

Scaling Up Pastured Livestock Production: Benchmarks for Getting the Most Out of Feed & Land

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Raising animals outdoors on deep-rooted, perennial pastures can have significant benefits for the environment, animal welfare, and human health. Yet, today, pastured meat remains a niche market. It's estimated that less than 5% of the 32 million beef cattle, 5% of the 121 million hogs, and 0.01% of the 9 billion broilers produced in the U.S. in 2017 were raised and finished on pasture.^{1, 2, 3, 4} What would it take to make pastured systems the mainstream model of animal agriculture? And how might scaling up affect land use and the environment?

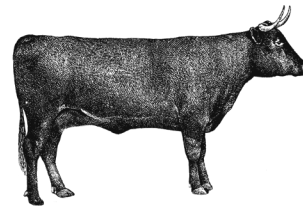
These are complex questions that involve daunting challenges in production, marketing, and distribution. As a starting point, we know that pastured livestock farms must be profitable businesses in order for the pastured livestock market to grow. This means it's important to optimize the two biggest expense categories for any pastured livestock farm: land and feed. Additionally, it's important to understand how much land it takes to produce pastured meats, so that we can estimate how much land it would take to scale up production in a given region.

To explore these interconnected questions of efficiency and scalability, Pasa Sustainable Agriculture worked with 10 diversified pastured livestock farms in Pennsylvania to develop feed and land efficiency benchmarks for three of the most common meat animal groups: beef cattle, pigs, and broilers. With these benchmarks, pastured livestock farmers can work to improve efficiency or cut costs.

LOCATIONS OF PASTURED LIVESTOCK FARM STUDY PARTICIPANTS

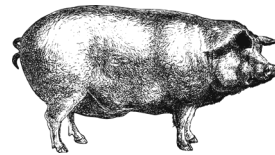


PERCENTAGE OF LIVESTOCK RAISED & FINISHED ON PASTURE IN U.S.



5%

of 32 million beef cattle



5%

of 121 million hogs



.01%

of 9 billion broilers

We also used these benchmarks to offer insight into how different livestock models translate to different land use scenarios for a state or region. With these benchmarks and insights in mind, we can work to better understand what sustainable meat production—and consumption—looks like in practical terms for farms and communities.

METHODS

We conducted detailed interviews with 10 pasture-based livestock farms in Pennsylvania raising combinations of grass-finished cattle, pastured pigs, and pastured broilers. All of the farms provide animals with continuous access to pasture, except during farrowing and brooding periods for pigs and broilers. We also consulted the farmers' 2016 and 2017 records on production, processing, feed rations, and grazing practices.

METHODS, CONT.

Farmers reported processed animals as an average *hanging weight* per animal, or the weight of the animal after it has been slaughtered, blood drained, and offal removed. Because the conversion from hanging weight to marketable meat yield varies from processor to processor, we standardized values for converting from live weight to hanging weight, and from hanging weight to meat yield, using values from farmer experience and published references (Table 1).^{5, 6} For beef and pork, we estimated meat yield as bone-in retail cuts, while for chicken we estimated meat yield as whole, dressed birds.

TABLE 1: PROCESSING RATIOS USED TO ESTIMATE MARKETABLE MEAT YIELD

Animal	% hanging weight / live weight	% meat yield / hanging weight
Beef cattle	55%	65%
Pigs	70%	75%
Broilers	70%	80%

To estimate the total amount of land needed to raise animals on each farm, we inventoried hay purchased off the farm and divided feed mixes for each animal type into their component crops. We then used 2017 Pennsylvania yield data from the National Agricultural Statistics Service (NASS) to estimate the land area needed to produce these crops.⁷ We standardized hay quantities to 87% dry matter. While some of the farmers we interviewed sourced non-GMO feeds, none were certified organic. This is important to highlight since organic crop yields in the U.S. are on average approximately 20% lower than conventional yields, which will tend to translate into lower land-use efficiency for organic livestock operations.⁸

We used an *annual time-step* to gather and analyze records for each of the 10 farms we examined. Essentially, this means that we accounted for all the animals coming in or out of a farm in a given year, without tracking individual cohorts of animals that may take more than a year to mature (e.g. beef cattle), or that may be born in the fall of one year and slaughtered in the summer of the next (e.g. pigs). We also did not account for feed or hay that may have been stored on a farm over winter, and instead assumed that the winter inventory is fairly constant year to year.

