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Economics of Raramuri Criollo and British crossbred cattle production in the Chihuahuan desert: Effects of foraging distribution and finishing strategy

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ABSTRACT

Significant challenges for raising beef cattle exist in the arid and semi-arid regions of the United States. Limited forage availability and small profit margins are among the greatest concerns in Western U.S. ranching operations. One potential option for ranchers in these regions is using alternative cattle genetics, such as Raramuri Criollo (RC), a Mexican heritage biotype of cattle brought to the Americas by Spanish Conquistadors. Previous research has shown that compared to commercial beef breeds, RC cattle exhibit behavior traits that result in foraging patterns that could reduce the environmental footprint of rangeland animal agriculture. We investigated the profitability of raising this biotype in an alternative production system (grass finishing) in the Chihuahuan Desert by producing enterprise budgets for a herd of RC cattle on the Jornada Experimental Range. Results show that RC cattle have lower operating and overhead costs when compared to Angus x Hereford (AxH) crossbred cattle. This reduction in costs allowed the RC cattle operation to have greater net returns to land and risk when compared to an AxH cattle operation in the same location. Raising RC cattle could be a means of strengthening the economic sustainability of desert beef cattle ranching in the United States.

1. Introduction

Livestock managers have long sought to improve grazing distribution in extensive arid pastures, to minimize supplemental feed costs and reduce erosion near watering points, by developing new water sources and strategically placing supplements to lure cattle to ungrazed areas (Holechek et al., 2011). The potential of breed and individual animal selection to improve grazing distribution has also been explored (Bailey, 2004; Wesley et al., 2012). Selecting a beef cattle breed or individual animals with traits that are more suitable for foraging in semi-arid and arid environments may be the least costly way to improve livestock distribution and reduce the environmental footprint of rangeland animal agriculture (Spiegal et al., 2019) (see Table 5).

Criollo cattle, a type with promising characteristics and behaviors for improving distribution, by best estimates were brought into North America in 1598 when Don Juan de Oñate introduced between 2500 and 7000 cattle (Rouse, 1977). One type of Criollo known as Raramuri Criollo (RC) underwent 500 years of adaptation to the harsh conditions of the Sierra Tarahumara in northern Mexico with minimal genetic influence of improved beef breeds (Anderson et al., 2015; Armstrong et al., 2022; McIntosh et al., 2020). The USDA-ARS Jornada Experimental Range (JER) in southern New Mexico introduced 27 RC cows and 3 RC bulls in 2004–2005, purchased from individual families near Chinipas Municipality, Chihuahua Mexico (27°20′N, 108°30′W) (Estell, 2021).

Since then, multiple studies investigating foraging habits the Raramuri biotype have been conducted in the shrub-encroached grasslands

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of the northern Chihuahuan Desert (Estell, 2021). Researchers have found that when compared to AxH crossbreds in the American Southwest, RC exhibit greater heat tolerance in summer (Nyamuryekung'e et al., 2021) and show lower preference for grazing-sensitive palatable grasses than conventional beef breeds (Estell et al., 2022). In addition, during seasons when green forage was relatively scarce and patchily distributed, RC were found to achieve greater distribution than conventional cattle types (Nyamuryekung'e et al., 2022; Peinetti et al., 2011; Spiegal et al., 2019).

To date, grass finishing has been the primary marketing option for RC in New Mexico and neighboring states, as the biotype finishes well on grass (McIntosh et al., 2021) and tends to be passed over at auctions in the conventional production chain due to color and non-conventional body conformation (Enyinnaya, 2016). In contrast to the conventional supply chain in which calves born on Southwestern ranches are exported to the US Southern Plains for backgrounding on wheat pasture and ultimately finishing on grain in feed yards, the grass-finishing approach may perform more favorably in relation to producer and consumer goals for environmentally-friendly and humanely-raised beef, profitability, climate change adaptation, and climate change mitigation (Barnes, 2011; Jackson, 2022). However, grass-finishing is not a silver bullet, and a better understanding is needed about the economic and environmental tradeoffs of adopting the grass-finishing approach. From an economic perspective, for example, grass-finished RC beef has been successfully marketed in the Southwest grass-fed beef market to a limited degree, with apparent positive consumer acceptance of meat quality and cost savings may be imparted by the RC's broader pasture distribution in times of low forage production – however, additional costs can be incurred in time and effort for direct marketing.

