Scaling-up U.S. Grass-fed Beef Market: Implications for Beef Market, Crop Markets, and Land Uses

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1. Introduction

The grass-fed beef (GFB) market is a fast-growing sustainable cattle production industry that distributes beef with healthy benefits. The GFB originates from the cattle that spend nearly all their lifetime in pastureland, whereas the conventional cattle live the last six months in feedlots. This natural production method that spends more extended time on grazing may become a future industrial tendency, based on previous studies (Mu et al. 2018; Mu, McCarl and Wein 2013; Fei, McCarl and Thayer 2017; Cho and McCarl 2017; Havlík et al. 2013) that found grazing land share will increase and compete with cropland as climate change slows down crop production. Furthermore, the resulting forage finished beef provides healthier nutrient and fatty acid profiles that satisfy an increasing share of health-conscious consumers (Daley et al. 2010).

Mainly due to the perceived nutritional benefits, a price premium stimulates current GFB production (McCluskey et al. 2005; Lusk and Parker 2009; Xue et al. 2010). According to the USDA national GFB report, a GFB steak cut is more than twice as expensive as conventional beef on average (Wang, Isengildina-Massa and Stewart 2022). This price premium serves as an incentive to attract more cattle farmers to transfer their production system. However, as the market share expands, the price premium will diminish according to the previous studies on similar health-conscious raised organic food markets (Wier and Calverley 2002). Therefore, understanding the consequential GFB market share and price under economic equilibrium condition is vital to inform cattle farmers when and where to enter the market.

Although the current hefty price premium motivates GFB producers to expand their production level, industrial challenges including unstable forage supply and processing limitation, shrink their profit margins. Expanding GFB production requires more pasture, which potentially increasing pasture land rent and competing land with crop and forest. Also, Poore et al. (2020) state the frequent summer rainfall in the southern U.S. (the central GFB production area) inhibits a stable forage supply, which in turn affects the year-round availability of GFB. Another major obstacle is the lack of proper processing facilities. As most GFB producers are small-scale, they are often unable to meet minimum operation requirements for large slaughter plants. Transporting the cattle to existing large slaughter plants over long distances requires high transportation costs. To expand the local processing capability, Gwin (2009) proposed to construct mobile slaughter units, which are likely to be promising as USDA (2021) announced $500 million for expanded small processing facilities. The absence of stable forage supply and processing ability lead to a lack of economy of scale, which further cause GFB producers are unable to compete with import markets, such as Australia that take advantages of all-season grazing and large production scale. These problems are fundamental to the GFB industry and are necessary to be addressed in a model that constructs an enlarged GFB market.

The scaling-up GFB market will also impact associated agricultural markets and land uses. GFB also requires more pastureland to raise cattle which results in land competition with crops. Also, the less demand for feed grains alters the grain commodity markets, especially the corn market. It results in less demand for cropland, cropland reallocation and potential lower market price. The changes in grain prices can further affect the input cost of conventional beef and other livestock, as well as the bioenergy industry.

Understanding the economic effects of expanding the GFB market to other sectors is necessary for the production decision-making of farmers from other markets and informing the comprehensive influences to policymakers. Previous studies (Capper 2012; Clark and Tilman

2017; Hayek and Garrett 2018; Sitienei, Gillespie and Scaglia 2015; Dillon, Rotz and Karsten 2020; Cheung and McMahon 2017) have explored market and environmental consequences of enlarged GFB market share but did not construct an integrated market equilibrium model to investigate the related agricultural market and land changes.

Inspired by concealed transitions brought by the thriving GFB market, this paper aims to explore the consequent market distributions and potential of resources to support the expanded GFB production in the United States using an integrated agricultural sector model. In detail, we will investigate 1) the consequential GFB market equilibrium share, price and production distribution, 2) the regional forage resource and cropland reallocation, along with the land transferring between cropland and pasture, and 3) the related agricultural commodity production and price changes. The analysis will be done under various assumptions of GFB price premium levels compared with conventional beef.

2. Model

To systematically capture the underlying economic processes, an integrated agricultural sector model, FASOM, is applied with an endogenous price feature. FASOM is a partial equilibrium model that has been widely used to simulate the U.S. agricultural market equilibrium under perfect competition assumptions for decision and policy-making purposes(Baker et al. 2013; Murray, McCarl and Lee 2004; Alig, Adams and McCarl 1998). The endogenous price feature allows the model to reflect consumer, farmer responses to market price and structure changes. More details of the model are discussed in these files (Beach and McCarl 2010; Adams et al. 2005). In this study, we will upgrade FASOM to include quarterly forage supply, GF cattle operation, movement under all growing stage, and GFB price premium. The new market equilibrium of all agricultural commodities, land and other resources reallocation, GFB operation distribution, along with the regional farm income changes will be investigated in this study.

