Use of Conservation Reserve Program Land for Biorefinery Feedstock Production

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Abstract

Legislation passed in 2002 enables managed harvesting and grazing of Conservation Reserve Program (CRP) land, including harvesting of biomass. The objective of the research is to determine the cost to acquire, harvest, store, and deliver a steady flow of biomass from CRP grasslands to a biorefinery.

Introduction

The Conservation Reserve Program (CRP) was established by enabling legislation in the 1985 Farm Bill. It sets aside highly erodible and environmentally sensitive acres of cropland under 10-15 year contracts. Land under CRP is planted to conservation crops such as perennial grasses and trees. Landowners receive an annual rental payment for the land from the federal government. The purpose of CRP is to cost-effectively assist producers in conserving and improving soil, water, and wildlife resources.

The 1985 Farm Bill generally provided that no commercial use could be made of land enrolled in CRP, but permitted haying or grazing during droughts or similar weather-related emergencies. This issue of inability to unconditionally use the biomass resources available on CRP land has been debated since the onset of the program. Several authors have suggested the use of the land under CRP for production of biomass feedstock for biorefinery use and have considered the economic gains to both farmers and the federal government from using CRP land for biomass production (Downing, Walsh, and McLaughlin; Walsh, Becker and Graham; Epplin; Walsh et al.).

The Farm Security and Rural Investment Act of 2002 (FSRIA) enables managed harvest of CRP grassland acres a maximum of once every three years (USDA, 2002; USDA, 2003). Amendments included in the FSRIA provide for haying, grazing, and allow for production and harvesting of biomass for biorefinery feedstock. The legislation requires that acres used for grazing, haying or biomass harvest shall be assessed a 25 percent annual rental payment reduction. With current regulations it is likely that removal of biomass from CRP grasslands in Oklahoma could be conducted over a 120-day period beginning July 2.

In 2003 a total of 34.2 million acres were enrolled in the CRP at an average annual rental rate of $48 per acre. This included more than one million acres of grassland in the state of Oklahoma at an average rental rate of $32 per acre (USDA, 2003). This large acreage of perennial grasses could serve as a resource for providing biorefinery feedstock and could reduce the total federal government's annual CRP rental payment.

A biorefinery is a facility that converts (refines) biological material (biomass) into products. Breweries and wineries are examples of facilities that convert biological material (i.e. grain, grapes) into relatively high value products including beer and wine. A facility that produces subsidized ethanol from corn grain is another example of a biorefinery. In some respects, a biorefinery is similar to a petroleum refinery that uses crude oil as a feedstock and produces fuels and other products.

Research and development programs are underway to produce technology that will enable conversion of biomass feedstock from crop residues (such as corn stover and wheat straw), native grasses (such as switchgrass), and introduced perennial grasses (such as fescue) into useful products. The economic success of an unsubsidized biomass biorefinery will depend upon its ability to either produce unique valuable products or to produce products that are comparable in value but more economical than fossil based substitutes.

A biorefinery that relied exclusively on massive quantities of bulky feedstock produced on CRP lands would be expected to be located in an area with concentrated CRP enrolled acres. The Southern Plains of Oklahoma, Kansas, and Texas include an area of concentrated CRP acres. A region that includes 77 Oklahoma counties, 32 Texas counties, and 52 Kansas counties has a combined CRP enrollment of more than 4.9 million acres on which perennial grasses have been established.

The objective of the research is to determine the cost to acquire, harvest, store, and deliver a steady flow of biomass from CRP grasslands located in Oklahoma, Kansas, and Texas to a biorefinery. Two types of sensitivity analysis are conducted. First, models are solved with biorefinery feedstock requirements of 1,000, 2,000, and 4,000 tons per day to determine the tradeoff between feedstock transportation cost and biorefinery size. Second, models are solved with the legislated restricted harvest season of 120 days and with an unrestricted harvest season to determine the potential economic consequences of a restricted harvest season.

