Forage and Cattle Planner (FORCAP)

Reference Manual, 2013

(see price updates in the User manual)

Version 1

By

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Forage and Cattle Planner (FORCAP): Reference Manual, 2013

I. Introduction

The Forage and Cattle Planner (FORCAP) was developed to allow producers, extension agents, and researchers evaluate the effects of cow-calf and forage management decisions on net returns (NR) and greenhouse gas (GHG) emissions. FORCAP estimates GHG emissions and NR for a one year time period for specific, user-entered parameters for a cow-calf operation in steady state (herd size is not changing and mature cows and bulls are modeled at their average weight with forage species mix predetermined but user-defined for the year). Cumulative year-to-year effects are not estimated nor are potential price changes that may result from changes in production or input use. Results, unless otherwise specified, pertain to a one-year time frame. Users enter operation-specific farm, forage, and cattle production parameters to determine the NR and GHG emission changes of different input, management, agronomic, and economic variables. FORCAP provides pertinent economic and GHG emission estimates for different operations with a user-friendly interface while accounting for agronomic, environmental, animal performance, and economic relationships that are often interlinked (e.g. raising soil fertility not only affects forage growth but also, forage species composition, how animal nutrient needs are met, the stocking rate and ultimately economic returns and GHG emissions per farm, per pound of live-weight produced, or per acre). Inputs, production methods, and site characteristics modeled in FORCAP are specific to cow-calf and forage production in the Ozark Highlands region of Northern Arkansas and Southern Missouri; however many of the parameters modeled are applicable to other regions and forage / cattle enterprises.

The reference manual provides a summary of the 2012 University of Arkansas, Division of Agriculture Cow-Calf Drought Survey in an attempt to provide insights on baseline or bench mark farm characteristics by farm size, and continues by describing the modeling background, methodology, scientific principles, and formulas utilized to estimate NR and GHG emissions in FORCAP[1]. The user manual provides operating instructions for installation and use of FORCAP.

II. Benchmark Farm Operation Details

Arkansas Cattle Producer Survey

The summer of 2012 was one of the worst droughts in decades having a dramatic impact on cow-calf and forage producers in Arkansas. Precipitation from April to July was below seasonal norms for most of the state (Figure 1). Additionally, precipitation events producing large quantities of rainfall were short in duration, thus not allowing sufficient time for water to

1 Note that reference manual has an accompanying user manual that describes how and where to enter parameters in each tab of the FORCAP model (Keeton et al., 2013).

be absorbed into agricultural soils (Smith et al., 2012a). Cow-calf producers were adversely affected due to diminished pasture productivity, reduced hay production, lower calf weaning weights resulting from earlier marketings, expected incidence of more reproductive failure due to reduced cow weights and body condition scores (BCS), and increased input costs for water, pasture maintenance, and supplemental feeds. To capture the economic consequences of the drought, an online survey was distributed in August 2012 to cow-calf producers that are part of the University of Arkansas Cooperative Extension Service Animal Science Department's blog list as well as cattle producers that applied for assistance with the Arkansas Department of Agriculture. This resulted in direct e-mail contact with 971 producers via the Animal Science Constant Contact List and 916 producers via the Department of Agriculture with an unknown amount of overlap between the two mailing lists. The survey was also announced at producer drought meetings conducted at Hot Springs (Aug. 15, 2012) and Harrison (Aug. 16, 2012) with a pretest conducted at Quitman (Aug. 7, 2012). A total of 545 responses from 58 counties were received using Qualtrics, an on-line survey tool administered by the University of Arkansas, after getting Institutional Review Board approval (IRB #: 12-08-033).

Figure 1. Deviation from normal precipitation levels for five locations in Arkansas

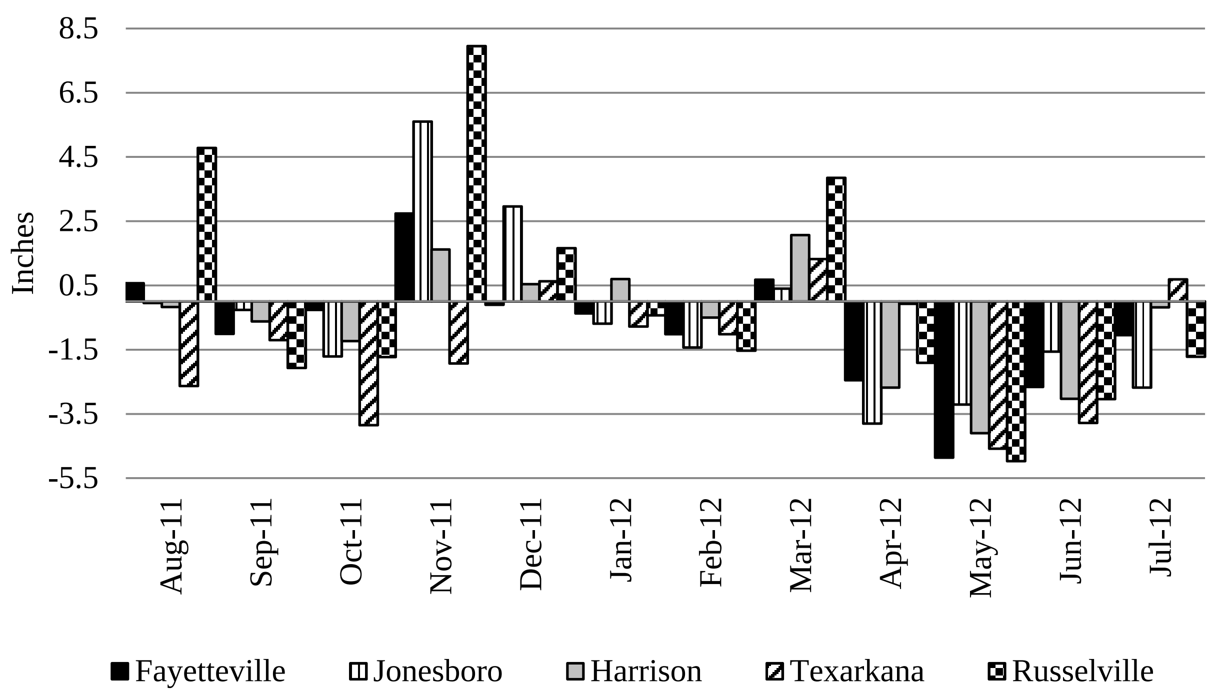
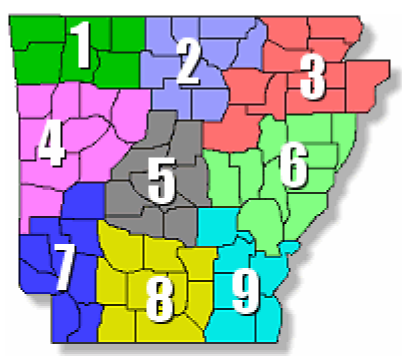


