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

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Introduction

Farmers, agribusiness, policymakers, and others have shown considerable interest in the potential for on-farm production of lignocellulosic biomass for energy production (English *et al*., 2006). Perlack *et al*. (2005) estimates that more than a billion tons of lignocellulosic feedstock such as corn stover, wheat straw, and switchgrass could be produced annually in the United States. Compared to other agricultural commodities, transportation costs from grower to processor for lignocellulosic biomass feedstocks will be relatively high, due to the bulkiness and low energy density of lignocellulosic feedstocks. This transportation cost factor will likely result in a more locally-grown market situation for biomass feedstock. Thus, the development of biobased industries, at least initially, will hinge on the local availability of sufficient, cost competitive biomass feedstocks.

One possible alternative for supplying biomass to the biorefinery 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). This research analyzes the potential of a West Tennessee grain farm to supply lignocellulosic biomass under contract to a biorefinery. Under this market scenario, the processor likely will have an interest in providing production contracts or other incentives to induce farmers to supply sufficient feedstocks to keep the plant operating at capacity.

A number of factors may influence farmers' willingness to supply biomass feedstocks such as corn stover, wheat straw, and/or switchgrass to a local processing facility. For example, how do biomass crops such as switchgrass compare to traditional crops with respect to costs of production, yields, price potential in terms of its energy equivalent to gasoline or coal, net returns, and risk (variability of net revenues) under different management practices, weather conditions, energy market conditions, government policies, and contract pricing arrangements provided by the processing plant? Supplying biomass feedstocks will require changes in the way farmers manage their operations.

The ability of farmers to respond to a potential market for biomass feedstocks will be constrained by on-farm economic, structural, and resource constraints (e.g., time constraints, equipment constraints, land ownership, debt structure, farm size, production activities (i.e., crop, livestock), soil type and topography, farm program participation, etc.). For example, who would pay for investment in perennial crop establishment, harvest equipment, and storage for the biomass? Would the farm have enough labor resources to grow and harvest the crop? Farmers who must bear all of the feedstock price, production risks, and financial risks may not be willing to supply biomass or be willing to supply limited amounts of biomass at all to a processing facility. The willingness of farmers to provide biomass feedstocks will be a function of biomass feedstock profits, variability of profits, and correlation of profits relative to traditional crop profits. These factors will vary with respect to the contractual incentives that may be offered by the processing facility. Thus, an understanding of the factors that will affect farmer decisions to supply biomass feedstocks is essential.

Currently, research about the potential risks and risk management benefits of on-farm biomass production is lacking. In addition, analysis of the impacts of potential biomass contract structures on risk and return and farmer willingness to supply biomass is also limited. Larson *et al*. (2005) evaluated the risk management benefits of a marketing contract with a penalty for production underage or excess production is sold at the spot market price based on the energy equivalent value as a substitute for gasoline on farmer willingness to supply switchgrass, corn stover, or wheat straw. However, the Larson *et al*. (2005) study did not evaluate other potential contract alternatives such as acreage contracts (Paulson and

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Babcock, 2007), gross revenue contracts (Garland, 2007), or other financial incentives that could be used to induce on-farm biomass production for a processor. Thus, the objective of this research is to evaluate the ability and willingness of farmers to provide lignocellulosic biomass feedstocks under risk given their on-farm situation and potential contractual arrangements with user facilities.

Methods and Data

A farm-level model was developed to evaluate contract biomass feedstock production under risk for a northwest Tennessee 2,400 acre grain farm. The farm was assumed to produce corn, soybeans, and winter wheat (Tiller, 2001). The representative farm also was assumed to have the opportunity to provide biomass feedstocks to a local single-user facility that produces ethanol. The farm was assumed to be able to produce three energy crop production alternatives: corn stover, wheat straw and switchgrass. Thus, the representative farm had the choice between producing corn grain only or corn grain and corn stover. Similarly, the representative farm could produce wheat grain only or wheat grain and wheat straw for sale to individual, wholesalers, and retailers or wheat straw for ethanol production.

