Abstract

This study estimates the profitability of double-cropping systems as a source of livestock feed and the cost per ton of dry matter as source of lingocellulosic feedstocks for ethanol production. Crop yields were measured from full season and winter wheat double-crop plot trials at the Purdue University Agronomy Center for Research and Education during 2008 and 2009. Enterprise budgets were constructed to estimate annual net returns and cost of production per ton of dry matter. Results indicate wheat grain double-crop systems have the potential to allow farmers to serve both markets.

Economic Analysis of Biomass Production Utilizing Winter Wheat Double-Cropping

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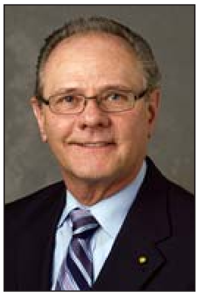
Introduction

Farmers have entered a new era in which they are expected to provide not only food, feed, and fiber, but also fuel (Tyner, 2008). Increasing the per-acre quantity of agricultural products to satisfy these demands is a significant scientific challenge. The increase in the demand for biofuels in the form of corn ethanol has had a major effect on grain markets. In order to satisfy this demand increase, cropping systems in the Midwest have evolved to a greater reliance on the corn (*Zea mays L.*) – soybean (*Glycine max L.*) rotation or even corn-corn (Stranger and Lauer, 2003). However, rotations of continuous corn and corn-soybeans cannot be sustained without substantial additions of fertilizers (Pimentel et al., 1995). Many have expressed concern about groundwater contamination, soil erosion, depletion of fossil fuel resources, and risks to human health and wildlife habitats they perceive accompanying this cropping system. (Reganold et al., 1990).







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The ability to produce ethanol from lingocellulosic[1] biomass may provide the possibility for Midwestern farmers to diversify their cropping systems. Cellulosic biomass is the nonstarch, fibrous part of the plant material and is attractive as an ethanol feedstock because it is renewable and abundant (Perlack et al.) Perennial crops such as poplar (*Populous spp.*), switchgrass (*Panicum virgatum L.*), mixed grasses, or miscanthus (*Miscanthus sinenis A.*) have been explored (James et al., 2010). These crops will require Midwest farmers to develop new production skills and modify existing production, harvest, and storage systems. These crops also commit farmers to biomass production for multiple years (John & Watson, 2007). The production of these perennial crops reduces producers' flexibility to respond to market price signals as market conditions change.

An alternative source of cellulosic feedstock for ethanol production is the use of crop residues. Corn stover and wheat straw are readily available, but formal markets and a transport system for the products does not currently exist (Malcom, 2008). These also seem to be an expensive source of biomass (Erickson et. al, 2011).

In parts of the Midwest, cropping systems could be altered to focus on more double-crop production. Double-cropping is popular in the southeastern U.S. where winter wheat (*Triticum spp.*) is a major crop grown in rotation with summer soybean, corn, sorghum (*Sorghum bicolor L.*), and cotton crops (*Gossypium L.*) (Kumar et al., 2007). Winter wheat with soybean double-crop is common in the southern areas of the Midwest. Shifting focus from grain to livestock feed or ethanol feedstock production allows an increased number of double-crop possibilities with winter wheat. Winter wheat combined with corn silage, grain sorghum, sorghum silage, and sweet sorghum silage are possibilities. Farmers are familiar with production practices for these species and these crops are produced with the machinery that is already on the farm for grain and silage production. These cropping systems are combinations of annual crops, providing a farmer flexibility to adjust to market signals from year to year.

Objective

Based on the assumption that farm owners aim to maximize expected profitability from crop production, this study's objective is to evaluate the profitability of thirteen double-crop production systems providing livestock feed. The study also estimates the cost of producing a ton of dry matter to determine which systems might be most competitive as an ethanol feedstock. Overall, this study intends to answer the question of how profitable these alternative cropping systems are expected to be and whether they will be competitive with corn, soybean, and wheat production. The study expects to find a set of double-crop systems that include cellulosic feedstock crops that will be economically competitive.