Table 1. Number of drought survey responses by crop reporting district (CRD), 2012 estimated number of beef cows, and estimated economic loss to Arkansas producers from reduced forage and beef production

CRD	Number of Survey Responses	2012 Estimated Number of Beef Cows	Estimated Economic Loss from Reduced Forage and Beef Production in Millions of $
1	62	208,500	29.5
2	48	84,200	11.9
3	31	57,300	8.1
4	32	90,700	12.8
5	32	61,800	8.8
6	4	20,100	2.8
7	27	59,300	8.4
8	5	21,500	3.0
9	4	11,000	1.6
Not Disclosed	161	294,600	41.7
State Total	406	909,000	128.4

Table 1 shows the location, by crop reporting district (CRD), of the 406 commercial cow-calf producer respondents as well as the 2012 USDA estimated number of beef cows for each CRD in Arkansas. As anticipated, the majority of the respondents were located in the Ozark Highlands eco-region located in parts of CRD 1 to 5 in the North, West, and Central portion of the state (Figure 2) as those are the regions with the largest number of cow-calf operations.

Figure 2. Crop reporting districts (CRD) in Arkansas



Survey Design

The survey was designed to measure differences in forage and cow-calf production between August 2011 to July 2012 and a typical year (defined as a 3-year average of August 2008 to July 2011). Respondents were asked to report on their type of cow-calf operation – commercial, purebred, or both as well as their control over calving season (spring, fall, year round, or other). Only responses from commercial producers were reported in the reference manual, as FORCAP was designed for commercial cow-calf production rather than purebred operations which have different farm and cattle management parameters (e.g. maintaining male calves on the farm past weaning age and the use of artificial insemination to improve breeding success and accuracy of breed traits). Questions regarding calving season were important to determine how much seasonal detail with respect to sale prices, forage needs, and forage availability would be needed. The remaining questions centered on:

- hay (amounts fed, prices paid and received, acres harvested, and fertilizer use);
- feed supplements other than hay (type and cost);
- animal statistics (sale weights for steer and heifer calves, selling age for calves, number of and weight of cows bred, number of calves weaned annually, and number of bulls used);
- pasture (acreage, use of cross fencing, frequency of resting periods for individual pastures, forage species composition, and fertilizer use);
- planned and actual responses to the drought up to the end of July 2012 and for the remainder of 2012.

The average response time to the survey was 34 minutes.

Survey Results

Results of the 2012 drought survey can be found online at http://srmec.uark.edu/beef/. For the purposes of this manual, commercial cow-calf producer responses to the 3-year average questions were utilized. The operations were segmented into three benchmark farm sizes: small (30 or fewer bred cows), medium (31 to 90 bred cows), and large (greater than 91 bred cows). Small, medium, and large operation sizes were determined to be a function of the number of bred cows per bull and to more or less create groupings of operation size that would contain roughly the same number of observations in each category. For example, it was assumed that one bull could successfully breed 30 cows per season. For each operation size, responses were further divided into four calving seasons (year-round, fall, spring, and dual). Half of the respondents indicated that they practiced year-round-calving on their operation. Spring- and fall-calving season was used by 18% and 7%, respectively while a dual-calving season (spring and fall) was utilized by 25% of producers. Questions pertaining to forage composition, herd characteristics, and fertilizer application are summarized by farm size and calving season with weighted averages by farm size shown in Tables 2 to 4. Survey results, along with expert opinion and literature review, thus establish the baseline for representative small, medium, and large benchmark farms in FORCAP.

Forage Composition

Hay acres, pasture acres, percentage of total acres in hay, number of pasture paddocks, species composition, number of acres of winter wheat or ryegrass planted in the fall, and number of survey responses (Obs.) are shown in Table 2. Land holdings for small, medium, and large operations averaged 46, 103, and 304 acres of hay and 65, 163, and 710 acres of pasture, respectively. Of note, an extremely large operation influenced the land holdings for large, dual-calving operations (the operation was left in the analysis as extremely large operations, while not the norm, are present in the region). Producer responses to species composition of forage acres resulted in higher percentages of bermudagrass and clover than anticipated. Producers' responses indicated that bermudagrass was estimated to compose 33 to 41 percent of the forages in hay and pasture stands, while clovers comprised 33 to 40 percent, respectively. Seeding ryegrass and winter wheat was a practice producers in the region utilized to establish a winter or spring grazing forage.

Table 2. Summary of commercial cow-calf producer responses to forage questions in the 2012 University of Arkansas Cow-Calf Drought Survey

					Pasture Species Composition (% by area)						
Operation Size	Calving Season	Hay Acres	Pasture Acres	Hay Acres % of Total	Bermuda	Fescue	Clover	Other	% Total	Ryegrass / Winter Wheat Acres	Obs.
Small	Year-round	40	54	42	36	12	36	10	94	7	60
	Fall	49	91	35	34	12	34	6	86	9	11
	Dual	47	74	39	33	5	39	4	80	4	23
	Spring	58	72	45	29	3	31	3	66	16	25
	Weighted average	46	65	42	34	9	36	7	85	8	NA
Medium	Year-round	109	166	40	30	10	30	6	75	23	69
	Fall	113	138	45	43	4	36	2	84	31	8
	Dual	115	144	44	43	4	45	1	93	20	26
	Spring	66	183	26	25	6	30	4	64	19	21
	Weighted average	103	163	39	33	7	33	4	78	22	NA
Large	Year-round	153	321	32	36	7	34	6	82	36	25
	Fall	180	320	36	40	0	60	0	100	150	1
	Dual	462	1,195	28	43	11	45	5	104	80	28
	Spring	251	329	43	47	0	45	0	92	99	9
	Weighted average	304	710	32	41	7	40	5	93	66	NA

Herd Characteristics

Cow weights, steer and heifer weights (at sale age), weaning age, breeding failures and death losses, number of calves weaned, number of bred cows, number of bulls, stocking rate, and number of survey responses (Obs.) are shown in Table 3. Average cow weights were 1,073 to