Procedure

The economic model used to conduct the study is an enhancement of the model developed by Tembo and described by Tembo, Epplin, and Huhnke. For a given case study area Tembo's model was designed to determine the number, size and distribution of biomass-based biorefinery processing capacity that maximizes industry net present worth and the optimum quantities of biomass stocks and flows. He built a multi-region, multi-period, mixed integer mathematical programming model to identify key cost components, potential bottlenecks, and reveal opportunities for reducing costs and prioritizing research.

Tembo's model and case study considered (i) a variety of feedstock; (ii) recognized that a biomass biorefinery would require a steady flow of feedstock and broke the year into 12 discrete periods (months); (iii) recognized that different feedstocks have different harvest windows and that the dry matter yield of species depends upon the time (month) of harvest; (iv) recognized that storage losses will occur and depend upon location of storage and time of storage; and (v) included multiple biorefinery sizes and locations that enabled investigation of the tradeoff between economies of biorefinery size and feedstock transportation costs (Tembo, Epplin, and Huhnke).

Tembo used the model to determine, for specific regions in Oklahoma, the most economical source of biomass, inventory management, biorefinery size, and biorefinery location. Tembo's model was innovative but contained several limitations. He used conventional agricultural machinery cost estimation software to compute biomass harvest costs on an acre rather than ton harvested basis. These charges were assessed independent of yield. Tembo did not place any restrictions on the number of acres that could be harvested during a time period. His method results in two potential problems. First, harvest costs varied by ton since they were fixed per acre for each species independent of expected yield. Second, since harvest capacity was not constrained, the base model determined that it was optimal to harvest more than 80 percent of total biomass tonnage required for an entire year in the month of September. He assumed that the market would provide harvest machines in a timely manner. However, the assumed capacity does not currently exist and a large investment in harvest machines would be required to achieve the capacity necessary to harvest the annual quantity of required biomass in a short time period. In effect, his modeling effort did not appropriately account for harvest costs.

Thorsell et al. designed a coordinated harvest unit that provides a capacity to harvest a given number of tons per time period. The harvest unit includes a coordinated set of harvest machines consisting of mowers, rakes, balers, tractors, and bale transporters. It is assumed that field speeds of machines may be adjusted with crop yield to achieve the throughput capacity. The coordinated harvest unit may result in substantial size economies associated with harvest machines. The cost estimates were developed under the assumption of a coordinated set of harvest machines operated by specialized harvest crews with extended harvest windows.

Data

CRP acres were based upon 2003 enrollment (USDA). Biomass yield estimates for perennial grasses produced on CRP acres were obtained from a survey of professional agronomists in the respective production region (counties). Yield adjustment factors that account for relative differences in expected yields depending upon harvest month were also obtained from professional agronomists.

Harvests costs were based upon the harvest unit as described by Thorsell et al. A harvest unit is defined as a coordinated set of harvest machinery, which includes ten laborers, nine tractors, three mowers, three rakes, three balers, and a field transporter. The annual ownership and operating cost of one harvest unit is estimated to be $580,000. A single harvest unit provides a throughput capacity of 341 tons per harvest day. Potential harvest months vary by species. The number of harvest days per month depends upon the weather. Harvest days per month were based upon monthly mean field-workday estimates for Oklahoma (Reinschmiedt).

The biorefinery is expected to operate 350 days per year and expected to have a biomass feedstock requirement of either 1,000, or 2,000, or 4,000 dry tons per day. Storage at the biorefinery is limited to the amount that could be used in a three-week period (21,000, 42,000, and 84,000 tons for the 1,000, 2,000, and 4,000 tons per day biorefineries, respectively). Field storage is not restricted. Field storage cost was estimated at $2 per ton per month and field storage losses were estimated at 0.5 percent per month. Minimum biomass inventory at the biorefinery was assumed to be equal to zero and storage losses at the biorefinerey were assumed to be equal to 0.1 percent per month.