Our benchmarks include land and feed needed to support the entire herd of cattle or pigs, including breeding stock, replacement heifers or sows, and weaned animals that won't be processed until the following year. For farms that sell or purchase live stocker calves or feeder pigs, we estimated the meat yield "embedded" in those animals based on their live weight at the time of purchase. We then added or subtracted this from the farm's annual total meat yield.

For each farm and animal type, we estimated a *gross meat yield* and an *adjusted meat yield*. The gross meat yield is the marketable meat yield from all animals processed and marketed by the farm in the study year. The adjusted meat yield takes into account the marketable meat embedded in purchased stockers or feeders, or in live animals sold to finish on other operations.

For example, if a beef farm processed 20 animals for a combined hanging weight of 13,000 pounds, we would estimate the gross meat yield as:

$$= 13,000 \text{ LBS. HANGING WEIGHT} * (65\%) = 8,450 \text{ LBS.}$$

If this same farm also bought three stockers from another farm that were about 300 pounds live weight at the time of purchase, then later sold six stockers that were 500 pounds live weight at the time of sale, we would then estimate the adjusted meat yield as:

$$= [13,000 \text{ LBS. HANGING WEIGHT} * (65\%)] - [3 * 300 \text{ LBS. LIVE WEIGHT} * (55\%) * (65\%)] + [6 * 500 \text{ LBS. LIVE WEIGHT} * (55\%) * (65\%)] = 9,139 \text{ LBS.}$$

For broilers, farmers received days-old chicks from hatcheries, but we were unable to estimate the "embedded" resources required to support hens at the hatchery. Therefore, the gross meat yield and adjusted meat yield is the same for broiler operations.

By taking this annualized approach, we are assuming that 2016 and 2017 were fairly typical years on these farms. If a farm was in the process of significantly scaling up or scaling down its herd size, then the annual time-step approach won't be accurate. Likewise, if a farm stored significantly more hay or feed over the winter than usual, that could skew our numbers. Still, although the annual time-step approach has these shortcomings, it's a practical method for benchmarking efficiency using records that most farms can easily maintain. And by averaging over multiple years and multiple farms, we can hone reasonable benchmarks.

FEED & LAND EFFICIENCY BENCHMARKS

For each animal type, we summarize key benchmarks for feed and land efficiency in the tables below. We also share farm-scale indicators that provide context for the size and structure of each farm enterprise.

Pastured Beef Cattle

Feed efficiency

The most efficient of the five beef cattle farms we examined produced 164 pounds of meat per ton of hay, while the two least efficient farms produced 28 pounds of meat per ton of hay.

Land efficiency

The most efficient of the five beef cattle farms we examined produced 71 pounds of meat per acre of pasture and hay acres, while the least efficient farm produced on average 31 pounds of meat per acre.

TABLE 2: PRODUCTION BENCHMARKS FOR 5 GRASS-FINISHED BEEF FARMS*

FARM-SCALE INDICATORS									EFFICIENCY BENCHMARKS	
Farm	Year	Stockers purchased	Stockers sold	Carcasses marketed	Gross meat yield (lbs.)	Adjusted meat yield (lbs.)	Pasture (acres)	Hay-only (acres)	Adj. meat yield per ton hay	Adj. meat yield per total land acres
A	2017	9	-	23	7,931	6,014	70	15	164	71
A	2016	8	-	22	7,944	6,392	84	16	156	64
B	2016	-	-	8	2,123	2,123	30	15	55	47
C	2016	-	25	19	7,636	11,985	250	36	133	42
C	2017	-	28	18	7,770	13,276	266	54	92	42
D	2016	-	-	18	5,959	5,959	110	35	48	41
E	2016	2	-	13	5,125	4,553	90	52	28	32
B	2017	-	-	7	2,034	2,034	37	29	28	31

*Many farms harvest some of their hay from pasture acres that they also use for grazing, while also purchasing additional hay from other farms. In this table, "hay-only" acres refers to the acreage needed to produce the additional hay purchased on other farms, while "adjusted meat yield per ton hay" includes all hay fed, including purchased hay or hay harvested from grazing pastures.