All environmental and economic costs and benefits must be considered when evaluating RC production as an adaptation strategy. Here we focus on the economics of grass finishing RC cattle in the Chihuahuan Desert of southern New Mexico compared to AxH in a conventional cow-calf approach in which calves are exported off the ranch for the next phase of feeding. We focus explicitly on forage use rather than the environmental implications of using specific animal genetics, which is an analysis beyond the scope of this study. We use and expand on the findings of Peinetti et al. (2011) – who found that RC distribute themselves more widely than AxH on a large, heterogeneous desert pasture during seasons when forage is scarce – to estimate how much harvestable forage in a pasture might increase because of the improved grazing distribution of RC cattle. We then compare the economics of AxH beef cattle production (cow-calf enterprise) to RC production (grass-finishing enterprise) using enterprise budgeting, assuming various levels of forage increase for the RC type. We close with a discussion of remaining questions in the literature with regards to the impact of cattle genetics on conditions beyond the ranch gate, and highlight areas of potential future research.

2. Materials and methods

2.1. Overview

We developed a multi-step process to evaluate the economic costs and benefits of grass finishing RC in the northern Chihuahuan Desert. First, we modeled a medium-sized ranch in Southern New Mexico (4662 ha; 150 Animal Units Year or AUY) which we consider "typical", characterizing standardized costs and returns of infrastructure and practices regardless of cattle type (see Animal Unit definition in Suppl. Mat.). This typical ranch contains 4662 ha (46.6 square km) and was assumed to require 31.2 ha/AUY and to have a carrying capacity of 150 AUY. Typical of southern New Mexico ranches, Bureau of Land Management (BLM) and state trust land provides most (80%) of the grazing capacity in our typical ranch. We then used that typical ranch as the setting to compare economic outcomes of raising an RC herd vs. an AxH herd, so that economic outcomes could be compared. Comparative enterprise budgets reflect the years 2013–2014, but we contend that this timeframe reflects current (2021) conditions because prices are comparable when comparing real prices.

2.2. Enterprise budget data sources

Costs, returns, and typical beef production rates and practices for the typical AxH ranch (4662 ha; 150 AUY) were defined from published budgets and summary statistics (Bevers, 2014; Hawkes and Libbin, 2014; Torell et al., 2012). Property and livestock taxes were defined using mill rates (the tax payable per dollar of assessed property value) for Southwest New Mexico counties. Summary statistics reported from the Standardized Production Analysis (SPA) program at Texas A&M University provided additional beef production and cost data. Both published and unpublished SPA summary statistics (see the Definition section in Suppl. Mat.) for Texas and New Mexico ranches were used to define selected cost items (Bevers, 2014). Typical investments in buildings, improvements, machinery, and vehicles were defined from the medium Southwest ranch budget described by (Hawkes and Libbin, 2014) and by New Mexico ranch value studies (Torell et al., 2012).

Input from the JER livestock manager was obtained in 2014, which provided breed-specific information about inputs and both operational and overhead costs for the RC and AxH cow herds raised on the JER. This input was used to adjust the enterprise budgets' costs and forage requirements for RC cattle. Ranch manager input was based on experience with a herd of 139 RC cows and 13 bulls, and a herd of 55 AxH cows, raised concurrently on the 121,406-ha JER. Prices for selected cost items, like supplemental feed and veterinary expenses (cost items that were expected to be significantly different between the two study breeds), were verified and updated to current levels from online product seller websites. Production and cost data recorded and observed by the JER during 2014 were the primary source of information used to define the RC budget. In addition, website reviews were conducted and phone conversations were held with Southwest Criollo cattle producers (Kimble, 2013a; Kimble, 2013b; Price and Price, 2014; Susieville Cattle Susieville Cattle Company, 2014) to solicit their input. The conventional AxH budget was defined to represent typical Southwest ranches in the deserts of southwest New Mexico which is different in some cases from AxH production on the JER, as the JER is a research and not a commercial ranch.

