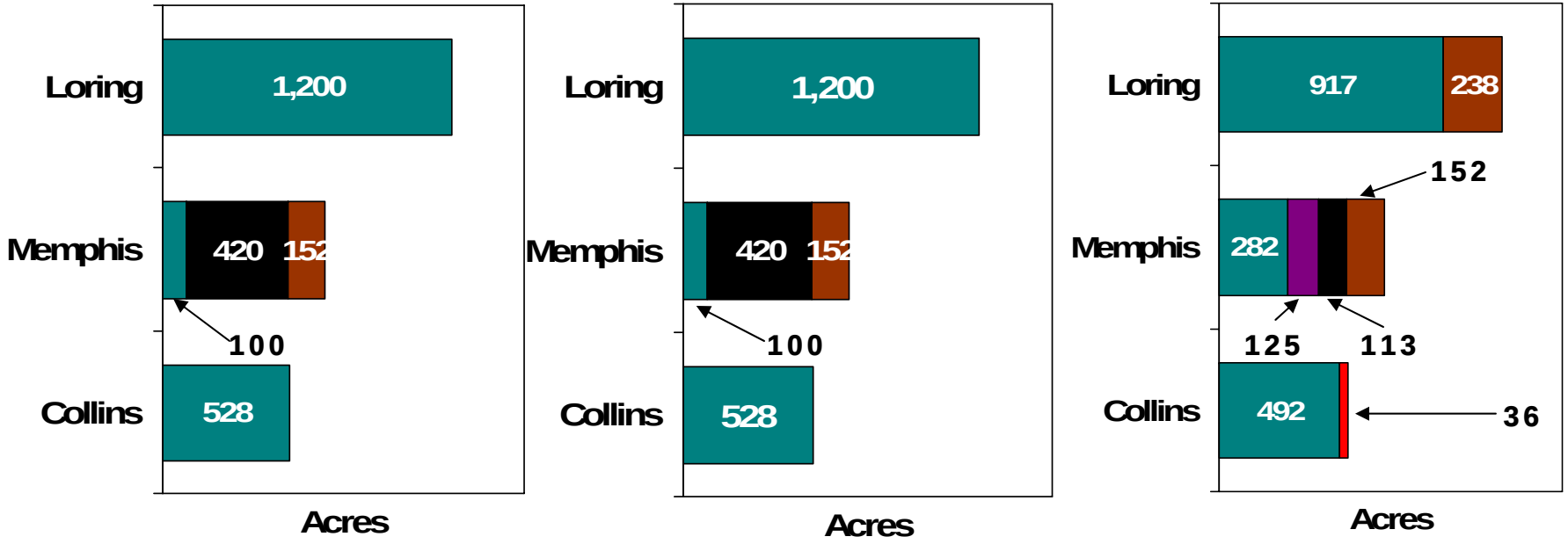
- **100 years of yields for each crop alternative were simulated for each crop and soil type using ALMANAC and 100 years of daily weather data.**
- **100 years of correlated crop, fertilizer nitrogen, and diesel fuel prices for each crop alternative were simulated using @RISK:**
  - Tennessee average yearly corn, soybean, and wheat prices for 1977 through 2006 were used to calculate distribution parameters for each crop price distribution (Tennessee Department of Agriculture, 1978-2006 Annual Issues).
  - Price data for estimating the nitrogen fertilizer and diesel fuel distribution parameters were obtained using 1977 through 2006 prices reported in *Agricultural Statistics* (USDA-NASS, 1977 through 2007 Annual Issues).
  - Net energy-equivalent to wholesale gasoline biomass prices (accounts for energy to convert to ethanol) for 1977-2004 were used to calculate prices and distribution parameters for @RISK Wang et al., 1999; U.S. DOE, 2007).
  - Prices were inflated to 2006 dollars by the Implicit Gross Domestic Product Price Deflator (U.S. Congress, Council of Economic Advisors, 2007).
  - Inflated prices then were detrended using procedures described by Pelletier (2002) to remove the long-term downward trend in real crop prices.
- **Production costs from Tennessee Extension budgets (Gerloff,2007a; 2007b).**