FAMER INSIGHT: LOCALLY-ADAPTED GENETICS

Bill Callahan of Cow-A-Hen Farm in Lewisburg, Pennsylvania relies on locally adapted genetics as a key way to boost the efficiency of his pastured cattle herd, which has been exclusively bred on-farm for 25 years. He began his operation with a Holstein dairy herd, and has since brought in Charolais, Simmental, and Hereford genetics through bulls as the herd has become steadily more adapted to the unique environment of his pastures. He carefully selects mother cows based on breeding success and calf survival. While many farms favor cows that birth large calves, because large calves can lead to higher value stocker cattle or to more marketable meat per animal, Bill finds that with smaller calves he has very



COW-A-HEN FARM, PENNSYLVANIA

few problems with cow and calf mortality. Additionally, smaller-bodied animals take less time to mature, helping maintain cash flow on the farm.

Pastured Pigs

Feed efficiency

The most efficient of the eight pastured pig farms we examined produced 0.16 pounds of meat per pound of feed, while the least efficient farms produced 0.08 pounds of meat per pound of feed.

Land efficiency

The most efficient of the eight pastured pig farms we examined produced 1,186 pounds of meat per acre of cropland used to grow feed, while the least efficient farm produced on average 313 pounds of meat per acre of cropland.

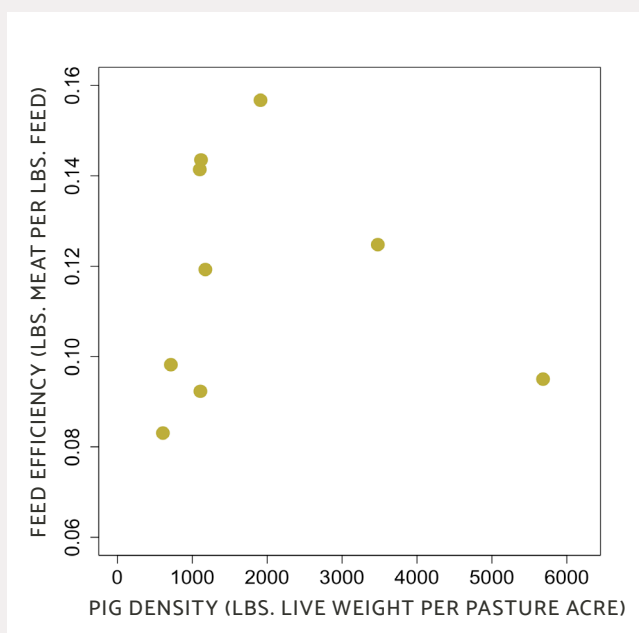
TABLE 3: PRODUCTION BENCHMARKS FOR 8 FARMS RAISING PASTURED PIGS

FARM-SCALE INDICATORS								EFFICIENCY BENCHMARKS	
Farm	Year	Stockers purchased	Stockers sold	Carcasses marketed	Gross meat yield (lbs.)	Adjusted meat yield (lbs.)	Pasture (acres)	Adj. meat yield per lb. feed	Adj. meat yield per cropland acre.
F	2016	170	-	123	26,891	24,660	40	0.12	1,186
B	2017	12	-	65	6,821	6,380	20	0.08	733
G	2016	-	-	35	5,015	5,015	5	0.16	591
H	2016	-	8	85	13,856	14,066	24	0.14	540
H	2017	-	-	85	13,856	13,856	24	0.14	532
D	2016	-	55	26	3,000	5,966	2	0.10	469
E	2016	40	-	50	6,388	6,388	3.5	0.12	468
I	2017	-	5	36	5,724	5,816	10	0.09	372
J	2017	24	10	130	23,430	22,485	60	0.10	313