Data and Methods

Expected annual net returns are the prevailing factor determining the adoption of a new farming system (Wesley, et. al, 1995). Estimating differences in annual net returns among crop systems requires identifying differences in crop yields, variable production costs, and fixed costs of production systems. Field experiments were conducted with thirteen winter wheat double-cropping systems (Figure 1) at the Purdue University Agronomy Center for Research and Education (ACRE) in West Lafayette, Indiana.

Total grain yield, residue produced, and harvest moisture percentage were recorded for each of the plots. There were thirteen double-crop production systems, evaluated using randomized complete block design with four replicates in two growing seasons: 2007-2008 and 2008-2009. The plots were 15 feet wide and 30 feet long. In addition to the double-crop combinations listed in Figure 1, full-season crops of corn, soybeans, winter wheat, and grain sorghum were planted. All crops following winter wheat were seeded into wheat stubble using no-till practices. Each crop was managed using best management practices for that species. A complete list of specific hybrid lines, planting dates, harvest dates, and detailed enterprise budgets are presented in Navarro (2010).

The economic analysis was performed by developing per-acre enterprise budgets, based on the agronomic production data from ACRE, taking into consideration specific inputs applied and yields achieved. The profit potential of the winter wheat double-crop systems was determined by combining individual enterprise budgets.

To calculate total revenue for each crop system, the average yield from the ACRE plots is multiplied by the market value of grain in Indiana during the corresponding harvest month (USDA/NASS, 2009).

There is no formal market for green chop and silage crops, therefore a per-ton price was taken from relationships reported in the literature. For corn and sorghum silage, price was based on the price of corn grain. A corn silage price was determined using a relationship between corn and corn silage developed by Massey and Horner. This relationship is presented in equation 1. The net price of corn used in this approach is the grain price adjusted for grain harvest cost, grain drying and hauling, and value of stover removal. The sorghum silage price was determined using a relationship between corn and sorghum silage developed by Dumler (2008). This relationship is presented in equation 2.

1) Corn silage price ($/ton)=
Net price of corn grain ($/bu.) x 8
2) Sorghum Silage Price ($/ton) =
Price of Corn Grain ($/bu.) x 8 x 80%

The price of winter wheat green chop and silage was based on relationships developed by Edwards (2009). Using the yield results of the field plots at ACRE, each ton of winter wheat green chop was estimated to be equivalent to 4.55 bushels of grain. For the winter wheat harvested as silage at mid-grain stage, a grain to silage ratio of 4.65 was used. The price of green chop or silage was determined by multiplying these two parameters by the harvest price of wheat.

Direct and overhead charges were estimated for each production system. The cost estimates represent the costs producers would incur if they adopt any of the double-crop combinations under review. Cost data for this study were collected from a variety of primary and secondary sources and represented 2009-2010 conditions in the state of Indiana (Edwards & Smith, 2008; Miller, et. al., 2009).

Budget direct costs included the following: seed, fertilizer, chemicals, fuel to dry the crop to a safe moisture level for storage, machinery operation (including fuel, oil and repairs), crop insurance, miscellaneous costs, and interest on direct costs. Budget overhead costs take into account labor (adjusted for the labor hour requirements for each particular crop), machinery fixed charges, drying and handling equipment investments, and land. Shared annual overhead charges occurred between double-crop systems that have the same harvest machinery requirements, such as wheat, grain, and soybeans where the same combine can be used for both crops. With other combinations there is a need for additional machinery investments; an example of this would be wheat, grain, and corn silage. In this case the full overhead cost of machinery to harvest grain is allocated to grain budgets and the full overhead cost of machinery to harvest silage is to silage budgets. One-half of the double-crop annual land charge is allocated to winter wheat and one-half was allocated to the following crop.

Net returns per acre were calculated by subtracting total charges from total revenue. For details about the estimated costs see Navarro (2010). To compare annual net returns and dry matter costs across each double-cropping system, winter wheat harvesting possibilities were paired with the companion crop. Full season crops represented annual cropping systems with no winter wheat grown as a previous crop.