Representative Farm Quadratic Programming Model

- Net revenue means and variance-covariance matrix constructed using potential crop activities.
- The main resource constraints were for soil type, labor and straw and stover harvest periods.
- Land for each soil type was restricted to 1,200 acres of Collins soils, 528 acres of Loring soils, and 672 acres of Memphis soils.
- Six bimonthly labor periods were specified in the model. Labor requirements by period were from University of Tennessee crop budgets (Gerloff, 2007a; 200b). Labor availability by period was for a family of four (Johnson, 1991).
- It was assumed that the farm could hire an additional 2,000 hours of labor per year at $8.50/hour (Gerloff, 2007a;2007b). Hired labor was assumed to have an efficiency of 90% (Musser et al., 1984).

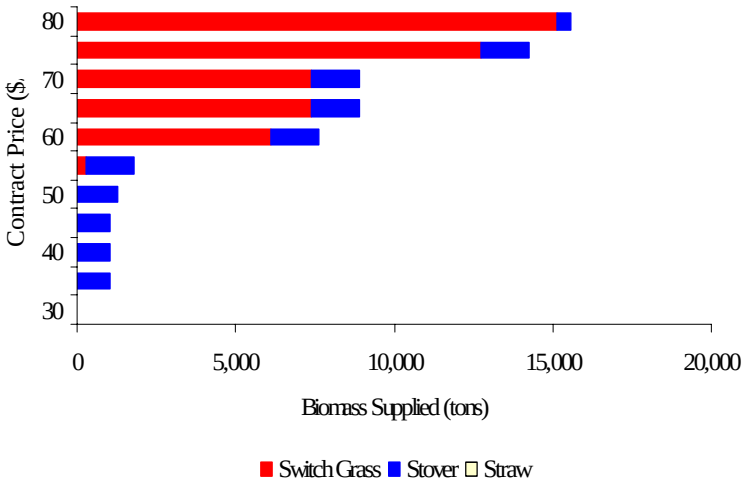
Base and SPOT Contract Scenario Results

Statistic	No Biomass Crops	With Biomass Crops	
		Risk Neutral	Risk Averse
Mean NR	$472,175	$472,175	449,666
Std Dev NR	$152,926	$152,926	$139,154
Biomass	------	0 dt	324dt



Biomass Supplied Under the STANDARD Contract Results

Risk Neutral Decision Maker--STANDARD Contract on 75% of Expected Yield with No Planting Incentive