2.3. Enterprise budget structure and assumptions

A Microsoft Excel based enterprise budget template was developed that considers annual forage requirements and forage balance (Tanaka et al., 1987; Workman, 1986). The enterprise budgets provide a listing of revenues and expenses for each breed in a standardized format, reflecting the year 2013. Revenues for the herd were calculated based on expected sale weight and price for the year 2013, taking into account steers and heifers sold and retained, as well as cull animals. The analysis considered differences between Criollo and AxH in forage requirements and foraging habits.

Based on the observation that RC cattle graze areas further from water that are not typically used by English breeds (Peinetti et al., 2011), three different levels of assumed forage use were considered for the model ranch. First, we considered no change in forage harvest between the two breeds. Second, we considered the scenario where the RC cattle enterprise would have the same number of mature cows as the AxH ranch with an extended period required to grass-finish RC animals for sale, as shown by the forage demand analysis presented below. This would represent a 50% increase in AUM harvest, slightly less than the change computed from the Peinetti et al. (2011) study. Third, we considered a 25% increase in forage harvest as an intermediate level.

Differences in rates of gain, production performance, sale prices, production costs, and timing of sale are considered in the budget comparison as point estimates. A stochastic budget analysis whereby costs, prices, and key production factors were analyzed as statistical distributions instead of point estimates (see for example Evans et al., 2007) was not possible given the limited information available about Criollo cattle price and production variability over time.

The format and procedures used for the cost and return (CAR) estimation conform to the standards established by the American Agricultural Economics Association (AAEA, 2000). The cost definition includes opportunity costs of operator investments and labor and management inputs. Cash versus non-cash expenses are identified. Ownership costs were included using the capital recovery method to annualize economic depreciation and opportunity cost as a single cost component (AAEA, 2000, Eq. 6.7).

The budgets were prepared assuming a 12-month production cycle. Various classes and ages of livestock are present on the ranch during a particular month, some of which will be sold next year and the following year. The timing of sales is different between conventional and RC cattle enterprises. With timing differences, AAEA (2000) suggested that expenditures and revenues should be accumulated to a common point in the production process using time adjustment calculations and a nominal interest rate. Following this guideline, expenses and revenues were discounted to the end of the current production year (December) using a 5% discount rate. Private land use and the forage produced on private land is not included as a cost item in the budgets; therefore, the calculated net return is a return to land and risks.

2.4. Livestock production and forage demand analysis

Forage demand was computed monthly and summed for the year by animal class. The metabolic weight ratio procedure (see definition section in Suppl. Mat.) was used to define forage demands for the herd. To make computations tractable, all calves were assumed to be born in the same month. In reality, at the time of the study, bulls remained with the cow herd yearlong, and about 85% of calves were born on the JER in June and July with another flush of calves in March and April.

Breeding animals were assumed to be of variable ages and to have a constant mean weight throughout the year. The mean weight of calves and sale animals at monthly intervals was estimated using growth curves defined for calves (all breeds) raised in the deserts of Southeast Arizona (Tronstad and Teegerstrom, 2003, Table 1, Nov. Sale, No Suppl.). Rates of mean daily gain commonly referred to as average daily gain (ADG) were scaled up or down relative to the Arizona study so that weights at the time of sale were similar to those realized on the JER. The estimated monthly weights were used to calculate monthly Animal Unit Equivalency (AUE) factors (see AUE definition in Suppl. Mat.). Calves less than six months of age were not considered to have a forage demand. The number of animals of a particular class residing on each of the model ranches for each scenario was determined from the assumed calving percentage, cow replacement rate, bull-to-cow ratio, and the percentage of sale animals carried past weaning. The budget analysis was conducted assuming a constant cow-herd size over time.

2.5. Key assumptions

Key assumptions and differences in the definition of the conventional and RC enterprise budgets are shown in Table 1. The AxH budget was defined to be a cow-calf operation selling weaned calves in November. Brood cows are kept in the herd until they are about 10 years old and replaced with ranch-raised replacement heifers. Bulls provide 5 years of productive service with culling at about 7 years of age. By comparison, the RC enterprise was defined to sell grass-fed steer yearlings at 30 months of age. There is currently a strong demand for RC breeding animals and RC producers are either saving heifers to build their own herds or selling females to others. Thus, it was assumed that heifer calves are sold as bred-yearling heifers at 24 months of age.