A quadratic programming model incorporating farm labor and land quality constraints, biomass yield variability, crop and energy price variability, alternative contractual arrangements, and risk aversion was developed for the analysis. The objective function was to maximize the certainty equivalent value of whole farm net revenues for different levels of risk significance (McCarl and Bessler, 1989). Risk significance levels (α) of 50, 60, 70, 80, and 90 percent were used to generate risk-efficient farm plans for different levels of absolute risk aversion. The risk levels model the certainty of obtaining or exceeding a maximized lower level confidence limit on net revenues (Dillon, 1999). Thus, for a risk neutral decision maker a 50% percent certainty that the actual net revenues will meet or exceed expected net revenues. For risk-averse decision makers, a higher probability of certainty is required on net revenues; thus, risk significance levels (α) of higher than 50% is required.

The three resource constraints specified in the model were for soil type, labor, and available field days for wheat straw and corn stover harvest. Total land was restricted to 2,400 acres and 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 crop budgets by Gerloff (2007a; 2007b). Labor availability by period was for a family of four (Johnson, 1991). In addition to family labor, it was assumed that the farm could hire an additional 2,000 hours of labor per year at $8.50/hour (Gerloff, 2007a). Hired labor was assumed to have an efficiency of 90% in the model to account for the extra management time for the farm operator (Musser, Mapp, and Barry, 1984). The number of suitable days available to harvest corn stover and wheat straw after grain harvest was constrained to 21-10 hour days. For the soybean-wheat double crop, the available days to harvest straw between the wheat grain harvest and the planting of the soybean crop was assumed to be 10-10 hour days.

The potential biomass contracting alternatives modeled for the West Tennessee representative crop farm were: 1) a spot market contract (SPOT) where biomass is priced yearly on its current energy equivalent value as a substitute for gasoline at the processing plant gate, 2) a standard marketing contract (STANDARD) with a penalty for production underage or excess production is sold at the spot market price (Musser, Mapp, and Barry, 1984; Paulson and Babcock, 2007), 3) an acreage contract (ACREAGE) which provides a guaranteed annual price on the actual biomass produced in each year on the contracted biomass acreage (Paulson and Babcock, 2007), and 4) a gross revenue contract (REVENUE) which 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).

The four potential types of contracts that could be used to encourage biomass production offer different levels of biomass price, yield, and production cost risk sharing between the representative farm and the processor. The SPOT contract assumes that all of the output price, yield, and production cost risk from biomass production is borne by the farmer. With the STANDARD contract, a portion of the price risk on expected production is shifted from the producer to the biorefinery. All of the price risk is shifted from the farmer to the processor with an ACRAGE contract but the farmer still incurs the entire yield and production cost risk. On the other hand, the gross revenue contract provides the greatest potential risk benefits to the farmer because all of the biomass price and yield risk is assumed by the processor. In addition, a contract provision for switchgrass that provides a financial incentive to reduce production cost risk by covering the materials cost of establishing the switch grass stand was also modeled. The gross revenue contract and the planting incentive are two potential switchgrass production incentives that are being consider for contract production for the cellulosic ethanol pilot plant being constructed for Tennessee Biofuels Initiative (Garland, 2007). The time period for each of the four types of contracts modeled was assumed to be 5 years (Garland, 2007).

A 99 year distribution of net revenues for each the crop activity was simulated for use in the quadratic programming model to determine risk-efficient farm plans under the alternative contracting scenarios. The variables treated as random in the simulation of net revenues were crop prices, crop yields, nitrogen fertilizer price, diesel fuel price, and selected biomass harvest and transportation costs as a function of harvested yield. The ALMANAC crop model (Kiniry *et al*., 2005) was used to simulate random crop yields for the continuous crop and crop rotations on the Loring, Memphis, and Collins soils for the representative farm. A 99 year set of real, detrended, and correlated prices for corn, soybeans, wheat, wheat straw, corn stover, switch grass, nitrogen fertilizer, and diesel fuel were simulated using the @Risk simulation model in Decision Tools (Palisade Corporation, 2007). Energy equivalent price series for switchgrass, corn stover, and wheat straw as an ethanol based energy substitute for gasoline were constructed using wholesale gasoline price data for 1977 through 2004 (U.S. DOE, 2008) and biomass conversion to ethanol factors from Wang, Saricks, and Santini (1999). The number of gallons of ethanol assumed to be produced per dry ton (dt) of biomass was assumed to be 69.2 gallons for wheat straw, 72 gallons for corn stover, and 76 gallons for switchgrass. Contract prices for corn stover and wheat straw were adjusted downward by 5 percent and 9 percent, respectively, from the contract price for switchgrass to reflect the lower gallons per dt produced.