Estimates of field to biorefinery transportation distances were based upon map miles from cities located near the center of the two counties. Bhat, English and Ojo estimated the cost of transporting a 17 dry ton truckload of biomass as $TC_{ij} = 34.08 + 1.00\ d_{ij}$ where TC_{ij} is the estimated cost of transporting a 17 dry ton truckload of biomass from production region i to biorefinery j and d_{ij} is the round-trip distance in miles. The average per dry ton transportation cost can then be determined by dividing by the assumed truck capacity of 17 dry tons. A feedstock dry matter content of 85 percent is assumed.

The average rental rate for Oklahoma CRP land is $32 per acre (USDA, 2003). If the land is harvested for any purpose the rate will be reduced by 25 percent or an average of $8 per acre. An access and acquisition fee of $10 per acre was assessed in the model to compensate landowners for the reduction in CRP payment and removal of biomass.

Model

A multi-region, multi-period, mixed integer mathematical programming model was constructed to include all CRP grassland acres in the 77 counties of Oklahoma, 32 counties of Texas, and 52 Kansas counties. Each county in the study area is considered as a separate region. Eleven potential biorefinery locations were identified. The biorefinery locations were included in the model as binary variables and the model was solved to select the most economical site for location. By policy, an enrolled acre can only be harvested once in three years. Since it is unlikely that every potential acre would be harvested for biomass, harvest was restricted to 25 percent of the acres of the CRP enrolled acres in a county.

This study differs from prior studies in several respects. The harvest unit as designed by Thorsell et al. is incorporated into the model as an integer activity that for an annual cost (depreciation, insurance, interest, taxes, repairs, fuel, oil, lubricants, and labor) provides capacity to harvest a given tonnage per month. Monthly capacity depends upon the number of harvest days per month and the number of endogenously determined harvest units. The model breaks the year into 12 discrete periods (months) enabling a flow of feedstock to a biorefinery and recognizes that the expected dry matter yield depends upon the time (month) of harvest and that storage losses will occur and depend upon location of storage and time of storage.

The model contains what McCarl and Spreen denote as sequencing activities in that harvest, storage, and transportation are sequenced to provide a flow of material to the biorefinery. The sequencing provides within-period dynamics. The model contains storage and inventory, in that biomass from CRP grasslands may be harvested and placed in storage in either four or eight of the months (depending upon the restriction) and biomass may be removed from storage for use in each of the twelve months. Alternatively, biomass may be transported and processed in the harvest month. Decisions regarding biomass production, harvest, storage, and transportation are assumed made repeatedly in all years of biorefinery life, what may be referred to as a representative single period. This type of model is appropriate when (i) resource, technology, and price data are assumed to be constant and (ii) a long-run steady state solution is acceptable. Biorefinery location is endogenously determined (Tembo, Epplin, and Huhnke).

Results

A total of six models were solved. These models were differentiated by biorefinery feedstock requirements (either 1,000 or 2,000 or 4,000 tons of biomass per day) and by the length of the harvest season. In Oklahoma, harvest of CRP land is currently restricted to a 120-day harvest season beginning July 2. In the absence of policy restrictions, for the region of the study, biomass could be harvested on CRP grasslands from July through February. This option is referred to as an unrestricted harvest season.

Table 1 includes a summary of results from the six models. As expected, as the size of the biorefinery is increased from 1,000 to 4,000 tons per day, the average one-way distance to transport biomass from the fields to the biorefinery increases from 60 miles to 99 miles for the 120-day harvest season. This increases the transportation cost from $9.09 to $13.62 per ton. This increase in transportation cost increases the cost to deliver a steady flow of feedstock from $59 to $64 per ton. The results are similar for the case of an unrestricted harvest season. Average transportation distance increases from 64 to 105 miles, and, transportation cost increases from $9.51 to $14.32 per ton as biorefinery size increases from 1,000 to 4,000 tons per day. The average feedstock transport distance for both the 120-day harvest and unrestricted harvest window for all three biorefinery sizes is graphed in Figure 1.