1,250 lbs and did not vary statistically (p-value < 0.10) based on operation size. At sale, steer weights were 564 to 750 lbs, heifer weights were 503 to 700 lbs, and weaning age was 7.7 to 12 months. Larger operations indicated later weaning age and consequently recorded increased calf weights compared to medium and small operations. Average daily gain (ADG), assuming an 80 lb birth weight for calves was 1.9 to 2.3 for steer calves and 1.7 to 2.0 for heifer calves. Breeding failures and calf death losses appeared to be correlated with calving season. Fall-calving producers recorded substantially lower breeding and death losses (small 10%, medium 9%, and large 7%) than other calving seasons (Table 3). This difference may be attributed to the reduced impact of fescue toxicosis in fall- calving herds which is supported by the empirical study as reported by Smith et al., 2012b and Caldwell et al., 2013. Number of cows, calves weaned, and bulls for large operations using a dual-calving season were skewed due to the inclusion of a large operation with in excess of 3,000 head of bred cows. Simple averages were calculated by calving season and operation size and as such, each operation was weighted equally which would reduce the impact of extremely large operations when compared to using a weighted average using number of head as a weighting tool. Average stocking rate, herein defined as the number of acres per cow, ranged from 2.2 to 5.3 acres per bred cow, with smaller operations indicating more acres per cow than larger operations (Table 3). This could be a result of better quality pastures available to larger producers and / or more attention paid to grazing strategy implemented by larger producers where a greater percentage of income is derived from cattle production than is the case for smaller, part-time cattle operations.

Table 3. Summary of commercial cow-calf producer responses to cattle questions in the 2012 University of Arkansas Cow-Calf Drought Survey

Operation Size	Calving Season	Cow Weight (lbs)	Steer Weight (lbs)	Heifer Weight (lbs)	Weaning Age (Months)	Breeding Failures and Calf Death Loss	# of Calves Weaned	# of Bred Cows	# of Bulls	Stocking Rate (Acres / Cow)	Obs.
Small	Year-round	1,156	588	530	8.3	24%	14	19	1.1	2.92	60
	Fall	1,114	593	503	7.9	10%	15	17	1.0	5.31	11
	Dual	1,194	584	540	7.7	3%	21	21	1.1	3.44	23
	Spring	1,164	618	548	7.7	18%	15	19	1.2	3.86	25
	Weighted average	1,161	594	533	8.0	17%	16	19	1.1	3.44	NA
Medium	Year-round	1,144	564	528	8.1	23%	42	55	2.4	3.02	69
	Fall	1,100	629	537	9.2	9%	52	57	2.4	2.42	8
	Dual	1,190	575	535	8.5	22%	43	56	2.2	2.59	26
	Spring	1,123	580	558	8.3	27%	43	59	2.7	3.13	21
	Weighted average	1,147	573	535	8.3	23%	43	56	2.4	2.91	NA
Large	Year-round	1,073	607	542	8.6	36%	81	126	4.8	2.54	25
	Fall	1,250	750	700	12.0	7%	130	140	4.0	2.29	1
	Dual	1,213	635	602	8.9	23%	265	345	13.5	3.46	28
	Spring	1,178	661	598	10.1	13%	129	148	6.7	2.22	9
	Weighted average	1,153	629	579	9.0	27%	170	227	8.9	2.90	NA

Fertilizer Application

A low response rate (13%) to the fertilizer questions in the survey and ambiguous interpretation of questions by the respondents regarding elemental fertilizer quantities compared to actual amounts of fertilizer applied diminished the representativeness of the results presented in Table 4 and hence caution is advised when interpreting application quantities. Responses did reveal that poultry litter application on hay and pasture (1.5 to 3.0 tons / acre) was a common practice in the region (33% of respondents indicated poultry litter was applied to pasture or hay acres). Nitrogen application was more prevalent than application of P or K. As expected, hay acres were more heavily fertilized with both N and poultry litter and is likely a function of more fertile soils and level topography allowing easier access with equipment for fertilizer application than pasture acres.

Table 4. Summary of commercial cow-calf producer responses to fertilizer questions in the 2012 University of Arkansas cow-calf drought survey

		Hay Acres				Pasture Acres			
Operation Size	Calving Season	N (lbs / acre)	P (lbs / acre)	K (lbs / acre)	Poultry Litter (tons)	N (lbs / acre)	P (lbs / acre)	K (lbs / acre)	Poultry Litter (tons)
Small	Year-round	135	114	96	2.12	101	74	67	1.60
	Fall	125	0	0	2.33	100	0	0	1.33
	Dual	160	181	217	1.50	93	106	88	1.50
	Spring	183	84	106	2.83	165	121	156	2.80
Medium	Year-round	170	105	162	2.37	111	56	54	2.02
	Fall	175	0	0	2.25	50	0	0	1.60
	Dual	170	65	131	1.64	130	57	84	1.44
	Spring	135	93	75	1.72	127	80	67	1.60
Large	Year-round	81	60	53	2.55	93	41	41	1.85
	Fall	150	0	150	3.00	0	0	0	3.00
	Dual	129	76	92	2.06	117	59	55	2.00
	Spring	235	200	225	2.00	163	250	250	1.75

III. Data and Methodology

FORCAP was designed so users could compare their operation (‘Your Farm’) to a representative ‘Bench Mark’ farm. The 2012 drought survey, expert opinion, existing University of Arkansas cow-calf budgets, and literature reviews were used to develop the ‘Bench Mark’ farm. The establishment of the ‘Bench Mark’ farm allows users to compare their operation with a typical operation in the region of similar size, site characteristics, inputs, and production methods. The subsequent sections provide a description of the listed inputs, site characteristics, and production methods along with the methodology used to estimate farm NR and GHG emissions. The methodology and parameters are segmented into five categories: farm parameters, herd characteristics, forage production, GHG emissions, and budgeting and economic analysis.

Farm Parameters

Size of Operation

Users can choose a 'Bench Mark' farm to compare to their operation. Three choices are available: *Small* - 120 acres (0 hay acres and 120 pasture acres); *Medium* - 240 acres (60 hay and 180 pasture acres); or *Large* - 600 acres (150 hay and 450 pasture acres). Pasture and hay acres for 'Your Farm' can be entered as any positive number and are required to reflect the total number of forage acres available to the operation. Pasture and hay acres should add to the total number of acres an operation has available. As such, hay acres grazed in the fall should not be included in pasture acres or pasture acres with excess forage harvested as hay should not be included in hay acres. Available land base does not differentiate between owned acres and leased acres (see budgeting and economic analysis). Selection of different farm sizes provides a suggestion for acreage and perhaps more important to NR calculations, a suggested list of equipment and buildings along with ownership charges employed by the operator.