Corn, soybean, wheat, and soybean-wheat production costs were derived from University of Tennessee Extension budgets (Gerloff, 2007a). All three biomass crops were assumed to be harvested using a large round bale system with the bales being moved to the edge of the field before transport to the user facility. Switchgrass production costs were estimated using a budget produced by University of Tennessee Extension (Gerloff, 2007b).

Results and Discussion

The important findings from this research were as follows. First, under the SPOT scenario, biomass prices averaged \$27.68/dt (standard deviation of \$9.34/dt) for wheat straw, \$29.44/dt (standard deviation of \$15.50/dt) for corn stover, and \$34.77/dt (standard deviation of \$7.43/dt) for switchgrass. When biomass crops were priced annually based on the energy equivalent price, the production of biomass crops did not enter into the optimal crop mix for any risk significance level except the most risk-averse 90 percent level. For this level of risk aversion, only 36 acres on switchgrass was planted on the poorest quality Collins soil. No other biomass crops were planted on the rest of the farm. Thus, an average of only 324 dt of biomass would be supplied by the representative farm under the SPOT contract scenario. In general, the net revenues from biomass crops were not high enough under SPOT contract prices to induce biomass production Results indicate that a contract price above the energy equivalent price would be needed to encourage biomass production on the representative farm.

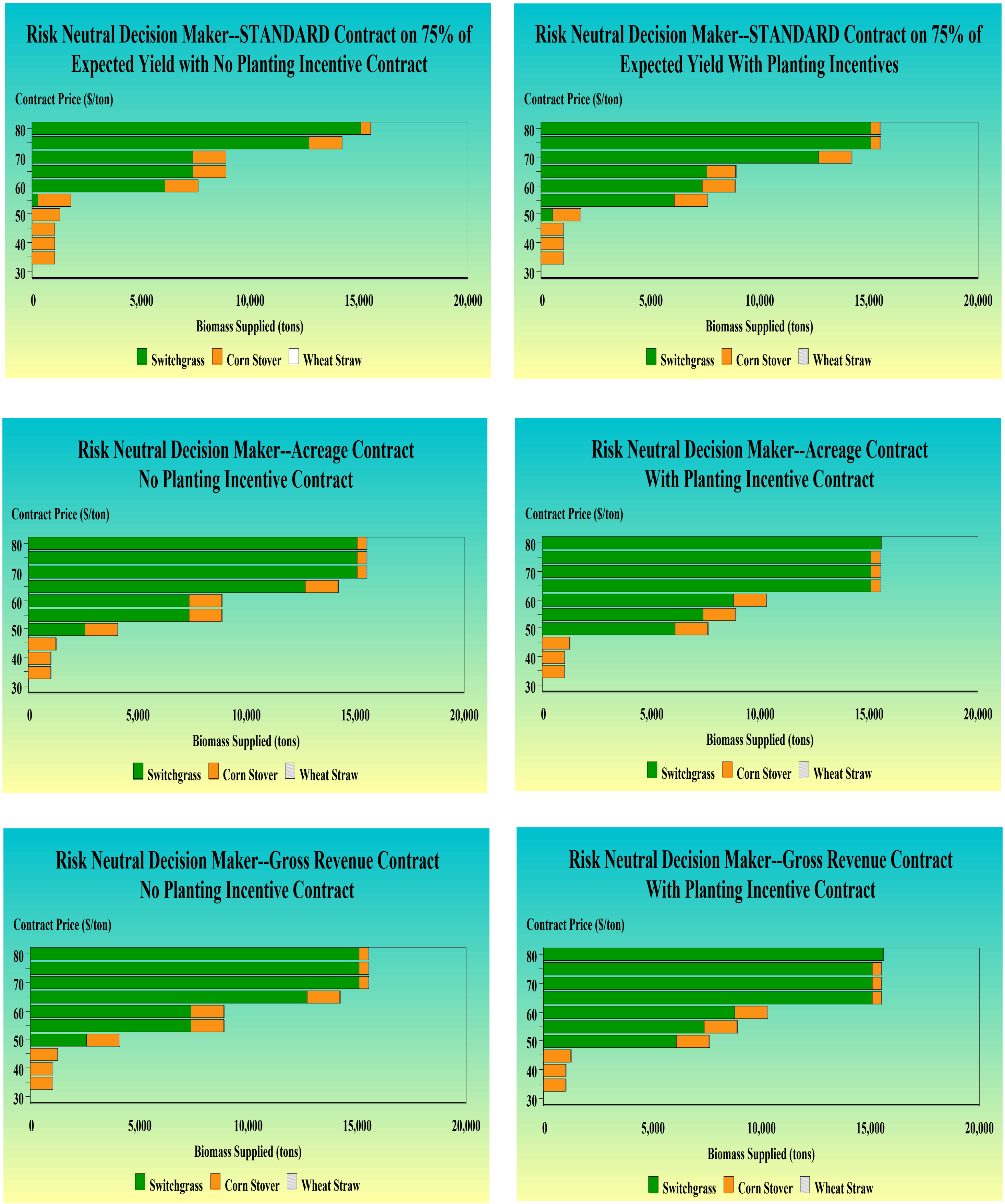
Second, the ACREAGE and REVENUE contracts were more effective at inducing maximum farm biomass production at lower contract prices than the STANDARD contract for a risk neutral decision maker (Figure 1). Under the assumption of risk neutrality, the same amount of biomass was supplied by the representative farm under the REVENUE contract as under the ACREAGE contract. Expected biomass crop net revenues were identical for both contract structures. Most of the biomass supplied by the representative farm under the STANDARD, ACREAGE, and REVENUE contracts was from switchgrass. In addition, some corn stover was produced but no wheat straw was supplied for ethanol production by the representative farm.