FARMER INSIGHT: SUPPLEMENTING FEED WITH FORAGE

Some farmers in our cohort wondered if pastured pigs can offset their feed consumption by foraging for roots and other resources. If access to pasture did indeed help to reduce feed consumption, we might expect to see a negative relationship between feed efficiency and the density of animals on pasture. Our data don't support this hypothesis—we didn't find a significant correlation between live weight per acre of pasture and meat per pound of grain fed (**Figure 1**). These data don't prove that pastures can't be managed in a way that offsets some feed costs; they only show that our sample of farmers weren't realizing any feed offset from pasture. Moreover, these data don't speak to other benefits of greater access to pasture, such as improved animal welfare or more nutritious meat.

FIGURE 1: RELATIONSHIP BETWEEN FEED EFFICIENCY AND PASTURE DENSITY ON PASTURED PIG FARMS



Pastured Broilers

Feed efficiency

The most efficient of the eight pastured poultry farms we examined produced 0.88 pounds of meat per pound of feed, while the least efficient farms produced 0.27 pounds of meat per pound of feed.

Land efficiency

The most efficient of the eight pastured poultry farms we examined produced 4,958 pounds of meat per acre of cropland used to grow feed, while the least efficient farm produced on average 1,697 pounds of meat per acre of cropland.

TABLE 4: PRODUCTION RECORDS FOR 3 FARMS WITH PASTURED BROILER FLOCKS

FARM-SCALE INDICATORS						EFFICIENCY BENCHMARKS	
Farm	Year	Birds marketed	Gross meat yield (lbs.)	Adjusted meat yield (lbs.)	Pasture (acres)	Adj. meat yield per lb. feed	Adj. meat yield per cropland acre
H	2017	703	2,953	2,953	10	0.87	4,958
H	2016	743	2,976	2,976	10	0.88	4,781
F	2016	2,157	8,628	8,628	3	0.27	2,351
J	2017	6,880	25,800	25,800	25	0.37	1,697

Interestingly, although eight of the 10 farms in our group raised poultry, only three farms were able to generate production benchmark statistics for broilers. Most farmers raising broilers were also raising laying hens and turkeys, and a common practice was to feed all poultry animals from the same feed bins for at least part of the year. Feeding broilers, laying hens, and turkeys all from the same bins makes it impossible to accurately estimate the amount of feed invested in broilers. Although it's often convenient to feed different poultry groups from a common feed bin, this practice may lead to significant gaps in business planning and enterprise budgeting. Without being able to break down feed expenses by animal group, it is impossible to know if and when poultry enterprises are making or losing money. Developing record keeping practices to separate feed consumption by animal type is an important step forward in making pastured poultry farms more profitable and efficient.

FARMER INSIGHT: PREDATOR CONTROL

Brooks Miller at North Mountain Pastures in Newport, Pennsylvania finds that predator control is a key aspect of an efficient pastured poultry operation. Losses from predators anywhere in the production cycle significantly increases the total amount of feed needed to bring a bird to market. In 2016, Brooks developed a new brooder design using second-hand steel shipping containers. These containers virtually eliminate losses of chicks to weasels, rats, and other predators. He's also installed automatic feeders and waterers in the brooders. He finds that by keeping feed and water consistently available, chick growth and survival rates have also greatly improved.



NORTH MOUNTAIN PASTURES, PENNSYLVANIA

SCALING UP PASTURED LIVESTOCK SYSTEMS

What do these feed and land efficiency benchmarks mean for scaling pastured livestock farms to become the mainstream method of meat production?

First, it's clear that many pastured livestock farms likely have the ability to become significantly more efficient at translating feed and land into marketable meat. In our study, we saw a range of 56%, 74%, and 66% from the least to most land-efficient farms for grass-finished beef, pigs, and broilers, respectively.