Raramuri Criollo cattle are consistently described as having a very docile temperament, high fertility, and an exceptionally long

Table 1
Key assumptions and difference across genotypes.

Item	Conventional AxH Production	Criollo Cattle
Grazing practice	Continuous season-long stocking with limited water availability in the pasture resulting in poor grazing distribution when grazed with AxH animals.	Continuous season-long stocking with improved livestock distribution and higher forage use rates with RC cattle
Federal and state trust land use	The maximum allowable stocking rate is regulated on federal and state trust lands. This maximum level is met with the assumed 150 AUY use in the base model.	Land agencies would allow use to increase with documentation of improved livestock distribution using RC cattle
Marketing strategies	Sell heifer and steer calves on the commercial market after weaning in November	Sell grass-fed steers through direct marketing after finishing on rangeland for 30 months. Heifer caves not saved for replacements are sold in 24 months as bred heifers.
	Cull animals are sold in November	Cull animals are sold in November
Livestock sale prices	Obtain the mean market price reported in the conventional market	Limitations in marketing, slaughter, and processing results in a reduced net sale price relative to that reported in the conventional market. Cull animals receive no discount. Steers are discounted 17%, heifers 20%.
Livestock production		
Calving season	Calves are born in April. JER primarily calves in June but that is not common for conventional AxH cross herds.	Calves are born in June
Herd Replacement	Cows replaced after 10 years of service from retained calves. 13% of the herd is replaced each year. Heifer calf retention rate is 17% with the extra 4% sold as yearling heifers.	Cows are replaced after 16 years of service from retain calves. 7% of the herd is replaced each year.
Mean cow culling age (years)	10	18
Mean bull culling age (years)	7	12
Calf crop at weaning	85%	91%
Cow-to-bull ratio	16:1	30:1
Cow-to-horse ratio	35:1	35:1
Mean calf birth weight (kg)	34	12
Steer calf sale weight (kg)	216	
Heifer calf sale weight (kg)	204	
Finished steer sale weight (kg)	635	
Sale weight replacement heifers sold (kg)	386	431
Mean cow weight (kg)	454	363
Mean bull weight (kg)	612	499
Cow, bull and heifer death loss	1%	1%
Sale animals death loss	2%	1%
Bred heifer sale age (months)		24

reproductive life (Anderson et al., 2015). The ten years of production data and experience on the JER supports that contention. The mean weaning percentage for RC cows on the JER was 91% ± 5% compared to 87% ± 11% for AxH cows. The mean cow age at culling was considered to be 18 years for RC cattle compared to 10 years for AxH. RC bulls are expected to be in the herd for about 12 years and to service about 30 cows per year.

BLM and state trust land grazing fees are included as expense items in the enterprise budgets and the market value of grazing permits is included in the ranch valuation. Two important assumptions about the use and cost of BLM and state trust lands were made. First, it was assumed that the land agencies would allow increased grazing use when stocked with RC cattle. This assumption may be limiting as stocking rates are regulated on federal land. Second, forage productivity per hectare was assumed to be the same for each land ownership type. Consequently, any increase in forage availability was proportional across lands of different ownership. Grazing fee expenses increased as the number of available AUM's changed.

2.6. Beef prices and marketing

The AxH budget analysis assumes animals will be marketed and sold through traditional marketing channels. Two different beef price scenarios were considered: 1) annual mean prices received over the five-year period, 2009–2013 as reported by CattleFax (2014), and 2) the record level prices received during 2014. Production costs were defined for the 2013 production year and beef prices were adjusted to this same period, adjusting for inflation using the Producer Price Index (PPI).