A coordinated set of harvest machines was defined as a harvest unit and included as an integer investment activity in the model. For a 4,000 tons per day biorefinery, if the harvest window is restricted to 120 days, the model selects 61 harvest units as optimal (Table 1). Since a harvest unit includes three mowers, three rakes, three balers, nine tractors, and one transport stacker, the 4,000 tons per day biorefinery with a 120-day harvest window would require 549 tractors, 183 mowers, rakes, and balers, and 61 transport stackers. The estimated average investment in these harvest machines is approximately $36 million (Figure 2). If the policy imposed harvest season restriction was lifted, and harvested permitted from July through February the number of harvest units required to harvest biomass for a 4,000 tons per day biorefinery could be reduced from 61 to 29 (Table 1). And, the average investment in harvest machines could be reduced from $36 million to $17 million.

As described in Table 1 and shown in Figure 3, restricting the harvest window increases the cost to deliver a ton of biomass by $15 to $17 per ton depending upon biorefinery capacity. The harvest window restriction increases both harvest and storage costs. Figure 4 includes a chart of the estimated quantity of feedstock harvested per month for a 2,000 tons per day biorefinery from both a 120-day harvest season and an unrestricted harvest season. Monthly harvest is restricted by both the number of expected harvest days and by the endogenously determined number of harvest units.

The model contains storage and inventory activities. Biomass may be harvested and placed in storage and biomass may be removed from storage for use in each of the twelve months. Alternatively, biomass may be transported and processed in the harvest month. The model provides for feedstock storage at the biorefinery and storage in fields at remote sites. Figure 5 includes a chart of the estimated quantity of feedstock stored per month at field sites for a 2,000 tons per day biorefinery from both a 120-day harvest season and an unrestricted harvest season. If the harvest season is restricted to 120 days, replenishment of storage reserves begins with the first permissible harvest month of July. Harvest and increase of field storage inventory continues throughout August, September, and October. At the end of October, when by policy the harvest season must be completed, the combined field and biorefinery storage inventory must be sufficient to provide feedstock until harvest may be resumed in the following July. Feedstock is removed from field storage until the end of June when inventory of both field storage and storage at the biorefinery are reduced to zero. Minimum inventory constraints at the biorefinery were set to zero. Figure 6 includes a chart of the estimated quantity of feedstock stored per month at the biorefinery site for a 2,000 tons per day biorefinery from both a 120-day harvest season and an unrestricted harvest season. As shown in Figure 6, inventory is reduced to zero at the end of June in anticipation of a resumption of harvest in July.

For the unrestricted harvest window model, field inventory storage increases more gradually from August through February. The maximum quantity of required field storage for the unrestricted model is less than half of that required for the 120-day restricted harvest window model.

Conclusions

The Farm Security and Rural Investment Act of 2002 enables managed harvest of CRP grassland acres a maximum of once every three years for use as biorefinery feedstock. This study was conducted to determine the cost to acquire, harvest, store, and deliver a steady flow of biomass from CRP grasslands located in Oklahoma, Kansas, and Texas to a biorefinery. Two types of sensitivity analysis were conducted. First, models were solved with biorefinery daily feedstock requirements of 1,000, 2,000, and 4,000 tons per day to determine the tradeoff between feedstock transportation cost and biorefinery size. Second, models were solved with the legislated length of the harvest season of 120 days and with an unrestricted harvest season to determine the economic cost of a restricted harvest season.

It was determined that the estimated cost to deliver a flow of feedstock to a biorefinery ranged from $42 to $64 per ton depending upon the size of the biorefinery and the length of the harvest. Increasing biorefinery feedstock requirements from 1,000 to 4,000 tons per day increases required transportation distances and increases the expected cost by $5.04 per ton for the 120-day harvest model and by $6.91 for the unrestricted harvest model.