3. Scenario analysis

To simulate the grass-fed and conventional beef market, we construct three production phases for the beef industry: cow-calf operation, stocker operation, and grass-finished cattle feeding or grain-finished cattle feeding. The first two operations are almost the same for grass-fed and conventional beef production, cattle are pasture-raised. However, grass-fed ones are not allowed to be fed grain or other manufacturing byproducts, such as distiller-dried grains (DDG), in the model. The significant difference occurs at the final stage, where grain-finished cattle are sent to confined feedlots to raise to 1330 pounds while grass-finished cattle stay on grazing land with leaner 1144 pounds slaughter weight. Other important cattle budget parameters are shown in Table 1.

Table 1. Cattle Budget Parameters

Cow-Calf Operation			
Animal Units (AU)	0.8		
Hay (ton)	1.33		
Stocker Operation			
Calf Stocker			
Animal Units (AU)	0.16		
Beginning weight (lbs)	397		
Ending weight (lbs)	533		
Yearling Stocker			
Animal Units (AU)	0.22		
Beginning weight (lbs)	570		
Ending weight (lbs)	773		
Grain-Finished Cattle		**Grass-Finished Cattle**	
Feedlot Calf		*Grassfed Calf*	
Grain feed (lbs)	8900	Animal Units (AU)	0.75
Silage (ton)	1.13	Hay (ton)	0.48
Hay (ton)	0.4	Beginning weight (lbs)	612
Beginning weight (lbs)	612	Slaughter weight (lbs)	1144
Slaughter weight (lbs)	1330		
Feedlot Yearling		*Grassfed Yearling*	
Grain feed (lbs)	4940	Animal Units (AU)	0.67
Silage (ton)	0.1	Hay (ton)	0.11
Hay (ton)	0.1	Beginning weight (lbs)	864
Beginning weight (lbs)	864	Slaughter weight (lbs)	1144
Slaughter weight (lbs)	1330		

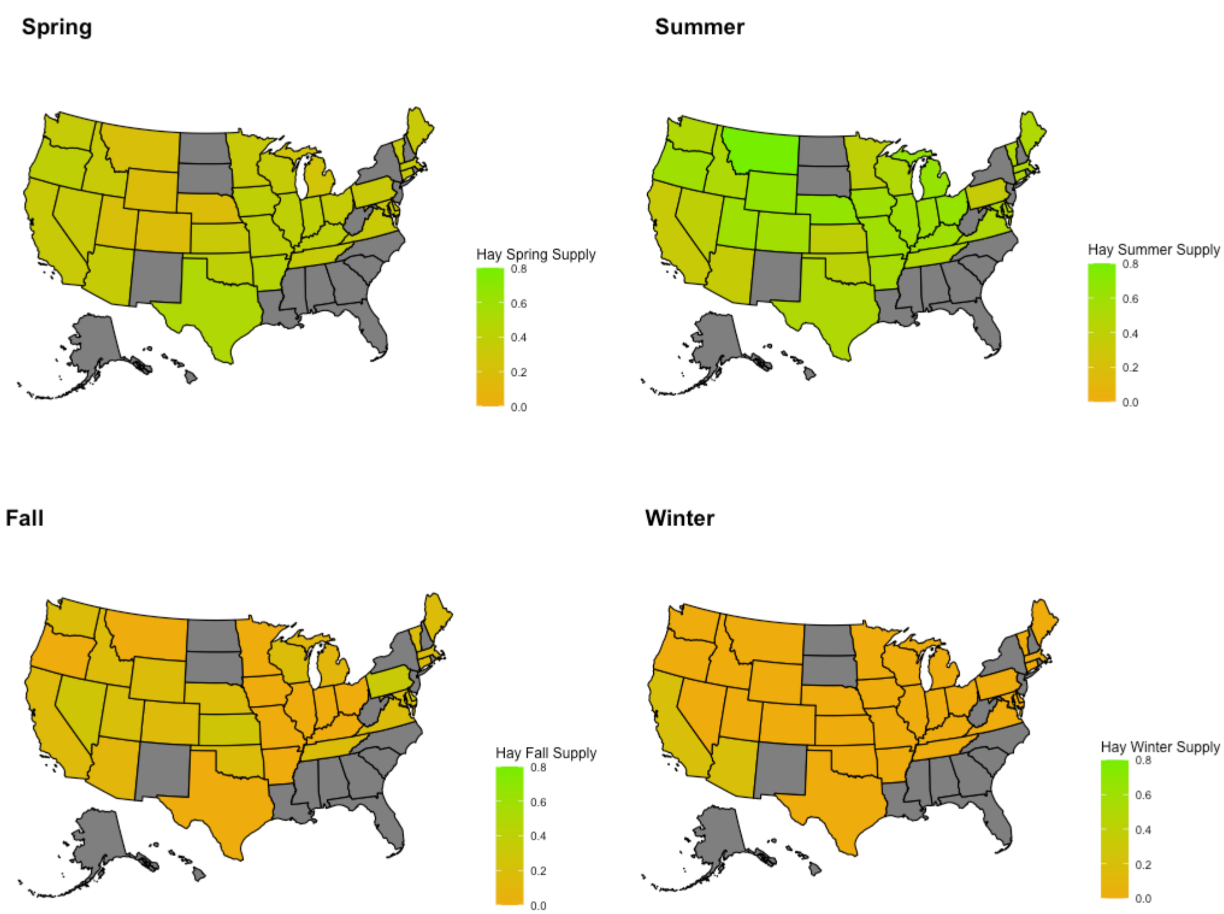
The magnitudes of cattle budget parameters shown in Table 1 correspond to feeding schedules of grass-finished and conventional beef production management reports published by various state university extensions (Neibergs and Nelson 2009; Reid and Tonsor 2017; Christensen and Schulz 2022). The two options, calf feeding and yearlings feeding, provided in stocker and feeding operations, are farmers' two risk management choices when expecting different grain prices. When grain feed costs are lower, producers may send feeders in the feedlot at a lower weight to attain more weight from grain-based formulas. On the other hand, when grain costs increase, feeders can stay in pasture land until they are around 200 pounds heavier before entering feedlots. Grass-finished cattle is an extreme situation in which feeders never enter the feedlots in their entire lifetime, which to a less extent, is a risk management strategy for cattle farmers when facing higher grain feed prices. To transfer the grain-feed formula to the grass-feed method, we assume that 1176 pounds of grain feed equals 2000 pounds of forage feed based on the unit of total digestible nutrients (Lalman 2002).