Grass fed producers generally receive a price premium. A national survey of grass-fed beef producers asked respondents to compare their own hanging carcass prices to the overall market and found 83% of respondents had obtained a price premium, with 25% reporting a premium of $1.65 per kilogram or more (Lozier et al., 2004). Without additional marketing effort, no price premiums would be expected, and in fact outside the grass-fed beef market RC cattle are discounted in sale price. As described by Alfredo Gonzalez, JER livestock manager, "RC cattle are treated like a roping steer in the sale ring". This attitude is largely driven by their smaller size and presence of horns. More research is needed to determine the net price received once direct marketing expenses, including opportunity costs, are considered. Without that research we consider best estimates of the relative market price of on-the-hoof animals received by the JER. When compared to per pound USDA reported beef prices, the JER livestock manager estimated that the net value of a finished RC steer is 17% less per pound than what is reported at New Mexico markets. Female animals are discounted by an estimated 20%. Table 2 lists the beef prices and per cow livestock investment values considered for the two alternative price scenarios[3].

3. Results

3.1. Forage demand

The assumed forage base of the model ranch, 1800 AUMs (Animal Unit Months) or 150 AUY, would provide year-long grazing for 112 mature AxH cows, 19 replacement heifers, 93 weaned calves, 9 bulls, and 4 horses. An estimated 1.34 AUY would be required per mature cow (Suppl. Mat. Table S1). Only 7% of available forage would be consumed by sale animals. By comparison, production with RC cattle requires about 2 AUY per mature cow. Over half the available forage is consumed by sale animals with a grass-fed beef operation. Because steers are not marketed until they are 30 months of age, it is nearly a 3-year production program. Offspring from various years are on the ranch in any given month (Suppl. Mat. Table S2). The number of mature cows would be 75 cows. To stock 112 mature RC cows with sale animals (the same number of mature cows defined for the AxH enterprise) would mean a 50% increase in forage demand, given the extended grazing period required for sale animals (112 mature cows × 2 AUY/cow = 226 AUY). Similarly, with a 25% increase in harvested forage the cow herd would be 92 cows.

Table 2
Beef prices used for alternative price scenarios[a].

Animal Class	Weight (cwt)	Units	Price adjustment factor[a]	2009–2013 mean	2014
AxH production					
Steer calf	4.75	$/cwt	1.00	$162	$271
Heifer calf	4.5	$/cwt	1.00	145	250
Culled replacement heifer	8.5	$/cwt	1.00	119	176
Cull cow	10	$/cwt	1.00	64	109
Cull bull	13.5	$/cwt	1.00	84	130
Brood cow investment value	1	$/head	1.00	1192	1700
Bull investment value	1	$/head	1.00	2384	3400
Horse investment value	1	$/head	1.00	2500	2500
RC Production					
3-yr old steer	9.5	$/cwt	0.83	95	183
3-yr old heifer	9	$/cwt	0.83	82	153
Bred 2-yr old heifer	1	$/head	0.8	986	1360
Cull cow	8	$/cwt	1.00	64	109
Cull bull	11	$/cwt	1.00	84	130
Cow investment value	1	$/head	0.80	954	1360
Bull investment value	1	$/head	0.83	1979	2822
Horse investment value	1	$/head	1.00	2500	2500

[a] Assumed price discount relative to reported New Mexico market prices.

3.2. Ranch investments

Using the hedonic ranch value model of Torell et al. (2012), investment in land buildings and improvements was estimated to be $4418/AUY (Suppl. Mat. Table S 3). With 150 AUY on the ranch, total ranch investment for the AxH model totaled $982,080 ($6547/AUY) with mean beef prices and just over $1 million dollars with 2014 prices (Table 3). Fewer brood cows and lower per cow values (Table 2) results in the RC budget having an overall investment that is about 90% that of the AxH model (Table 3) (see Table 4).

3.3. Ranch enterprise budgets

Enterprise budgets for AxH cattle are shown in Tables S4 and S5 (Suppl. Mat.), and enterprise budgets for RC cattle are shown in Tables S6 through S9 (Suppl. Mat.). For the AxH budgets, two cattle price assumptions were considered, firstly, the mean of prices observed from 2009 to 2013, and secondly, prices as observed in 2014, a year with relatively high cattle prices. For context, the mean price scenario is comparable to the current cattle prices, which as of writing are $137.44/cwt (2013 dollars) for steers, and $125.64/cwt for heifers. The RC budgets use the same price assumptions, as well as an increased number of AUY considered, so that the number of RC cattle would be the same as

[3] While Raramuri Criollo cattle would likely be sold at a premium, we use the same prices across both cattle types for comparison purposes. Further, these results can be interpreted as a 'worse case' scenario, where there is no premium.