CRP acres are dispersed, expected yields are relatively low, and harvest is limited by policy to an average of once in three years. The model was constrained to harvest no more than 25 percent of the CRP enrolled acres per county annually. The estimated average feedstock transportation one-way distance ranged from 60 to 105 miles. The estimated cost ranged from $9.09 to $14.32 per ton.

Given the underlying assumptions of the model, for the case study region, restricting harvest to a 120-day window imposes a rather substantial cost on the industry. The 120-day harvest window restriction more than doubles the expected harvest cost and more than doubles expected field storage costs. Restricting the harvest window increases the cost to deliver a ton of biomass by \$15 to \$17 per ton.

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Table 1. Results of Models Solved to Determine the Cost to Delivery a Steady Flow of Biomass from Conservation Reserve Program acres in Oklahoma, Kansas, and Texas to 1,000, 2,000 and 3,000 tons per day Biorefineries for both a 120-day Harvest Season and an Unrestricted Harvest Season.

Item	120-day Harvest			Unrestricted Harvest		
	Biorefinery Size (tons/day)					
	1,000	2,000	4,000	1,000	2,000	4,000
Acquisition and Field Cost ($/ton)	17.13	18.25	18.68	18.63	19.96	20.48
Harvest Cost ($/ton)	26.05	25.23	24.94	11.58	11.58	11.94
Field Storage Cost ($/ton)	6.67	6.76	6.74	2.46	2.46	2.36
Transportation Cost ($/ton)	9.09	10.51	13.62	9.51	10.95	14.32
Total Cost of Delivered Feedstock ($/ton)	58.94	60.76	63.98	42.19	44.96	49.10
Harvested Acres	238,908	407,958	734,340	271,481	445,577	814,403
Harvest Units (Number)[a]	16	31	61	7	14	29
Average Investment in Harvest Machines ($,000)	9,440	18,290	35,990	4,130	8,260	17,110
Harvest Months (Number)[b]	4	4	4	8	8	8
Total Biomass Harvested (tons)[c]	356,170	712,509	1,418,537	350,582	701,164	1,409,157
Average Distance Hauled (miles)	60	72	99	64	76	105

[a] A harvest unit includes ten laborers, three mowers, three rakes, three balers, nine tractors, and one transport stacker.

[b] In Oklahoma, harvest of CRP land is currently restricted to 120-days beginning July 2. In the absence of policy restrictions, for the region of the study, biomass could be harvested on CRP grasslands from July through February.

[c] The biorefinery is expected to operate 350 days per year. The model accounts for storage losses. Total storage losses are greater when harvest is restricted to a 120-day period.