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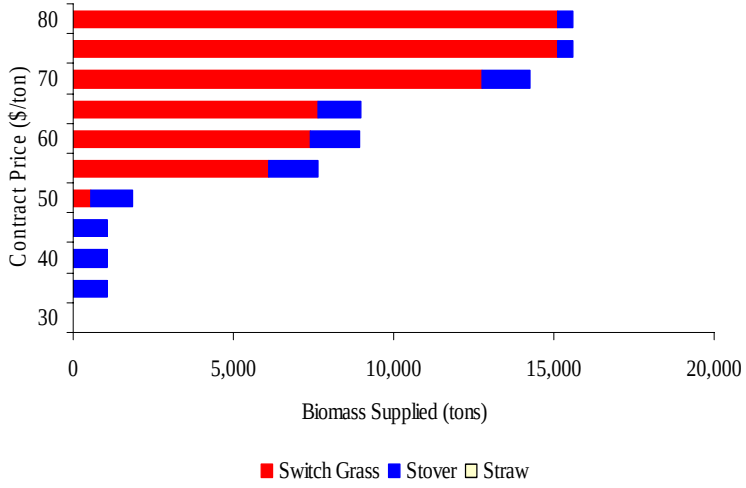
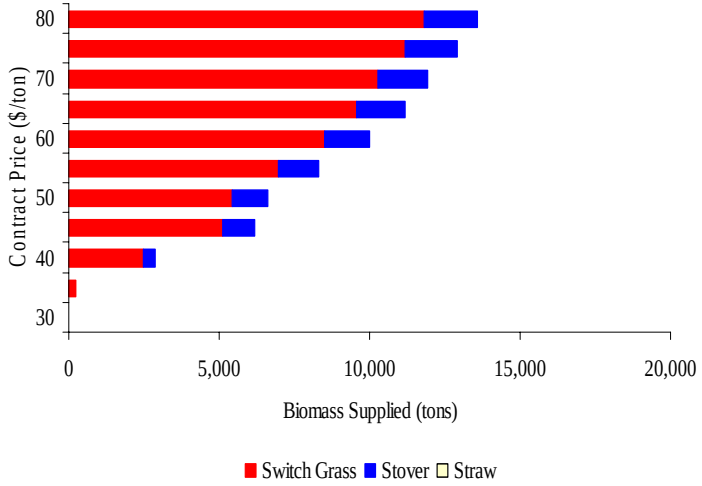
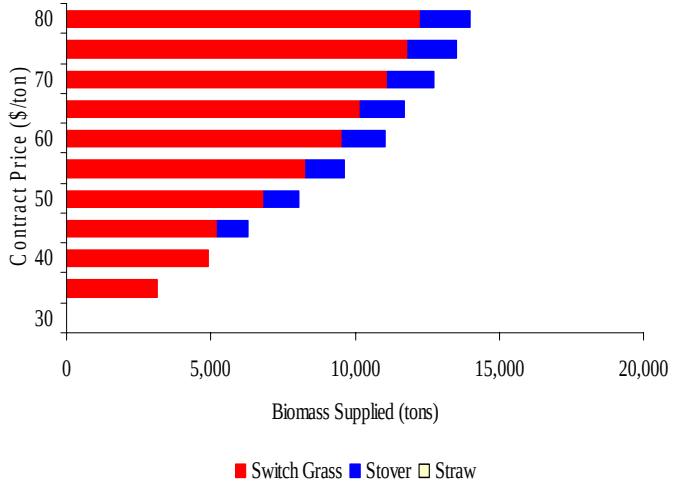


Risk Averse (ρ= 0.000017)Decision Maker--Standard Contract on 75% of Expected Yield with No Planting Incentive

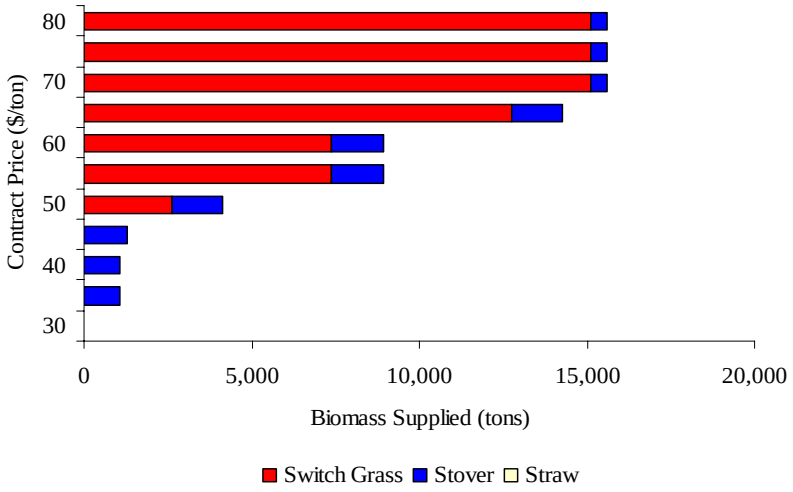


Risk Averse (ρ = 0.000017) Decision Maker--Standard Contract on 75% of Expected Yield with Planting Incentive