Results

Table 1 reports the estimated crop price, average yield, and annual net return for each crop. The full season crops of corn grain, soybeans, sorghum silage, and wheat grain provided positive annual net return. Soybeans provide the highest annual net return at $80 per acre. For the other single crops, grain sorghum, corn silage, wheat silage, and wheat green chop all had a negative annual return. Sorghum silage provided an average annual net return of $68 per acre and corn grain provided an average annual net return of $36 per acre.

For crops planted after winter wheat grain, soybeans had a negative annual net return and sorghum silage and sweet sorghum silage provided a positive annual net return. Harvesting wheat as silage rather than grain provides a longer growing season for the crop planted after the silage harvest. When harvesting wheat as silage, all of the crops planted after harvest except for sorghum grain have a positive estimated annual net return. All crops but corn silage planted after wheat green chop have a positive estimated net return.

Table 2 reports the annual net return for each full season and double-crop combination and the cost of producing a ton of dry matter. Table 2 ranks the cropping systems from the most profitable to the least profitable. Winter wheat grain followed by sorghum silage had the highest average annual net return of all the cropping systems under review with $244 per acre. Winter wheat silage in combination with sweet sorghum silage and sorghum silage ranked second and third most profitable with average annual net return of $165 per acre and $130 per acre, respectively. Full season soybeans were the fourth most profitable cropping system with $80 per acre, followed by sorghum silage. Winter wheat silage double-cropped with corn silage ranked sixth with $54 per acre. Full season corn grain ranked seventh with average annual net return of $36 per acre. Winter wheat silage followed by soybeans, winter wheat grain with sweet sorghum silage, and winter wheat green chop with soybeans rank in eighth, ninth and tenth place in annual net returns, respectively. The rest of the cropping systems under review resulted in negative average annual net return ranging from -\$9 per acre from winter wheat grain in combination with soybeans to -\$181 per acre from winter wheat green chop with corn silage.

Since cellulosic feedstock will be a commodity, low production costs will be important to profitability. The cost per ton of dry matter associated with the double-crop combinations generally were less than corn grain, soybeans, and grain sorghum grain. Annual crops of corn silage and sorghum silage were cost competitive with several of the double-crop combinations.

The large amount of yield produced by the double-crop combination of wheat silage and sorghum silage resulted in this system having the lowest cost per ton of dry matter at \$67 per ton. The next lowest cost per ton of dry matter was the single crop of sorghum silage at \$72 per ton. Soybeans had the highest cost per ton of dry matter at \$303 per ton. The small amount of crop residue produced by soybeans does not make it a potential cellulosic feedstock. Only dry matter from soybean grain was accounted for in this study. As a result double-crop alternatives containing soybeans were the most expensive per ton of dry matter.

The cost per ton of dry matter for double-crop combinations generally exceeded the cost of biomass from corn grain, corn silage and sorghum silage. For this set of crops sorghum silage provided the lowest cost per ton of dry matter.

Conclusions

Profitably is the prevailing factor determining the adoption of a new farming system (Wesley, 1995). Based on the assumption that farm owners aim to maximize expected profitability from crop production, this study evaluated the profit potential of thirteen double cropping systems established at the Agronomy Center for Research and Education at Purdue University, Indiana. The double-cropping systems were explored to determine if they provide a more profitable method of providing livestock feed. The cost per ton of dry matter was also calculated to provide an indication of which systems might be competitive sources of cellulosic feedstock for ethanol production.

The double-cropping systems all involved the use of winter wheat. The wheat was harvested as grain, silage, or green chop. Harvesting wheat as silage or green chop allows the following crop to be planted earlier in the growing season than if wheat was harvested as a grain crop. Crops combined with wheat to create double-cropping systems included grain crops of corn, soybeans, and sorghum, and silage crops of corn, sorghum, and sweet sorghum. In addition to the double-crop systems under review, five full season (single) crop systems were also considered. These systems were soybeans, corn grain, corn silage, sorghum grain, and sorghum silage. To estimate the average annual net return and cost per ton of dry matter, enterprise budgets were developed.