Forage supply is an important production factor for the grass-fed beef system. The forage supply is largely determined by seasonality. Based on suggestions of Professors from Ecology and Conservation Biology and USDA crop growing season, we assume quarterly forage supply factors for Animal Unit Month (AUM) of grazing land and hay production shown in Table 2 and Figure 1. We use these factors to divide the original FASOM annual model to the quarterly model.

Table 2. Quarterly AUM Supply Factors

	winter	Spring	summer	fall
The proportion of states above Kansas(the north of Kansas):				
	0.1	0.3	0.5	0.1
The proportion of states below Kansas(the south of Kansas):				
	0.1	0.3	0.45	0.15

Figure 1. Quarterly Hay Supply Factors



To keep by quarterly forage supply, we also apply quarterly factors to cattle production shown in Table 3, based on USDA cattle inventory data. We assign a larger factor to the spring season, 60% to spring-born calf and 30% to cattle herds, as most calves are given birth in spring, and at the same time, age group of older cattle herds (cattle over 500 pounds) slightly concentrates in this season.

Table 3. Quarterly Cattle Supply Factors

	spring	summer	fall	winter
Cowcalf	0.6	0.1	0.2	0.1
Stocker	0.3	0.21	0.25	0.24
Grass-fed calves	0.3	0.21	0.25	0.24
Grass-fed yearlings	0.3	0.21	0.25	0.24

Another critical feature in the model is the grass-fed beef price premium setup, we use market share and price premium coefficient calculated by Yu's dissertation (2021) and price premiums reported by Wang (2022) and embed these parameters into the original FASOM's beef demand curve to construct a new kinked demand curve. This demand curve proxies the grass-fed beef market, where price premiums will decrease as market share increases. To calculate the processing cost difference between grass-fed and grain-fed beef production, we implement Google Maps to estimate distances between pasture land and slaughterhouse, feedlots and slaughterhouse. Then, use the distance differences to proxy the processing cost differences. As a result, the average national distance is 13 miles, so we use $17.55 as an average national processing cost difference.

4. Results

4.1 GFB market equilibrium share

The market equilibrium result is shown in Table 4. Based on this result, the market equilibrium share of grass-fed beef attains 12%, that is similar to the countrywide average organic milk market share (Yu 2021). On the regional level, grass-fed beef production concentrates on Northern Plains and Northeast[1]. These results are reasonable as the Northern Plains are major beef production region with abundant resources and related facilities, and the Northeast has the largest share of health-conscious beef consumers (Yu 2021).

Table 4. Grass-fed beef and Grain-fed beef Market Equilibrium Results

Region	Grain-fed beef	Grass-fed beef
Corn Belt	6%	0%
Northern Plains	10%	93%
Lake States	0%	0%
Northeast	17%	6%
Rocky Mountains	13%	0%
Pacific Southwest	6%	0%
Pacific Northwest-east side	17%	0%
South Central	9%	0%
Southeast	11%	0%
Southwest	11%	0%
National	88%	12%

[1] The FASOM region definitions are in FASOMGHG model file (Beach and McCarl 2010).