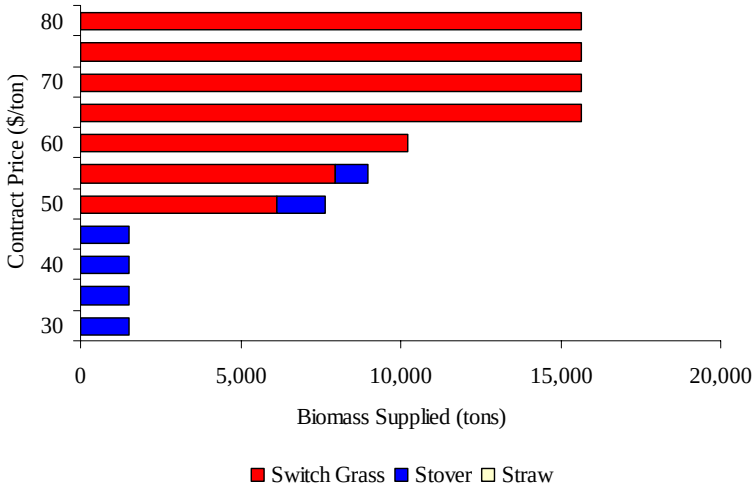


Biomass Supplied Under the ACREAGE Contract Results

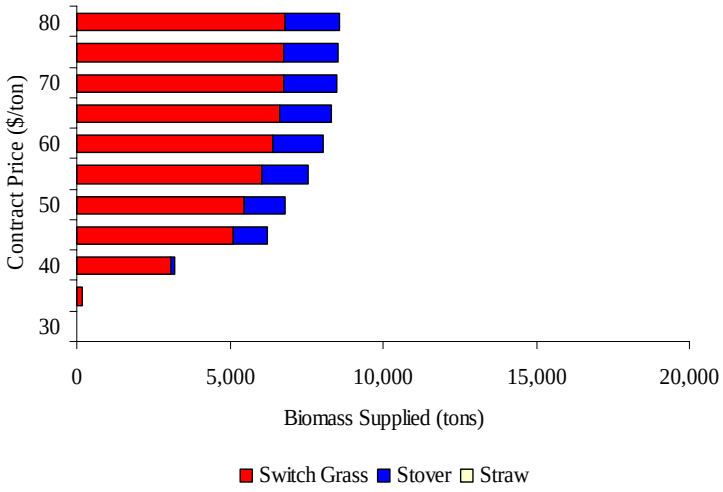
Risk Neutral Decision Maker--Acreage Contract
No Planting Incentive Contract



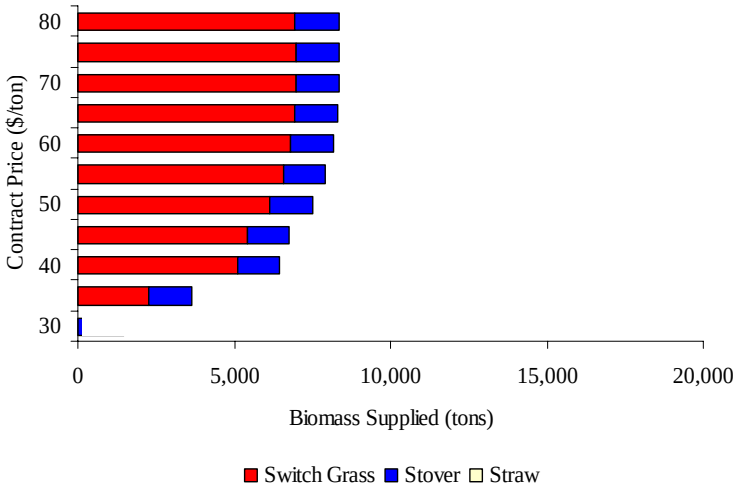
Risk Neutral Decision Maker--Acreage Contract
With Planting Incentive Contract