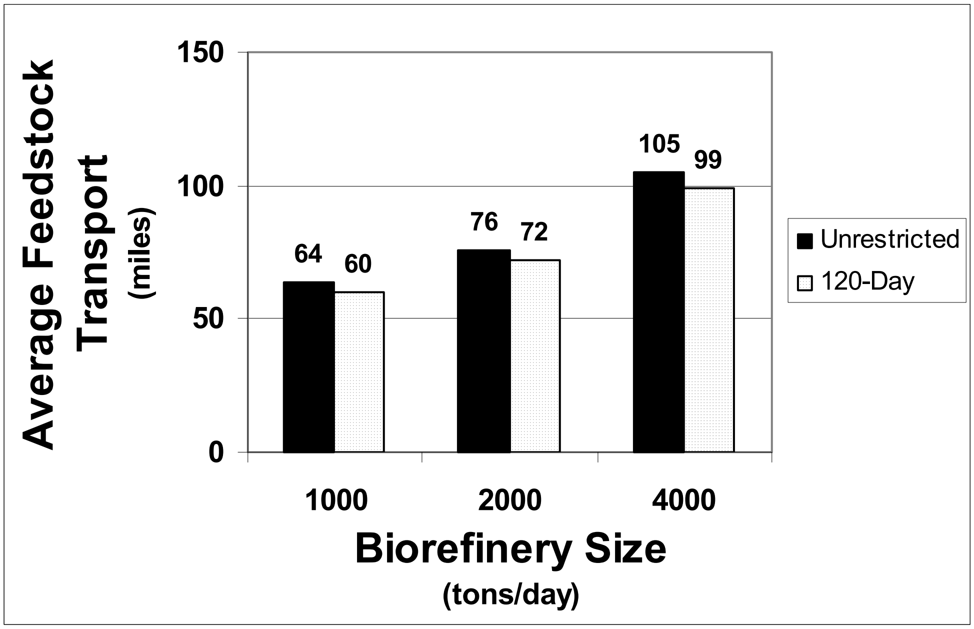

Figure 1. Estimated average one-way distance to transport biomass to a biorefinery from feedstock produced on CRP grasslands in Oklahoma, Kansas, and Texas from both a 120-day harvest season and an unrestricted harvest season for three biorefinery sizes.

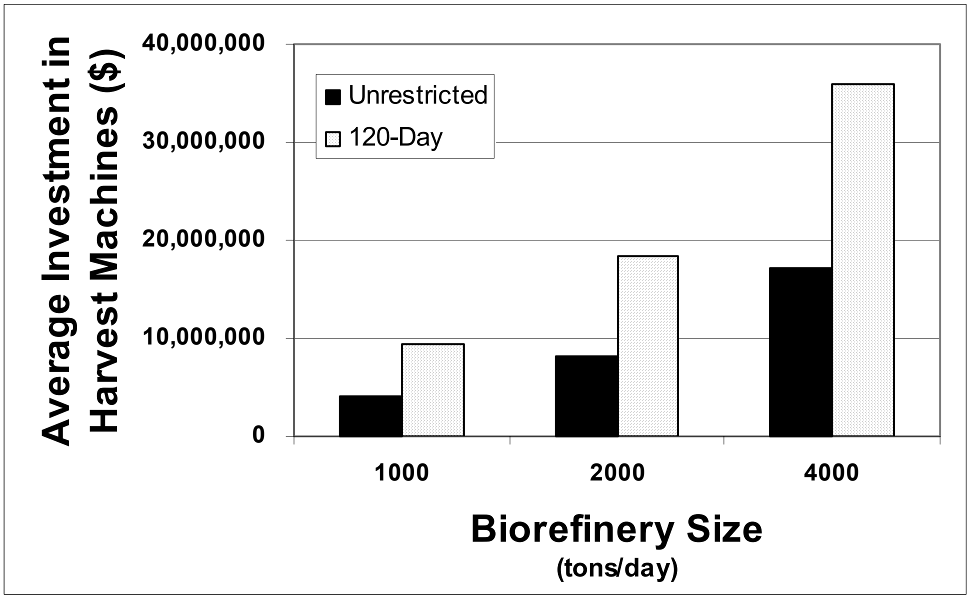

Figure 2. Estimated average investment in harvest machines to support 1,000, 2,000, and 4,000 tons per day biorefineries for both a 120-day harvest season and an unrestricted harvest season from feedstock produced on CRP grasslands in Oklahoma, Kansas, and Texas.