For a more comprehensive comparison, it's helpful to consider the land efficiency of confinement livestock farms where animals are kept indoors and fed grain. We consulted the scientific literature to summarize results from life-cycle analysis studies for confinement beef cattle,⁹ pigs,^{10,11} and broilers,^{12,13,14,15,16} in which scientists have conducted a comprehensive accounting of the resources needed to raise an animal from conception to processing. To put our own land efficiency estimates into context, we also reviewed published life-cycle analyses of grass-finished beef,¹⁷ pastured pig,^{10,11} and pastured poultry systems.^{12, 13,15,16} Because deep-rooted perennial pastures and hay fields can build soil health and protect water quality, while crop fields used to grow annual grains typically require much more intensive soil disturbance, it was important to distinguish between land efficiency for land used for perennial pasture and hay versus land used to grow annual crops.

Reviewing these numbers, we find that pastured operations are typically much less land-efficient than confinement farms. Cattle are by far the least land-efficient animal type, with the all-grass farms typically half as efficient with perennial land than confinement systems that typically blend grass-raised stockers and feedlot finishing phases. Pastured pork farms are approximately half as efficient as confinement pork farms at turning grain and cropland into meat, while our study participants were about 13% more efficient than the pastured systems analyzed in other published studies. Broilers were the most land-efficient animal type, and, perhaps counterintuitively, these data reveal pastured broiler operations may be 5 to 20% more efficient with cropland than confinement operations. This result might suggest that while pastured broilers may grow more slowly or burn more calories moving around on pasture than broilers in confinement, they can also supplement their feed with foraged seeds, insects, and vegetation.

TABLE 5: MEDIAN LAND-USE EFFICIENCY FOR BEEF CATTLE, PIGS & BROILERS*

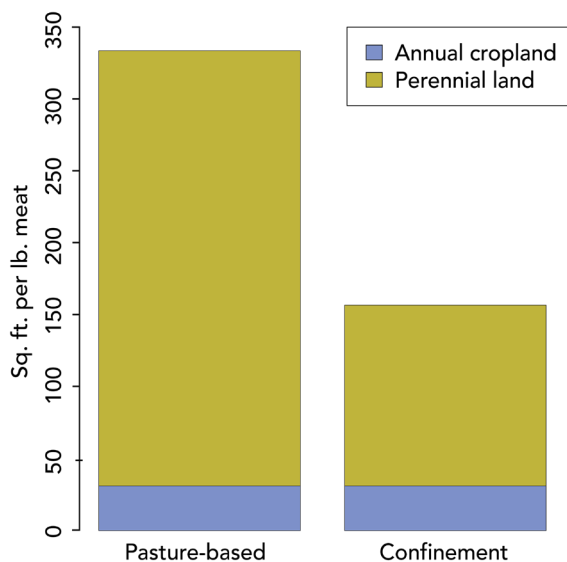
Animal	Farm type	Adj. meat yield per perennial acre	Adj. meat yield per cropland acre	Adj. meat yield per total acre
Beef cattle	Pastured (study participants)	41.7	-	41.7
	Pastured (literature review)	47.5	-	47.5
	Confinement (literature review)	99.5	1,221	92.0
Pigs	Pastured (study participants)	599	500	273
	Pastured (literature review)	-	432	432
	Confinement (literature review)	-	953	953
Broilers	Pastured (study participants)	1,032	2,351	717
	Pastured (literature review)	1,935	1,984	980
	Confinement (literature review)	-	1,877	1,877

**Note that conventional beef production in the U.S. typically involves grazing during the calf and "backgrounding phase", with animals finished on grain in feedlots for the final 160-180 days, or about 25% of their life span. Confinement hog and broiler operations are typically fed grain in confined conditions from birth to processing.*

So far, we've looked at land use separately for each animal group, but on many pastured livestock farms cows, pigs, broilers, and other animals will interact in ecologically important ways. Pigs or chickens may follow beef cows in different phases of a rotation and work to control weeds, break up pest cycles, and provide additional fertility to the grazing pastures. So, how much pasture and cropland are needed to produce a mix of beef, pork, and poultry meat, given that U.S. meat production is roughly 26% beef, 26% pork, and 42% chicken by total pounds produced? We calculated the amount of land needed to produce one pound of this "composite" mix of meat products on an integrated farm where cows, pigs, and poultry share pastureland, as compared to a one-pound meat equivalent from three separate confinement operations.