Table 5 shows grass-fed and grain-fed cattle production in primary cattle production FASOM regions. Based on the results, most grass-fed cow-calf operation is in Colorado, and most stocker and grass-finished operations are in Kansas.

Table 5. Grass-fed and Grain-fed Cattle Production

Grass-fed beef production in part of regions

Region	Cowcalf	Heifer Calf stocker	Steer Calf stocker	Heifer Yearling stocker	Steer Yearling stocker	Beef yearlings	Beef Calves
Texas	0%	0%	0%	0%	0%	0%	0%
Nebraska	0%	50%	0%	0%	0%	0%	0%
Missouri	1%	0%	0%	0%	0%	0%	0%
Kansas	0%	0%	100%	0%	0%	0%	100%
South Dakota	0%	50%	0%	0%	0%	0%	0%
Colorado	98%	0%	0%	0%	0%	0%	0%
New Mexico	1%	0%	0%	0%	0%	0%	0%
Louisiana	1%	0%	0%	0%	0%	0%	0%

Grain-fed beef production in part of regions

Region	Cow Calf	Heifer Calf stocker	Steer Calf stocker	Heifer Yearling stocker	Steer Yearling stocker	Feedlot Beef yearl	Feedlot Beef Calves
Texas	29%	13%	1%	0%	12%	21%	35%
Nebraska	11%	35%	0%	0%	0%	0%	6%
Missouri	13%	11%	0%	0%	0%	0%	2%
Oklahoma	10%	0%	18%	0%	0%	0%	4%
Kansas	9%	0%	26%	0%	53%	0%	8%
California	2%	5%	55%	0%	35%	76%	0%
South Dakota	10%	31%	0%	0%	0%	0%	17%
Iowa	7%	6%	0%	0%	0%	0%	9%
Colorado	3%	0%	0%	0%	0%	0%	10%
New Mexico	3%	0%	0%	0%	0%	0%	8%
Louisiana	3%	0%	0%	0%	0%	3%	0%

4.2 Regional forage and AUM land reallocation

The regional forage and AUM land allocations are shown in Table 6 and Table 7. Based on the results, 25519 acres of cropland growing hay, wheat, oats, and rye are assigned to conventional cattle production, and 6 acres of hay cropland are assigned to grass-fed beef production in Texas. While in Kansas, 17635 acres of cropland are assigned to conventional beef, whereas 3627 acres are allocated to grass-fed beef. As for land allocation, 12144 acres of cropland is transferred to pasture land for beef production in Texas. 10516 acres of forest land is transferred to pasture in Colorado.

Table 6. Regional Forage Allocation (Acre)

	Animal Units Cowcalf		
	Hay (Acre)		
Texas	21383		
Kansas	9788		
	Animal units Heifercalf Stocker		
	Wheatgrazing (Acre)	Oatsgrazing (Acre)	Ryegrazing (Acre)
Texas	3062	157	41
	Animal Units Steercalf Stocker		
	Wheatgrazing (Acre)		
Kansas	2647		
	Animal Units Steeryearling Stocker		
	Oatsgrazing (Acre)	Wheatgrazing (Acre)	
Texas	28	848	
Kansas		5200	
	Animal units Grass-fed Cowcalf		
	Hay (Acre)		
Texas	6		
	Animal Units Grass-fed Steercalf Stocker		
	Oatsgrazing (Acre)	Wheatgrazing (Acre)	
Kansas	5	437	
	Animal Units Grass-fed Beefcalves		
	Oatsgrazing (Acre)	Wheatgrazing (Acre)	Ryegrazing (Acre)
Kansas	10	3165	8.7
	Animal Units Grass-fed Beefyearlings		
	Ryegrazing (Acre)		
Kansas	1.4		

Table 7. Regional AUM Land Allocation (Acre)

	Animal Units Cowcalf			
	Cropland_Pasture (Acre)	Rangeland (Acre)	Pasture (Acre)	Forest_Pasture (Acre)
Texas	11815.15	73926	6952	
Colorado	688	5609		10516
Kansas	2382	12166	1747	
	Animal Units Steercalf Stocker			
	Cropland_Pasture (Acre)	Pasture (Acre)		
Texas	329	313		
	Animal Units Grass-fed Cowcalf			
	Pasture (Acre)			
Colorado	578			

5. Conclusion

The preliminary results of the grass-fed beef market model indicate a 12% grass-fed beef equilibrium market share. It is comparable with the average national organic milk share and suggests the future developing potential of the grass-fed beef market, as current market size is around 4%. The major beef productions are in Northern Plains and Northeast regions. The primary cattle production is located in Colorado and Kansas. In the future, higher price premium scenarios will be conducted to forecast the future beef industry as climate change intensifies the competition between crop production and livestock grazing. The resulting forage and land allocations will be reported in a quarterly level, and the related crop market impacts will be reported to forecast future industrial tendency.

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