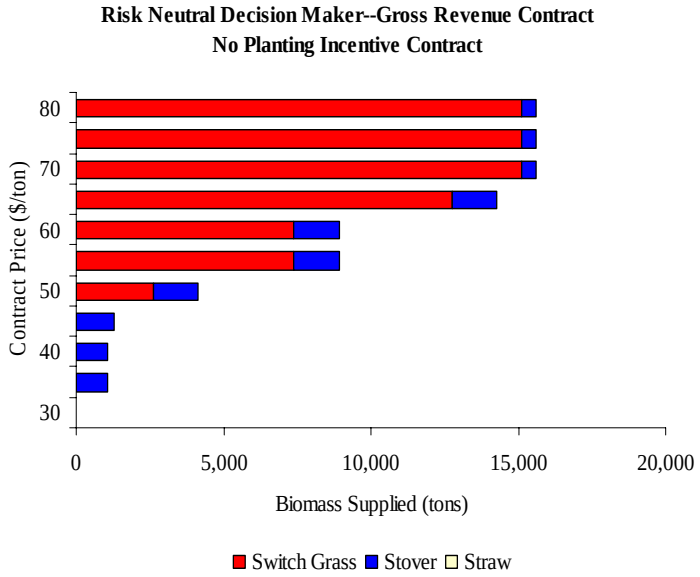
Risk Aversion (roh = 0.000017) Decision Maker--Acreage Contract , No Planting Incentive Contract

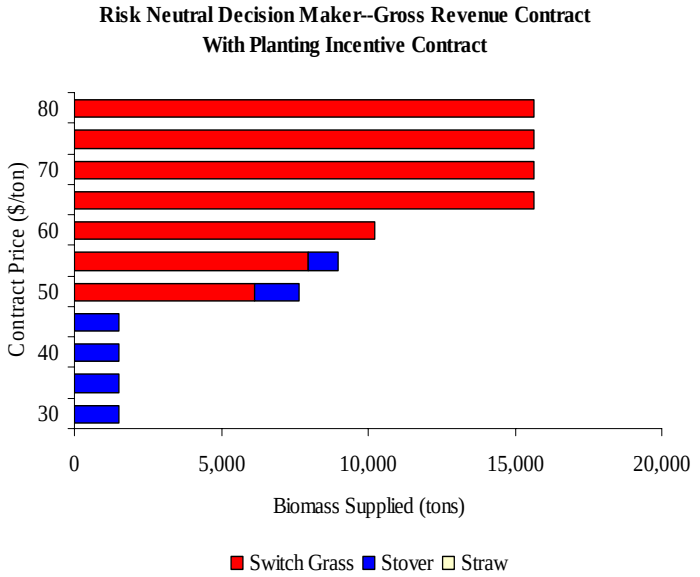


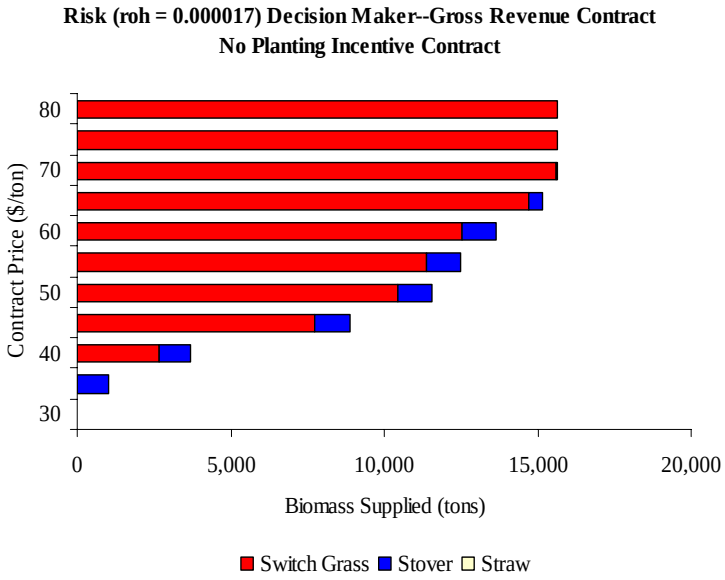
Risk (roh = 0.000017) Decision Maker-- Acreage Contract With Planting Incentive Contract