The estimated annual net return for full season soybeans and corn grain were \$80 and \$36 per acre, respectively. There were three double-crop systems that provided annual net returns larger than soybeans: wheat grain with sorghum silage, wheat silage with sweet sorghum silage, and wheat silage with sorghum silage. Winter wheat grain with sorghum silage provided the largest annual net return at \$244 per acre. The lowest cost per ton of dry matter was provided by winter wheat silage double-cropped with sorghum silage at \$67 per ton. The most profitable double crop system of winter wheat grain double-cropped with sorghum silage cost \$100 per ton of dry matter. Several double-crop systems and even some single crop choices have lower costs per ton of dry matter than this alternative, indicating that farmers may adjust their cropping system based on weather they chose the livestock feed market or the cellulosic feedstock market.

These results indicated that some double-cropping systems appear to provide economically competitive returns in Indiana compared to traditional full season corn and soybean crops. However, these results are dependent on the yield relationships found in the experimental plots and the estimated green chop and silage prices. The exact crops selected by farmers will depend on the relative prices that can be obtained as feed and cellulosic markets evolve and local yield relationships.

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Table 1. Estimated price, average yield from 2008 and 2009 ACRE plots, and estimated annual net revenue per acre for each crop

	Estimated Price	Average Yield	Net Return
Crops planted after green chop wheat harvest			
Corn grain	$3.66/bu	174 bu.	$18
Soybeans	$9.60/bu	54 bu.	$181
Corn silage	$26.88/ton	20 ton	-$42
Sorghum silage	$23.42/ton	19 ton	$42
Crops planted after wheat silage harvest			
Corn grain	$3.66/bu.	138 bu.	$15
Soybeans	$9.60/bu.	50 bu.	$152
Sorghum grain	$3.24/bu.	132 ton	$-$43
Corn silage	$26.88/ton	22 ton	$137
Sorghum silage	$23.42/ton	26 ton	$212
Sweet sorghum silage	$23.36/ton	29 ton	$247
Crops planted after wheat grain harvest			
Soybeans	$9.60/bu.	25 bu.	$-37
Sorghum silage	$23.42/ton	26 ton	$250
Sweet sorghum silage	$23.42/ton	21 ton	$24
Single Crops			
Corn for grain	$3.66/bu.	198 bu.	$364
Soybeans	$9.60/bu.	51 bu.	$80
Grain sorghum	$3.24/bu.	133 bu.	-$120
Corn silage	$26.88/ton	23 ton	-$103
Sorghum silage	$23.42/ton	25 ton	$68

Table 2. Single crop and double-crop systems annual net return and cost per ton of dry matter

Rank	Crop Description	Annual Net Return per Acre	Cost per ton of dry matter
1	Winter Wheat Grain + Sorghum Silage	$244	$100
2	Winter Wheat Silage + Sweet Sorghum Silage	$165	$82
3	Winter Wheat Silage + Sorghum Silage	$130	$67
4	Soybeans	$80	$303
5	Sorghum Silage	$68	$72
6	Winter Wheat Silage + Corn Silage	$54	$74
7	Corn Grain	$36	$144
8	Winter Wheat Silage + Soybeans	$29	$131
9	Winter Wheat Grain + Sweet Sorghum Silage	$16	$164
10	Winter Wheat Green Chop + Soybeans	$2	$214
11	Winter Wheat Grain + Soybeans	-$9	$231
12	Winter Wheat Green Chop + Sorghum Silage	-$97	$92
13	Corn Silage	-$103	$90
14	Winter Wheat Silage + Corn Grain	-$108	$125
15	Sorghum Grain	-$120	$169
16	Winter Wheat Green Chop + Corn Grain	-$162	$161
17	Winter Wheat Silage + Sorghum Grain	-$166	$116
18	Winter Wheat Green Chop + Corn Silage	-$181	$98

Figure 1. Double-cropping systems investigated using plot trials