Third, because the REVENUE contract reduced biomass crop net revenue variability relative to the ACREAGE contract, the REVENUE contract provided more risk benefits to the representative farm under the assumption of risk aversion (Figure 2). In addition, because of the greater price and yield protection offered with the REVENUE contract, switchgrass production was generally induced at lower contract prices than with the STANDARD contract. Fourth, results of this study suggest that a planting incentive to offset part of the cost of establishing switchgrass may be effective at inducing biomass larger 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 crops at higher contract prices, the greater the annual variation in biomass supplied to the processing plant. Thus, for a biorefinery, there may be a relationship between the annual variation in biomass material supplied and the cost of biomass materials. A higher contract price may induce more production on an individual farm. This could result in fewer farms in a more concentrated geographic area being needed to supply the plant. The biomass materials transportation cost may be lower but the biomass storage cost incurred to ensure a steady supply of feedstock to the plant may be higher with the increased variability of annual biomass production with higher contract prices.

Summary and Conclusions

This study evaluated the potential for a northwest Tennessee 2,400 acre grain farm to supply lignocellulosic feedstock to a biorefinery under alternative contract arrangements. The four potential types of contracts analyzed in this study offer different levels of biomass price, yield, and production cost risk sharing between the representative farm and the processor. Results indicate that a contract price above the energy equivalent price in a spot market type contract would be needed to induce biomass production on the representative farm. A contract that makes annual payments based on the



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

Risk Neutral Decision Maker--STANDARD Contract on 75% of Expected Yield With Planting Incentives

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

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

Risk Neutral Decision Maker--Gross Revenue Contract No Planting Incentive Contract

Risk Neutral Decision Maker--Gross Revenue Contract With Planting Incentive Contract

Figure 1. Representative Farm Biomass Supplied at Different Contract Prices for the STANDARD, ACREAGE, and REVENUE Contract Scenarios Assuming a Risk Neutral Decision Maker