Inputs

Users have the ability to adjust inputs to reflect those utilized on 'Your Farm'. Default inputs and starting values for each input were created to provide a template from which producers could build upon to more accurately reflect their specific circumstances. Default inputs are divided into eight categories: livestock; feed; fertilizer; fencing; interest, tax & insurance rates; fuel use; veterinary charges; and other (Figure 3).

- Livestock was divided into two primary categories, breeding livestock and market livestock. The breeding livestock category contains three animal groups [replacement heifers, bred cows (further segmented into young cows and mature cows), and bulls] which will be discussed in detail in the herd characteristics section. Market livestock was segmented into heifer calves, steer calves, and culled breeding stock. Steer and heifer calves were divided by gender into 100 lb weight categories from 300-700 lbs.
- Users are able to select a standard round bale of hay weighing either 800 lbs (4' x 5') or 1,000 lbs (5' x 5'). For simplicity, the quality and species composition of the forage imported to the farm was considered the same as that produced on the farm[2]. Other feed inputs available were corn, corn gluten feed, dry distillers grains (DDG), soybean meal, soybean hulls, cotton seed, cotton seed meal, hominy, range cubes, rice bran, generic blend, or other (see animal health and veterinary service section). Salt, minerals, and rumensin are also specified as feed. Supplemental feeds were not used to modify intake

[2] This assumption allows for the forage balance calculations (see forage production section), DMI, NE_m, and CP intake for each herd to be estimated using only one nutritional composition for hay. Important to note is that users have the ability to input different species composition for grazed forage and hay production on their farm and create alternate forage species using the 'Forage Species' tab.

requirements for the herd. Monensin, on the other hand, could be fed at 200 mg per head (adj. for animal category) per day to improve feed efficiency and reduce methane (CH_4) emissions from enteric fermentation. More discussion is relegated to the feed section of this manual.

- Lime pellets, ammonium nitrate, diammonium phosphate, potash, and poultry litter constituted the array of default fertilizer choices available. A user can also specify their own fertilizer.
- Fencing options include: barbed wire, electric wire, wooden corner braces, metal pipe corner braces, T-posts, electric fence posts, insulators for T-posts, electric fence chargers, and gates. Farm ponds and watering tanks were also included in fencing inputs.
- Property taxes, insurance charges, and capital recovery cost for ownership of capital assets were estimated using standard rates (Figure 5). Operating interest rate was assumed to be 6% and charged on half of total direct operating costs to estimate interest charges on an operating line of credit that would be used to pay for feed, fertilizer, and other direct costs.
- Diesel fuel was assumed to be used for all farm machinery. Fuel use includes: fuel for two cuttings of hay per year, staging to storage site, ¼ gal per acre (once prorated over a ten year stand life) for custom reseeding, hay feeding and field preparation.
- Twine was charged to on-farm hay production at 1/3rd lbs. per bale
- Veterinary services included prolapse, C-section, sick treatments, and bull soundness tests. Vaccinations are measured per cwt or per head and include: dewormer, pasturella 7 way black leg, 4 way viral, pinkeye, scour bolus, vibro-lepto 5, and brucellosis. Castration and growth implants are also allotted under veterinary services.

Prices

Users have the option of entering input prices for the inputs used on ‘Your Farm’ or choosing the default prices. Default prices for inputs other than cattle and fertilizer are estimated based on expert opinion, producer responses to the 2012 Arkansas Drought Survey (3-year average prices), or local retail prices prevalent in 2012. Included in the prices for fencing, corner posts, and gates is the labor required for installation. The cost of truck and / or ATV allocated to the beef enterprise is defaulted to $1 per bred cow as farm vehicles are not in the capital budget. Figure 3 shows the default prices for inputs recorded above. It is important to note that the ‘Bench Mark’ farm utilizes the default prices not the user entered prices if the defaults are not accepted for ‘Your Farm’. Cattle and fertilizer prices can be chosen from 2012, most recent five- or ten-year average prices as described below.

Figure 3. Default agricultural inputs and prices for the ‘Bench Mark’ and ‘Your Farm’ from the ‘Prices’ tab in FORCAP

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Prices for Selected Farm Products and Inputs

OK Press "OK" to accept all default prices (recommended before you start entering your own values)

FORCAP FORAGE & CATTLE PLANNER

	Item and Description	Unit	Yr 2012	Your Price ($)
	LIVESTOCK ... specify details under 'Cattle Options and Cattle Prices'			livestock only ☑
Steers	3 - 400 lb. Medium and Large Frame No. 1	$/cwt	$193.99	$205.30
Steers	4 - 500 lb. Medium and Large Frame No. 1	$/cwt	$174.96	$187.41
Steers	5 - 600 lb. Medium and Large Frame No. 1	$/cwt	$159.04	$171.09
Steers	6 - 700 lb. Medium and Large Frame No. 1	$/cwt	$146.60	$156.07
Heifers	3 - 400 lb. Medium and Large Frame No. 1	$/cwt	$165.28	$177.04
Heifers	4 - 500 lb. Medium and Large Frame No. 1	$/cwt	$152.85	$163.22
Heifers	5 - 600 lb. Medium and Large Frame No. 1	$/cwt	$142.28	$152.30
Heifers	6 - 700 lb. Medium and Large Frame No. 1	$/cwt	$133.87	$141.40
	Cull Cow (75-80% Lean Breaking Utility)	$/cwt	$76.35	$82.06
	Purchase Price of Breeding Bull	$/hd	$2,000	$2,000.00
	Cull Bull (Yield Grade 1 -2, 1,000 to 2,100 lb.)	$/cwt	$92.28	$94.54
	FEED			
	Hay delivered -- 4' x 5' or 800 lbs	$/bale	$45.00	$45.00
	Corn	$/lb	$0.15	$0.15
	Salt & Minerals (50 lb bag)	$/bag	$20.00	$20.00
	Rumensin (optional added cost to mineral)	$/bag	$12.00	$12.00
	FERTILIZER ... choose prices from list..		Yr 2012	fertilizer only ☑
	Lime	$/ton	$30.00	$30.00
	Ammonium Nitrate (34-0-0)	$/ton	$506.00	$506.00
	Diammonium Phosphate (18-46-0)	$/ton	$726.00	$726.00
	Potash (0-0-60)	$/ton	$647.00	$647.00
	Poultry Litter (3-2-3)	$/ton	$36.00	$36.00
	Application cost per acre	$/acre	$6.00	$6.00
	OTHER			
	Beef Checkoff	$/hd	$1.00	$1.00
	Insurance & Yardage	$/hd	$1.75	$1.75
	Sales Comission	% of sales	3.5%	3.5%
	Diesel Fuel	$/gal	$3.50	$3.50
	Custom charge for winter annuals	$/acre	$0.00	$0.00