Table 3
Summary of ranch investments with alternative beef prices and assumed stocking rates.

Investment Item	AxH Budget			Criollo Budget			
	Market Value	$/AUY	Annual Capital Recovery	Market Value	$/AUY	% of AxH Investment	Annual Capital Recovery
Land, buildings, and improvements	$662,693	$4418	$11,382	$662,693	$4418	100%	$11,382
Machinery and vehicles	131,000	873	11,682	131,000	873	100%	11,682
2009–2013 Average Beef Prices							
Purchased livestock	31,456	210	4166	14,652	98	47%	1333
Retain livestock	156,931	1046	4672	74,512	497	47%	2097
Total investment (150 AUY)	982,080	6547	31,903	882,857	5886	90%	26,494
Total investment (188 AUY + 25%)				904,378	4811		27,243
Total investment (226 AUY + 50%)				926,937	4101		28,043
2014 Beef Prices							
Purchased livestock	40,600	271	5540	17,700	118	44%	1600
Retain livestock	224,581	1497	7129	106,080	707	47%	3190
Total investment (150 AUY)	1,058,874	7059	35,733	917,473	6116	87%	27,854
Total investment (188 AUY + 25%)				948,073	5043		28,971
Total investment (226 AUY + 50%)				979,133	4332		30,066

Note: Investment category detail is only shown for the base of 150 AUY. Breeding animals are valued at current cost so investment value changes as beef prices change. A complete listing of breeding animals, buildings, improvements, machinery, and vehicles is shown in Supplemental Materials Table S3. Land, buildings, improvements, machinery, and vehicle investment does not change between scenarios.

Table 4
Comparison of differences in revenues, costs, and net returns to land and risk between Angus Hereford cattle and Raramuri Criollo cattle, 5-year 2009–2013 average real beef prices, 150 AUY assumed for Angus herefords, and 226 AUY assumed for Raramuri Criollo.

	AxH	RC
Revenue	$520	$391
Total Costs	$630	$450
Operating Costs	$359	$278
Supplemental Feed	$109	$54
Vet and Medicine	$4	$5
Overhead Costs	$270	$172
Vehicles, Buildings, Improvements	$154	$73
Livestock Investment	$59	$22
Operator Labor and Management	$31	$25
Net Return to Land and Risk	-$110/AUY x 150 AUY -$16,465	-$60/AUY x 226 AUY -$13,325

Table 5
Comparison of differences in revenues, costs, and net returns to land and risk between Angus Hereford cattle and Raramuri Criollo Cattle, 2014 real beef prices, 150 AUY assumed for Angus herefords, and 226 AUY assumed for Raramuri Criollo.

	AxH	RC
Revenue	$874	$648
Total Costs	$687	$475
Operating Costs	$370	$273
Supplemental Feed	$129	$75
Vet and Medicine	$14	$5
Overhead Costs	$317	$198
Vehicles, Buildings, Improvements	$154	$73
Livestock Investment	$59	$22
Operator Labor and Management	$31	$25
Net Return to Land and Risk	$186/AUY x 150 AUY $27,942	$172/AUY x 226 AUY $38,971

those stocked in the AxH budgets.

From our analysis, we found that if we assume that the ranch has AxH cattle with 150 AUY available from private and leased lands, with 5-year mean prices from 2009 to 2013, that the operation can support 112 cows. The operation's total annual discounted revenue is estimated to be $78,014, $698.52 per cow, or $520.10 per AUY. Total annual discounted operating costs, including operating loan interest is $53,915, $482.74 per cow, or $359.44 per AUY. Discounted cash costs are $3,987, and discounted non-cash costs are $36,576. Therefore, net discounted returns over operating costs are $24,099, net discounted returns over cash costs are $20,112, and annual returns to land and risk are -$16,465 (Suppl. Mat. Table S4).

If we again examine an operation with AxH cattle, but now assume that prices are those as observed in 2014, a relatively high price year, then total discounted revenues are now $131,042, and total costs, including both cash costs and non-cash costs are $103,101. Here, net returns over operating costs are $75,510, net returns over cash costs are $71,523, and returns to land and risk are $27,942. This contrasts to the results in the mean price scenario, where now returns to land and risks are positive (Suppl. Mat. Table S5).