Figure 2 shows that while pasture-based farms use more land in total than confinement operations, this additional land is mostly deep-rooted perennial pasture—not annual cropland with potentially associated soil disturbance, pesticide and fertilizer applications, and fossil fuel consumption. In fact, the annual cropland needed by pasture-based farms is almost equivalent to the cropland needed by confinement farms. Essentially, the total land base of a pastured livestock farm might be greater than a confinement operation, but its ecological impact could be considered not only lesser than the confinement model, but can even be viewed as ecologically regenerative in a well-managed system.

FIGURE 2: LAND NEEDED TO PRODUCE A 1-POUND COMPOSITE OF BEEF, PORK & CHICKEN



Sustainable Meat Production & Consumption

A bigger land-use footprint means more land needs to be devoted to agricultural production. Using Pennsylvania as an example, how many acres would it take for pastured livestock farmers like the 10 in our study to provide meat for all of Pennsylvania’s 12.8 million residents?

According to the 2017 Census of Agriculture, Pennsylvania has approximately 706,000 acres of pastureland and 4.6 million acres of cropland.⁷ Assuming all residents are consuming the USDA recommendation of 6 ounces of animal protein per day (many probably eat considerably more meat on a given day, some eat none, and nutritionists continue to study how much and what kind of meat is best), a rough calculation shows that we’d need to convert all of the state’s existing cropland into perennial

pasture *plus* we’d need to utilize an additional 7.2 million acres of pastureland and 1.2 million acres of cropland outside of the state to feed all of these animals from farms that hit our average land use efficiency benchmarks (Table 6). In contrast, if all of these animals were raised using confinement methods, we’d need to convert 4.9 million acres of pasture and 434,000 acres of cropland in Pennsylvania, *plus* we’d need to utilize an additional 885,000 acres of cropland outside of the state—in other words, far less land than the pastured model requires.

TABLE 6: CURRENT & HYPOTHETICAL LAND-USE IMPLICATIONS (IN ACRES) OF PRODUCING A MEAT SUPPLY FOR PENNSYLVANIA’S POPULATION

		Pasture-based	Confinement
Current PA land base	Perennial land	706,136	
	Annual cropland	4,651,210	
Land needed to supply PA population	Perennial land	12,536,694	4,922,975
	Annual cropland	1,222,700	1,319,229
Land used to supply PA population	Perennial land	5,357,346	4,922,975
	Annual cropland	0	434,371
Land needed in other states	Perennial land	7,179,348	0
	Annual cropland	1,222,700	884,858

It’s clear that if we all chose to eat pastured meats, we’d have more land in deep rooted, perennial pastures that protect water and enrich soil. While some of that expanded pasture land would replace cropland currently used to grow feed grains for confinement operations, we’d also have to convert substantial areas of cropland that could be used to grow food grains, veggies, and other crops directly consumed by people. Pastured livestock systems still have plenty of room to scale up in Pennsylvania and nationally as a farming method, but if it is to be our default method of meat production we will also need to make informed choices about how much meat we choose to consume to enable a healthier and more environmentally sustainable model of meat production to succeed.

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If you are interested in benchmarking your pastured livestock farm's land and feed efficiency, Pasa can work with you to calculate benchmarks for your farm using the methods outlined in this resource. Our spreadsheet can be accessed at pasafarming.org/land-feed-benchmarks-worksheet or contact research@pasafarming.org for more information. As more farmers contribute data using these tools, we can improve the accuracy of our benchmarks and help highlight more innovative practices that improve efficiency.