Item and Description	Unit	2012	Your Price ($)
FENCING			
Barbed Wire (double strand)	1/4 mile	$63	$63
Electric Wire (165 psi 12.5 gauge)	3/4 mile	$100	$100
Corner/Brace - Pipe	1	$250	$250
Corner/Brace - Wooden	1	$100	$100
T-post (6 ft)	1	$4.00	$4.00
Electric Fence posts	1	$2.50	$2.50
Insulators for T-posts	1	$0.25	$0.25
Charger	1	$250	$250
Gates	1	$50	$50
Farm Pond	1	$1,500	$1,500
Watering Tank (50% cost share)	1	$1,250	$1,250
INTEREST, TAX & INSURANCE RATES			
Capital Recovery Rate	% per annum	5.00%	5.00%
Operating Interest	% per annum	6.00%	6.00%
Property Tax Rate	% per annum	0.50%	0.50%
Insurance Rate	% per annum	0.80%	0.80%
FUEL USE & OTHER MISCELLANEOUS			
Fuel per acre for mowing, raking and staging	gal/acre	4.5	4.5
Custom pasture/hay establishment	$/acre	$14	$14
Fuel per day for feeding	gal per day	0.43	*0.71*
Fuel per day for checking cattle	gal per day	1.00	1.00
Twine per bale	$ per bale	$1.00	$1.00
Cost for Farm Vehicle	$/month	$30.00	*$50.00*
VETERINARY CHARGES			
Prolapse	Service chg. ($/hd)	$75	$75
C-section	Service chg. ($/hd)	$225	$225
Sick treatments	Avg. drug chg. ($/hd)	$15	$15
Bull Soundness	Service chg. ($/hd)	$30	$30
Net Cash Returns ($)	**13,577**	**GHG** (lbs. CO2 / lb sold)	**16.61**

Cattle Prices

Monthly average sale prices for number one medium and large steer and heifer calves in 100 lb increments (300 to 700 lbs; four price series for both steer and heifer calves), breaking utility and commercial grade cull cows 75 to 80% lean, and yield grade 1-2, 1,000 to 2,100 lb bulls were obtained for 2003 to 2012, using data from sale barns in Arkansas (Cheney, 2012). As such, users can select from three monthly price alternatives (Table 5); the last full current year (2012), five year average (2008 to 2012), or ten year average (2003 to 2012). Monthly weights and consequently prices are estimated based on the user specified calving distributions and weaning age (see herd characteristics). Alternatively, users can enter specific prices for each weight and animal category for ‘Your Farm’. Cattle prices are entered in dollars per hundred pounds sold ($ / cwt). The purchase price of bulls is entered in dollars per head. If more than one bull is on the enterprise, the use of an average price for bulls is recommended. If a bull is produced on ‘Your Farm’ the bull’s appraised or estimated value may be entered.

Fertilizer Prices

Commercial fertilizer prices were the average farm price for selected fertilizers from 2003 to 2012 from the United States Department of Agriculture Economic Research Service (USDA ERS, 2012). Default fertilizer prices utilized in FORCAP can be selected by the user as the last current year (2012), most recent five- or ten-year average prices (Table 6). Poultry litter prices were estimated based on extraction and hauling charges from expert opinion.

Table 5. 2012, 5-year, and 10-year annual average prices for four animal groups from all sale barns in Arkansas

Animal Group	Description	Unit	2012	'08 - '12	'03 - '12
Steers	# 3 - 400 Medium and Large Frame #1	$/cwt	193.99	144.47	139.49
	# 4 - 500 Medium and Large Frame #1	$/cwt	174.96	133.47	127.31
	# 5 - 600 Medium and Large Frame #1	$/cwt	159.04	123.58	117.24
	# 6 - 700 Medium and Large Frame #1	$/cwt	146.60	115.71	109.83
Heifers	# 3 - 400 Medium and Large Frame #1	$/cwt	165.28	123.16	120.66
	# 4 - 500 Medium and Large Frame #1	$/cwt	152.85	116.34	112.69
	# 5 - 600 Medium and Large Frame #1	$/cwt	142.28	110.21	106.12
	# 6 - 700 Medium and Large Frame #1	$/cwt	133.87	105.41	101.02
Cow	Cull (75-80% Lean Breaking Utility)	$/cwt	76.35	57.73	52.36
Bull	Breeding (Purchase Price)	$/hd	2,000	2,000	2,000
	Cull (Yield Grade 1 -2, #1,000 to 2,100)	$/cwt	92.28	70.66	64.71

Table 6. 2012, 5-year, and 10-year average annual prices for selected fertilizer as reported by the USDA

Fertilizer	Unit	2012	'08 - '12	'03 - '12
Lime Pellets	$/ton	30	29	25
Ammonium Nitrate (34-0-0)	$/ton	506	466	388
Diammonium Phosphate (18-46-0)	$/ton	726	685	503
Potash (0-0-60)	$/ton	647	635	432
Poultry Litter (3-2-3)	$/ton	36	36	36
Application cost per acre	$/acre	6.00	5.50	5.08

Again, users may enter their own prices ($ / ton) for lime pellets, ammonium nitrate (34-0-0), diammonium phosphate (18-46-0), potash (0-0-60), and poultry litter (3-2-3). If other forms of N, P, and K fertilizer are applied on their enterprise the user can use the custom blend section in the 'farm' tab that will estimate the elemental amounts of N, P, and K.

Herd Characteristics

This section of the manual provides a description of animal characteristics, cow-calf production methods, dietary requirements, and animal health for each representative herd. Animal groups; numbers of animals; weights, ages, breeding failures, and death losses; calving season and stocking rates; animal health and veterinary services; transportation and hauling; and dry matter intake (DMI) requirements are discussed below for the 'Bench Mark' farm and 'Your Farm' enterprises.