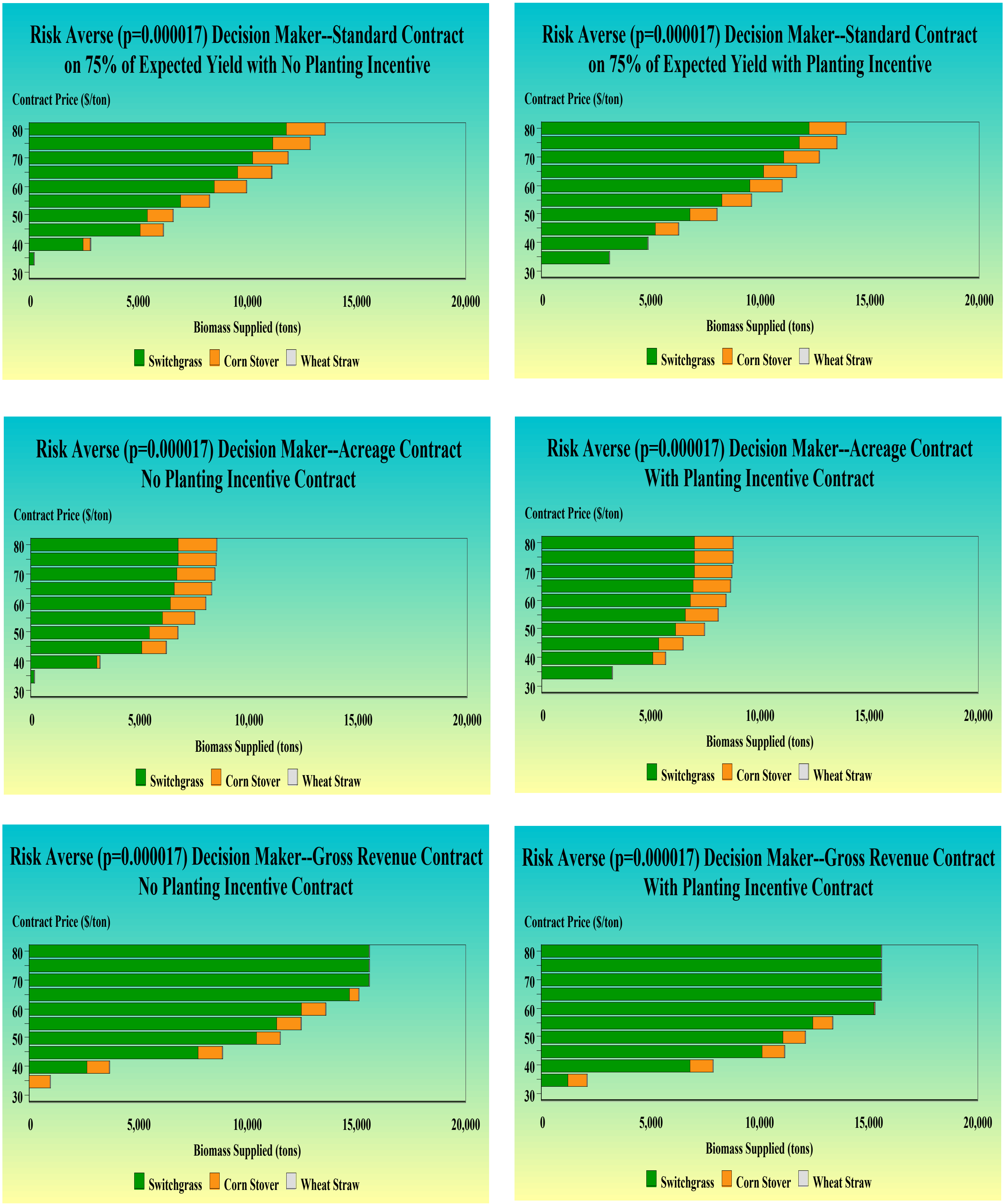


Figure 2. Representative Farm Biomass Supplied at Different Contract Prices for the STANDARD, ACREAGE, and REVENUE Contract Scenarios Assuming a Risk Averse Decision Maker (90 Percent Risk Significance Level)

expected biomass yield over the life of the contract rather than on annual yield induced the largest amount of production (primarily switchgrass) under risk aversion. Because of the price and yield protection offered with more this type of contract, biomass production was generally induced at lower contract prices. In addition, a contract with a provision to offset part of the cost of establishing a perennial crop such as switchgrass may be effective at inducing larger biomass production at lower contract prices. Finally, the annual variation in biomass supplied to the biorefinery was larger as more of the farm crop area was planted into biomass crop at higher contract prices. The increased variability in biomass production has implications on storage and transportation costs for a biorefinery needing a steady, year-round supply of biomass materials for processing.

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