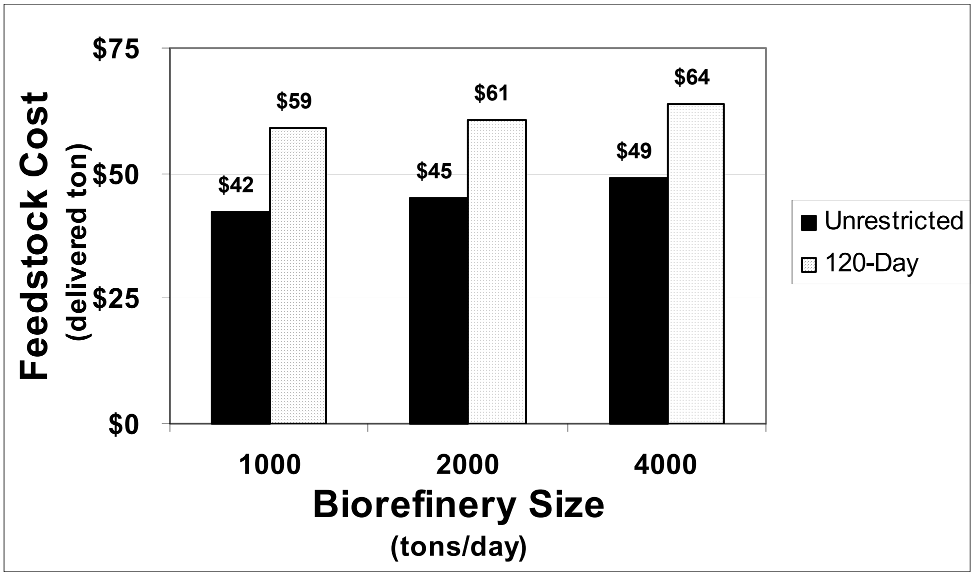

Figure 3. Estimated cost to deliver a ton of biomass to a biorefinery from feedstock produced on CRP grasslands in Oklahoma, Kansas, and Texas from both a 120-day harvest season and an unrestricted harvest season for three biorefinery sizes.

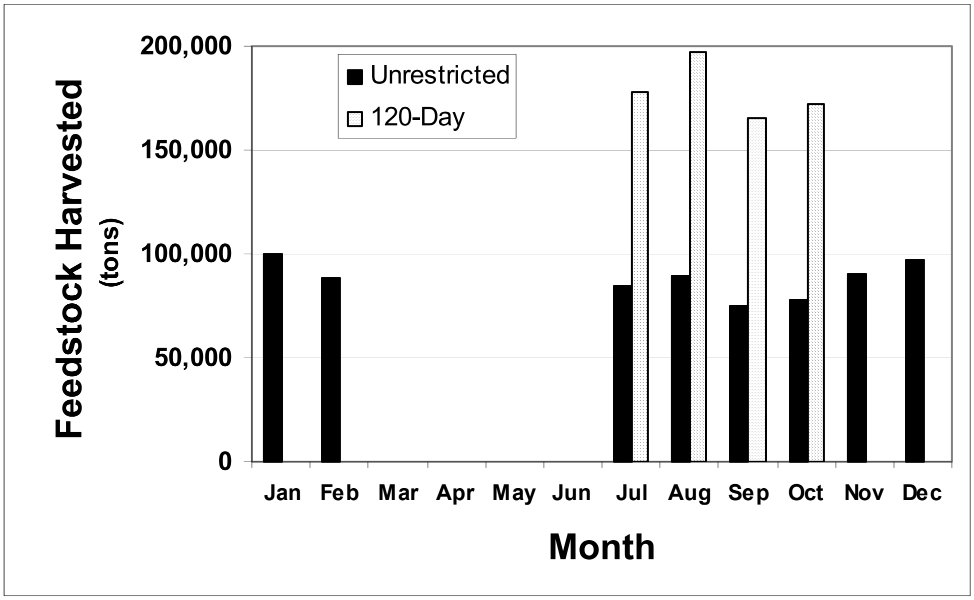

Figure 4. Estimated quantity of feedstock harvested per month for a 2,000 tons per day biorefinery from feedstock produced on CRP grasslands in Oklahoma, Kansas, and Texas from both a 120-day harvest season and an unrestricted harvest season.