<u>Animal Groups</u>

Six animal groups are defined in FORCAP: mature cows, young cows, bulls, replacement heifers, heifer calves for sale, and steer calves for sale. Mature cows are defined as cows having had at least two calves. Mature cows and young cows are further divided into breeding stock and culled cows. Cull cows are mature cows or young cows that are sold from the operation as a result of age, sickness, or breeding failure and are net of cow death losses. Cull cow sales are rounded to the nearest head. Mature cows in the breeding stock category are maintained on the operation throughout the production year. Young cows are those with first calf at foot and are part of the breeding herd. Replacement heifers are heifer calves (produced on the operation or bought if internal supply is insufficient to replace culled cows for maintaining the herd size) that have not reached breeding age but will replace culled breeding stock in future years. Bulls are defined as bulls used for breeding purposes only. A default of 25 mature and young cows per bull and four breeding seasons are specified and the user can modify these parameters. Heifer and steer calves for sale are animals that are sent to market at the time of weaning after adjusting for calf death losses. The ratio of steer to heifer calves is 50 / 50.

Number of Animals

The total size of the 'Bench Mark' farm herd is a function of the number of pasture acres in the operation and the fertilization strategy chosen. The total number of cows on the operation is used to estimate the numbers in the other animal groups. The total number of cows on the 'Bench Mark' farm is a function of operation size, pasture fertility, and targeted stocking rate.

Equation 1:

$$TC = {}^{PA}/_{SR}$$

Where:

TC	is total number of cows in the herd (mature and young cows)
PA	is pasture acres in the operation
SR	is pasture acres / cow (see calving season and stocking rate section below for default stocking rates)

For example, a *Small* operation with 120 acres of pasture using the *Lime only* fertilization strategy would be estimated to have a targeted stocking rate of 6 acres per cow or 20 cows, a *Small* operation with a *Medium* level of fertilization is estimated to have a targeted stocking rate of 3 acres per cow or 40 cows. The total number of cows on 'Your Farm' is user defined and will modify stocking rate according to pasture acres (*PA* / *TC* = *SR*). The total number of cows for both the 'Bench Mark' and 'Your Farm' consists of mature cows and young cows. The number of young cows in each herd is a function of the total number of cows and average number of calves over the productive life of a cow. The number of calves over the productive life of a cow is defaulted to six calves and cows are expected to have one calf per year (a calving interval of 12 months); however users may enter anywhere from 1 to 10 calves as the average number of calves produced over the life of a typical cow for both the 'Bench Mark' and 'Your Farm' operations.

Equation 2:

$$YC = TC - \left(TC/_{CL}\right) \cdot (CL - 1)$$

Where:

YC	is the number of young cows in the herd
TC	is the total number of cows in the herd
CL	is the average number of calves one cow has over her life time

For example, a herd with 48 total cows and an average of six calves over the productive life of the cow would result in 8 young cows being estimated for the herd. As such, the total cow herd (48) would be comprised of 40 mature cows and 8 young cows.

Bulls are also a function of TC. The default ratio of number of cows per bull was assumed to be 25:1 (one bull can service 25 cows annually). This ratio can be changed by the user for both the 'Bench Mark' and 'Your Farm' in the 'Genetics' tab.

Equation 3:

$$HS = TC/_{CPB}$$

Where:

HS	is number of bulls
TC	is the total number of cows in the herd
CPB	is the annual number of cows serviced by one bull

The number of replacement heifers is a function of cow death losses, breeding failures, total cows, and young cows. The number of replacement heifers allows the breeding herd to maintain its existing size assuming, cows that experience breeding failures are culled and sold at market and *YC* replaces cows that are culled or have died.

Equation 4:

$RH = TC \cdot (BF + DL)$ rounded up to the nearest integer if $BF + DL > YC / TC$ and

$RH = YC$ otherwise

Where:

RH	is the number of replacement heifers
YC	is the number of young cows in the herd
TC	is the total number of cows in the herd
BF	is the percentage of breeding failures
DL	is the percentage of annual cow death losses

Steer calves sold is a function of total number of cows, breeding failures, cow death losses, and calf death losses. All steer calves were assumed to be sold (no bulls are produced from within the operation).

Equation 5:

$$SCS = TC \cdot (1 - BF - 0.5 \cdot DL) \cdot (1 - CDL \cdot 0.5)$$

Where:

SCS	is the number of steer calves sold
TC	is the total number of cows in the herd
BF	is the percentage of breeding failures
DL	is the percentage of annual cow death losses
CDL	is the percentage of calf death losses

It was assumed that half of all calves produced on an operation are male and half are female. As such heifer calves sold is a function of *SCS* and *RH*.

Equation 6:

$$HCS = SCS - RH$$

Where:

HCS	is the number of heifer calves for sale (if negative heifers are purchased)
SCS	is the number of steer calves sold
RH	is the number of replacement heifers

If *RH* exceeded the number of heifer calves produced on an enterprise it was assumed that heifers were purchased at market value to account for shortfalls in order to maintain the size of the breeding herd.

The number of cows culled annually is a function of total number of cows, breeding failures, number of calves over the useful life of a cow, and cow death losses.

Equation 7:

$$CCS = RH - (TC \cdot DL)$$

Where:

CCS	is the number of culled cows sold
RH	is the number of replacement heifers
TC	is the total number of cows in the herd
DL	is the percentage of annual cow death losses

Cull cow sales (*CCS*) were assumed to occur at livestock auctions immediately following the culling decision (culled at the same weight as the average mature cow weight). The culling decision is made when cows are pregnancy-checked after weaning their calves. This assumption eliminates the option of feeding high protein supplement to culled animals to bring them to market at a heavier weight. Use of alternative software is recommended for feeding enterprises.

Weights, Ages, Breeding Failures, and Death Loss

Weights for all six animal groups for both enterprises are defined by the user. Default weights (in pounds) for breeding stock are mature cows- 1,250 lbs / hd, young cows- 1,000 lbs / hd, and bulls- 2,000 lbs / hd. For market livestock, birth weights were assumed to average 90 lbs for both steers and heifers. Weaning weights of 425 lbs and 400 lbs for steer and heifer calves, respectively, at 5 months of age were set as defaults with weaning weight increasing by 65 lbs and 60 lbs per month for steer and heifer calves, respectively. A default weaning age of 7 months for steers thus translated to a steer weight of 555 lbs and heifer calves weighing 520 lbs. Weaning age choice is restricted from 5 to 10 months of age post calving. Replacement heifers until weaning were the same weights as sale heifers and then assumed to grow at the same rate as prior to weaning for the remaining months of the year.