Now we consider an operation with RC cattle, with prices assumed to be the mean prices from 2009 to 2013, and 150 AUY available from private and leased lands.[3] Because of the longer length of production, 150 AUY can only support 75 cows. Because of the lower number of cattle in the enterprise, revenues are lower for this operation. However, at the same time, costs of this enterprise are likewise lower. Bred 2-year-old heifers are a valuable commodity for RC operations, and a large amount of the total revenue for a RC operation are for these cattle. Total discounted revenue is $58,701, and total discounted operating costs and operating loan interest are $41,650. Total allocated overhead costs are $34,842, and total costs are $76,492. Therefore, discounted net returns over all operating costs are $17,050, discounted net returns over cash costs are $12,556, and discounted returns to land and risk are -$17,792. Comparing these costs and returns on an AUY basis, revenues are considerably lower for the RC operation, but costs are also much lower. Net returns are comparable between both the RC and AxH operations, particularly when returns to land and risk are considered (Suppl. Mat. Table S6).

If we consider a RC cattle operation and assume 150 AUY and cattle prices as observed in 2014, then this operation can support 75 cows. Comparing between the previous mean price scenario and this scenario, as prices increase, revenues increase with little change in costs, so net returns are much greater. However, when this is compared against the returns achieved in an AxH operation, these net returns are considerably lower. All returns, both net returns over operating costs and returns to land and risk are positive (Suppl. Mat. Table S7).

If we consider an expanded operation for RC cattle, where we assume 226 AUY are available from private and leased sources, and mean cattle prices from 2009 to 2013, this provides a per-cow comparison between RC cattle and AxH cattle on an operation that has 150 AUY available. When comparing the RC operation with the AxH operation, the RC operation has considerably greater revenues, and only slightly greater costs. Therefore, net returns are themselves also greater for the RC operation. While net returns per cow are still negative, they are nearly 20% greater than those possible in the AxH operation (Suppl. Mat. Table S8).

Finally, we consider a RC cattle operation, assume the same 226 AUY, with observed prices from 2014. This provides a per-cow comparison between RC cattle and AxH cattle, under the greater prices observed in 2014. In this comparison, net returns are considerably greater for RC cattle on a per cow basis, nearly a 40% increase when returns to land and risk are considered (Suppl. Mat Table S9).

The differences between the main scenarios presented are summarized in. Presents the differences in revenues, costs, and net returns to land and risk between AxH cattle and RC cattle, under the 5-Year 2009–2013 mean real beef price scenario. Presents these same results under the 2014 real beef price scenario. In general, while revenues are lower for RC cattle given the prices assumed here, the costs for producing RC cattle are also lower. These reduced costs are both in operating costs, as well as overhead costs. Costs for producing RC cattle are reduced in every category. Supplemental feed costs are lower, capital costs are lower, and the cost of investment in the herd are lower. This major reduction in costs allows for increased profitability in the face of variable final sales prices.

In summary, the profitability of all operations, regardless of breed, is highly price sensitive. This is an obvious observation, but it reiterates a point that has repeatedly been made in the literature (Bastian et al., 2002, 2018; Fowler and Torell, 1987; Turner et al., 2013), that profitability of cattle operations is highly dependent on prices and costs, which may be highly variable. Despite this, a focus on pure profitability would ignore the additional benefits that are claimed by those that raise RC cattle, namely that they provide larger market and non-market benefits, such as a flavorful product that is lower in fat, produces high quality beef, and provides a larger value of ecosystem services on the range. When comparing a RC operation to an operation that runs traditional English breeds, the number of RC cattle that can be raised is lower due to the longer time to maturity. At the same time, the profitability of a RC operation is similar to an operation that runs English breeds, despite that longer time to maturity, and future policies that may compensate growers for their production of ecosystem services could close the profitability gap between them.