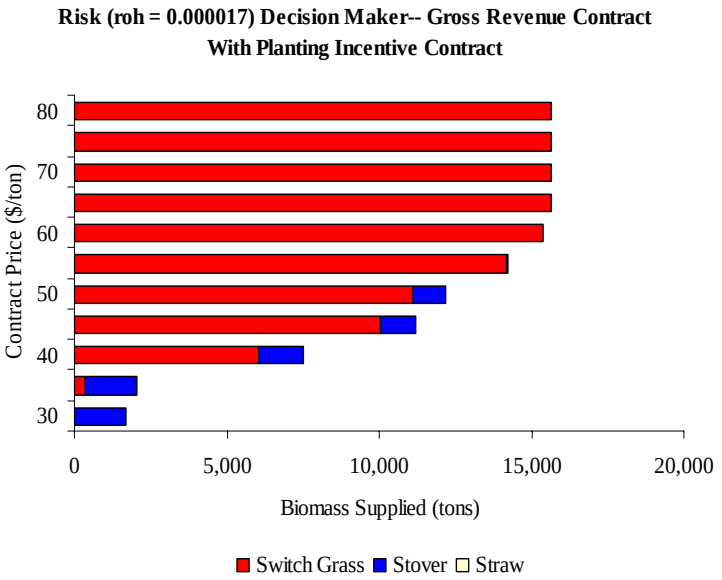


Biomass Supplied Under the REVENUE Contract Results

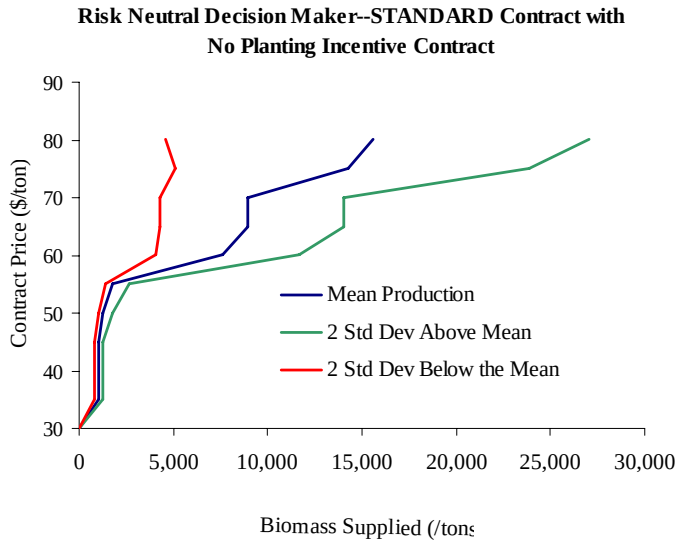


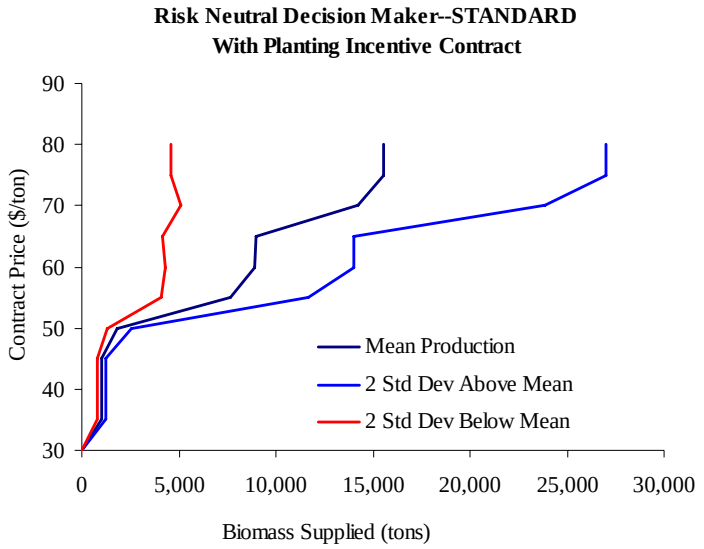


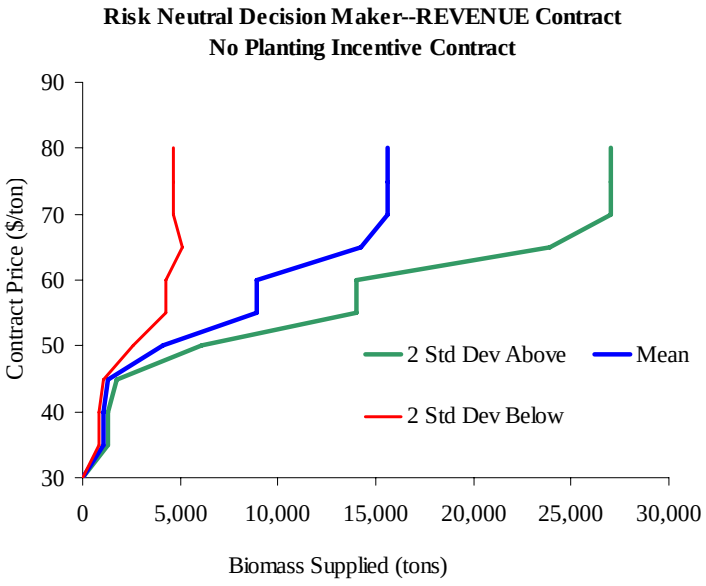


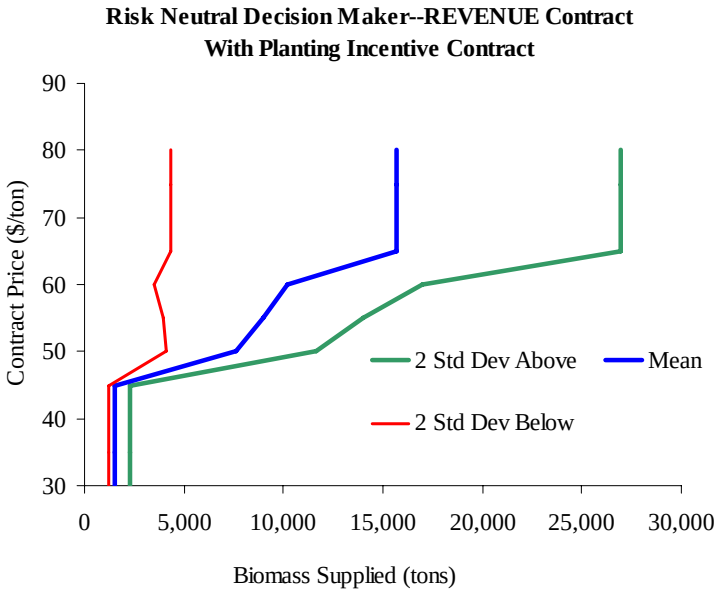


Variability of Biomass Supplied









Summary and Conclusions

- First, under the SPOT contract, the net revenues from biomass crops were not high enough induce biomass production.
- Second, the ACREAGE and REVENUE contracts were more effective at inducing maximum farm biomass production at lower contract prices than the STANDARD contract for a risk neutral decision maker.
- Under risk neutrality, the same amount of biomass was supplied under the REVENUE contract as under the ACREAGE contract.
  - Expected biomass crop net revenues were identical for both contract structures.

Conclusions

- Most of the biomass supplied under the STANDARD, ACREAGE, and REVENUE contracts was from switchgrass.
- Some corn stover was produced but no wheat straw was supplied for ethanol production.
- Third, because the REVENUE contract reduced biomass crop net revenue variability relative to the ACREAGE contract, the REVENUE contract provided more risk benefits under risk aversion.
- In addition, because of the greater price and yield protection offered with the REVENUE contract, swtichgrass production was generally induced at lower contract prices than with the STANDARD contract.

Conclusions

- Fourth, a planting incentive to offset part of the cost of establishing switchgrass may be effective at inducing larger biomass production at lower contract prices.
- The incentive may provide a method for the processor to reduce average per ton cost of material at the plant gate for perennial biomass crops such as switchgrass.
- Finally, as more of the farm crop area was planted into biomass crop at higher contract prices, the greater the annual variation in biomass supplied to the processing plant.