An adjusted weight (AW_{cows}) for the cow animal group was estimated to represent a cow unit (includes young cows, mature cows, and replacement heifers from one year of age to age at first breeding). This AW_{cows} was utilized for all months of the year to estimate dry matter intake requirements (DMI) and animal emissions (GHG emission section). The AW_{cows} for a representative cow accounts for cow death losses, weaning age, heifer weaning weight, breeding failures, number of calves over the life of the cow, and differences in weights for young cows and mature cows, as follows:

Equation 8:

$$AW_{cows} = mc \cdot BW_{mc} \cdot (1 - 0.5 \cdot DL) - \frac{\frac{12-WA}{12} \cdot mc \cdot BW_{mc} \cdot CCS}{TC} +$$

$$(1 - mc) \cdot BW_{yc} \cdot (1 - 0.5 \cdot DL) - \frac{\frac{12-WA}{12} \cdot (1 - mc) \cdot BW_{yc} \cdot CCS}{TC} +$$

$$\frac{HWW + (12 - WA) \cdot 60 + HWW + (BA - 12) \cdot 60}{2} \cdot \frac{(RH/TC) \cdot (BA - 12)}{12}$$

Where:

AW_{cows}	is the adjusted weight for the cow animal group
mc	is the fraction of mature cows of *TC* due to *CL* and defined as 1/*CL*·(*CL* – 1)
CL	is the average number of calves one cow has over her life time
BW_{mc}	is the body weight for mature cows
DL	is the percentage of annual cow death losses

CCS	is the number of culled cows sold
TC	is total number of cows in the herd (mature and young cows)
BW_{yc}	is the user specified body weight for young cows
BA	is the breeding age in months at first breeding
RH	is the number of replacement heifers needed to maintain herd size which depends on breeding failures, death losses and / or replacement age of cows
HWW	is the heifer weaning weight in lbs per head
WA	is weaning age in months

For example, a farm with 45 total cows, 1,250 lb mature cows and 1,000 lb young cows, weaning age of 7 months, weaning weight of heifer calves of 520 lbs, cow death losses of 1%, an average of six calves over the life of the cow, and breeding failures of 14% would result in a 1,156 lb representative annual average breeding cow weight for the operation which does not vary by month. Note that cow death losses and culling is spread evenly across mature and young cows (.5 in Equation 8). Culling occurs after weaning and hence the need for adjustment of culled cows leaving the operation for the time period between weaning age and the end of the year (12 months). This is presented in the first two lines in Equation 8 above. By the same token replacement heifers are represented by tracking their average weight from weight at 12 months through their age at first breeding when they gain 60 lbs per month multiplied by their time weighted fraction of the total herd or the third line in Equation 8 above.

A default weaning age of 7 months was used; however users have the ability to select any weaning age between 5 and 10 months for both farms. Users can override the default gain assumptions of 65 lbs and 60 lbs per month around time of weaning by selecting alternative weaning or sale weights. As such, weaning weights are assumed to be the market weight of *HCS* and *SCS*. Calves were not assumed to be fed on either the ‘Bench Mark’ or ‘Your Farm’ operation after weaning.

The average culling age of mature cows is a function of the age of replacements at first breeding, age of calves at weaning, and number of calves over the life of the cow.

Equation 9:

$$ACA = (BA + WA + CL \cdot 12)/12$$

Where:

ACA	is the average culling age of mature cows
BA	is average age of replacements at first breeding
WA	is calf weaning age
CL	the average number of calves one cow has over her life time

Average age of replacements at first breeding is defaulted to 15 months but can be user defined for both operations. Cull cow age was the age of the cow at last calving plus the weaning period to adjust for cows being culled after a pregnancy check at weaning. Default average number of calves over a cow's life was 6, but users can specify for both enterprises.

Years between bull purchases are a function of number of years of production per bull and the number of bulls for the herd. Years of production for a bull are usually limited to four years to avoid inbreeding.

Equation 10:

$$YBP = {}^{YB}/_{HS}$$

Where:

YBP is years between bull purchases
YB is the number of years of production from one bull
HS is the number of bulls

Breeding failures for 'Your Farm' are user defined and should represent the percentage of open cows in the herd at the conclusion of the breeding season. The 'Bench Mark' farm and default values for breeding failures were estimated from calving season and percentage of tall fescue in the pasture species composition. Breeding failure percentages by season are: fall- 6%, 9%, and 12%; spring - 20%, 34%, and 48%; and year-round – 14%, 25%, and 36% for species composition of tall fescue ranging from 0 to 74%, 75 to 84%, and 85 to 100%, respectively (Caldwell et al., 2013). Caldwell et al. (2013) specifically monitored breeding failure as a result of exposure to toxic tall fescue by calving season at the University of Arkansas Agricultural Experimental Research Station in Batesville, AR. Nonetheless, the user is cautioned that breeding failure leads to cow culling in FORCAP. Should the user select 'Year round' calving, an alternative approach is to modify calf losses to include abortions which would lower the number of calves sold per year but not the number of cows culled. As an example, extending the average calving interval (time between calves for a particular cow) due to poor reproductive performance from the standard 12 months to 13 months is the equivalent of increasing calf losses by $1/12^{th}$ or 8% or 1 extra month needed to produce a 12 month period's number of calves.

Total cow death losses is a function of total number of cows and the user defined percentage of cows deceased in one year. Note that deathlosses are automatically adjusted to higher or lower levels on the basis of anticipated calving difficulty if herd genetics are modified. The reader is referred to the user manual for details regarding this aspect of the model.

Equation 11:

$$TDL = TC \cdot DL$$

Where:

TDL is the total number of cow death losses for the production year

DL is the percentage of annual cow death losses
TC is the total number of cows in the herd

Total calf losses are a function of total number of cows, breeding failures, and percentage of cow and calf death losses.

Equation 12:

$$TCDL = TC \cdot (1 - BF - DL) \cdot CDL$$

Where:
TCDL is the total number of dead calves in the year
TC is the total number of cows in the herd
BF is the percentage of breeding failures
DL is the percentage of annual cow death losses
CDL is the percentage of calf death losses

Calving Season and Stocking Rate

Three calving seasons can be selected (spring, fall, or year-round) for the 'Bench Mark' farm. Spring-calving was estimated to occur in April, fall-calving in October, and year-round-calving is a distribution shown in Table 7 based on the study by Doye et al. (2008). 'Your Farm' has the same calving season options as above but also allows an option in which users can select up to four months and provide the corresponding percentage of calves born in each month[3]. The month(s) calves are born influences the timing calves are brought to market (based on weaning age; month born plus weaning age equals sale month) and the corresponding monthly sales price by weight category and gender. Additionally, calving season affects the dry matter intake (DMI) requirements for cows (see DMI requirements section below for details). Table 8 shows the estimated monthly DMI requirements for cows based on the number of months after calving (UACES, 2003).