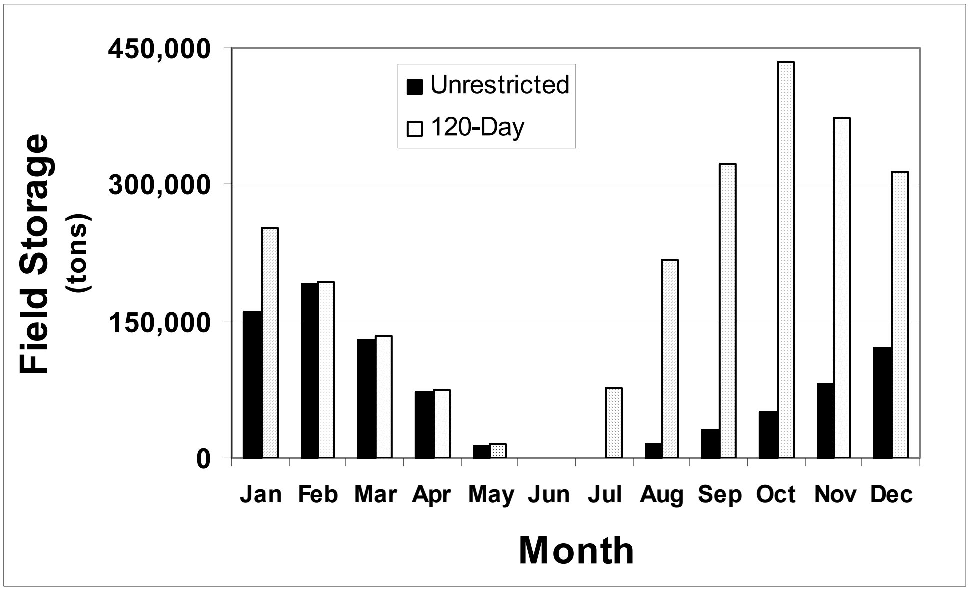

Figure 5. Estimated quantity of feedstock stored per month at remote sites for a 2,000 tons per day biorefinery from feedstock produced on CRP grasslands in Oklahoma, Kansas, and Texas from both a 120-day harvest season and an unrestricted harvest season.

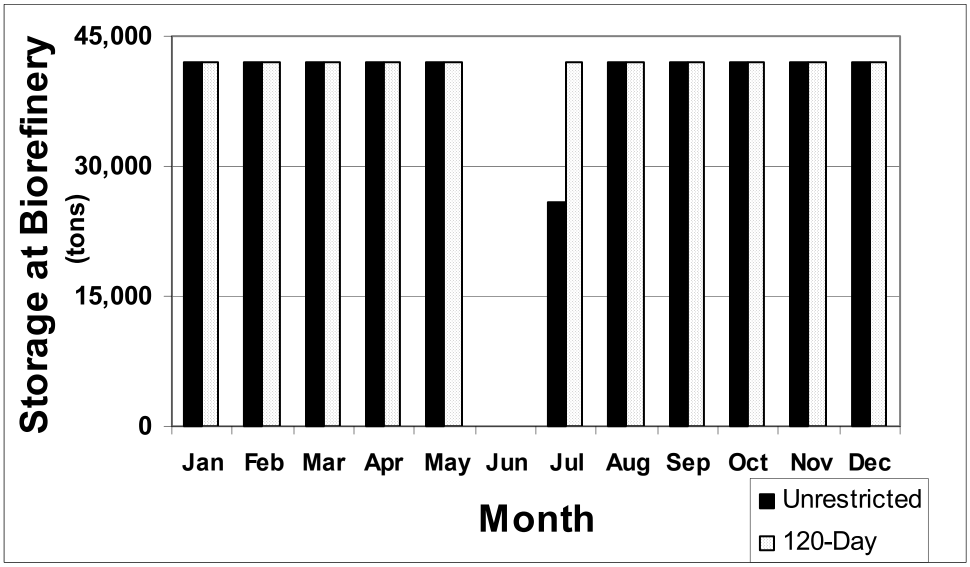

Figure 6. Estimated quantity of feedstock stored per month at the biorefinery site for a 2,000 tons per day biorefinery from both a 120-day harvest season and an unrestricted harvest season from feedstock produced on CRP grasslands in Oklahoma, Kansas, and Texas. Storage at the 2,000 tons per day biorefinery is limited to 42,000 tons.