4. Discussion

There are perceived problems with the conventional U.S. beef production system in that confined large-scale feedlots have been associated with air and water pollution, waste management problems, animal welfare issues, and human health concerns (Capper, 2012; Gwin, 2009). This has stimulated increased consumer interest in grass-fed, naturally raised, locally produced meats (Gwin, 2009; Mathews and Johnson, 2013). Demand from health and environmentally conscious consumers has allowed a small but growing number of livestock producers to market their animals directly to consumers. The 2012 Census of Agriculture reported an 8% growth in direct sales to individuals, restaurants, grocery stores, farmers markets, and at road-side stands when compared to 2007 when the last census was taken (USDA-NASS, 2014). Beef from alternative production systems including natural, organic (grain-fed or otherwise) and grass/forage-fed accounts for about 3% of the U.S. beef market and the alternative beef market has grown about 20% per year in recent years (Mathews and Johnson, 2013).

Many obstacles confront grass-fed beef producers, and these challenges have been detailed by several authors (GwinDurham et al., 2012; Gwin, 2009; Gwin et al., 2013; Johnson et al., 2012; Mathews and Johnson, 2013). The small, localized production and distribution network means a great deal of effort must be expended to market grass-fed animals. Limitations in marketing, slaughter and processing facilities are the main barriers to expanding the market for grass-fed beef (Gwin, 2009; Mathews and Johnson, 2013). From the environmental perspective, producers and consumers alike may be surprised to learn that grass-finishing tends to impart greater overall greenhouse gas emissions than grain finishing because animals live longer (Cusack et al., 2021)– though many grass-fed ranchers believe the practice is overall better for the land (Grassfed_Alliance, 2022). New technologies such as virtual fencing (Anderson et al., 2014) could provide ranchers greater control over the quality of forages grazed by grass-fed cattle which could lead not only to improved land use, but to improved animal diets which could result in reduced methane emissions (Ricci et al., 2014).

While the choice of breed has the potential to impact the ability of producers to manage forage more effectively, finding cattle breeds that can efficiently finish on grass can be problematic. Most conventional cattle are too large to finish quickly and easily on grass alone. Gwin (2009) notes that some grass-fed producers have invested in smaller cattle – "heritage" breeds like Red Devon, Murray Gray, and British White. One breed not mentioned that is expanding in the southwest grass-fed beef market is the Raramuri Criollo. There are many additional claims made about RC cattle production and the desirable attributes of this biotype. Much of what has been written, especially in the popular press, is very consistent, yet little has been verified scientifically. Anderson et al. (2015) summarized what was then known about Criollo cattle; their origin and history, their unique foraging behavior, and the genetic contributions these cattle have made to the American beef industry. The interested reader is referred to this paper and to Armstrong et al. (2022) for additional detail.

Here we have compared the economic viability of grass finishing with RC vs cow-calf ranching with a breed used widely in the American Southwest (AxH). Looking beyond ranch gates, to the level of the supply chain, increased adoption of grass finishing may prove to be an overall strategy for climate adaptation as water for grain finishing becomes increasingly scarce. According to unpublished data, grass-finishing with RC uses substantially less water than grain finishing with AxH (). Yet there is a GHG tradeoff because RC live longer. Thus, many factors need to be considered when assessing the sustainability of the entire supply chain, with respect to climate adaptation and climate change mitigation. Further research is warranted, as this paper is limited in scope to a comparison in profitability across two specific genotypes, and a consideration of GHG impacts, and/or other potential ecosystem service benefits is beyond the scope of this paper. In addition to the considerations here, one issue may be that of the continued value of the genetics of the RC genotype. While the genetics of the RC breed are currently valuable, a drop-off in demand for this genotype may considerably alter the profitability of a RC operation in the future. Another area of future research would be among potential producers of RC cattle to determine the future of the breed, and whether it will be a long-term consideration for a sizable number of producers.

Author credit statement

GLT, Writing Original Draft, Methodology, Investigation ;LAT, Conceptualization; Methodology Data curation; Formal analysis, Writing Original Draft; JE, Investigation, Writing Review & Editing; SS, Investigation, Writing Review & Editing; REE, Conceptualization, Funding Acquisition, Writing Review & Editing; AFC, Investigation; Writing Review & Editing; DMA, Investigation, Writing Review & Editing; ALG, Investigation, Methodology.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Andres F. Cibils reports financial support was provided by New Mexico State University.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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