Stocking rates (acres / cow) for the 'Bench Mark' farm were estimated from fertilization strategy (see forage production section below for fertilization strategy details). *Lime only*, *Low*, *Medium*, and *High* fertilization strategies were estimated to have stocking rates of 6.0, 4.0, 3.0, and 2.5 acres per bred cow. The stocking rate for 'Your Farm' is defined as the number of pasture acres divided by total number of cows (*PA* / *TC*).

[3] The four months selected do not need to be consecutive months or the same percentages. For example an operator using a dual calving season could select September (20%), October (30%), March (15%), and April (35%).

Table 7. Estimated calving distribution by month for a year-round-calving system

Month	Percentage of Calves Born
January	15
February	18
March	14
April	9
May	5
June	5
July	3
August	3
September	8
October	8
November	8
December	4

Table 8. Daily dry matter intake (DMI) requirements in lbs/day by animal group

Dry Matter Intake Requirements to Maintain a 1,200 lb Cow	
Month after Calving	Cow DMI (lbs / day)
1	30.80
2	29.40
3	27.90
4	26.70
5	22.40
6	22.80
7	23.30
8	24.30
9	24.10
10	24.60
11	29.20
12	30.60
Dry Matter Intake Requirements Steer and Heifer Calves	
Weight	
300	8.37
400	10.40
500	12.28
600	14.07
700	15.83
Dry Matter Intake Requirements to Maintain Bulls	
2,000 lb Bull	37.20

Animal Health and Veterinary Services

Supplemental feeds were used to balance total digestible nutrients (TDN). In the ‘Bench Mark’ farm if monthly forage (hay and grazed) was insufficient to meet TDN requirements for the herd then supplemental feed was required (see dry matter intake requirements section). User’s may select the type of from corn, corn gluten feed, DDG, soybean meal, soybean hulls, cotton seed, cotton seed meal, hominy, range cubes, rice bran, generic blend, or other. For other, the user must enter the cost of the feed in $/lb, lbs of CP per lb of DM, lbs of TDN per lb of DM and % DM of the feed. Table 9 shows the cost per lb, lbs of crude protein (CP) per lb of DM, lbs of TDN per lb of DM, and DM per lb of feed for the eleven default supplemental feeds. Supplemental feeds were not used in the estimation of animal rations (e.g. displacement of forage/DMI requirements) or GHG emission calculations. Hence energy needs of the cattle are expected to be derived from forages grazed and hay fed. Nonetheless users can identify quantities of supplemental feeds fed to each herd to estimate impact on cost. Supplemental feed can be user defined for ‘Your Farm’.

Table 9. Default supplemental feeds, cost ($/lb), crude protein (CP) content, total digestible nutrient (TDN) content, and dry matter (DM)

Supplemental Feed	Cost ($/lb)	lbs of CP per lb DM	lbs of TDN per lb DM	lbs of DM per lb of Feed
Corn	0.11	0.09	0.89	0.86
Corn Gluten Feed	0.08	0.24	0.80	0.80
DDG	0.10	0.29	0.85	0.85
Soybean Meal	0.19	0.54	0.87	0.88
Soybean Hulls	0.09	0.11	0.68	0.89
Cotton Seed	0.12	0.24	0.90	0.92
Cotton Seed Meal	0.15	0.46	0.75	0.90
Hominy	0.09	0.11	0.89	0.87
Range Cubes	0.15	0.21	0.79	0.95
Rice Bran	0.08	0.14	0.70	0.91
Generic Blend	0.12	0.36	0.84	0.85
Other	-	-	-	-

Default values for mineral and monensin were 2 oz / hd and 0 mg / hd, respectively. The amounts of mineral and monensin are weight adjusted to reflect the fact that one cow represents a fraction of bull, young cow, calf, and replacement heifer depending on user specified cattle parameters that affect these fractions.

A standard vaccination program was assumed to include: dewormer (one dose of 5 ml / cwt for all animal groups), pasturella (0.6 applications of 1 ml / cwt for heifer and steer calves), 7 way blackleg (one dose of 2 ml / hd for all animal groups), 4 way viral (one dose of 2 ml / hd for all animal groups, two doses for steer and heifer calves), pinkeye (0.1 doses of 2 ml for all cows, bulls and replacements), scour bolus (0.1 doses of 1 bolus / hd for all heifer and steer), vibroleptos (one dose of 2 ml / hd for all cows, bulls, and replacements), growth implants (half of all calves), castration (all steer calves), and brucellosis (half of all calves). Additional vet charges assumed in the 'Bench Mark' farm were: prolapsed (2% of total cows), c-section (1% of total cows), sick treatments (5% of all cattle), and bull soundness (all bulls). The user can accept the default or specify their specific herd health program. Costs change, GHG footprint does not as vaccines represent an insignificant amount of GHG emissions for the farm.

Transportation and Hauling

Transportation and hauling estimates the number of loads and miles traveled per load used to move cattle to and from sale barns and other locations (alternate sale locations and pastures). The 'Bench Mark' farm assumes the producer hauls culled cows to market and has its calves for sale custom hauled. *Small* and *Medium* operations can haul a maximum of 6 cows per load while *Large* operations can haul 8 (this is due to an estimated difference in stock trailer size).The default values also assume bulls and replacement heifers purchased (if any) are hauled with the owner's trailer. Finally, extra calves not hauled because of custom haul weight limits are hauled by the owner. Total mileage from all trips is used to estimate fuel use which is utilized for estimating fuel cost and GHG emissions[4]. Default mileage assumptions were 25 miles, one way, for each custom load and 15 miles, one way, for each owner load. Number of loads varied by operation size and stocking rate.

Dry Matter Intake (DMI) Requirements

Dry matter intake requirements were estimated from the University Of Arkansas Division Of Agriculture's Beef Cattle Nutrition Series Part 3: Nutrient Requirement Tables (UACES, 2003). Dry matter intake requirements for five animal groups (young cows and mature cows are represented at their AW_{cows} specified above) are estimated from user entered animal numbers, weights, weaning ages, and calving distribution. Gestation period directly affects the DMI requirements for cows; Table 8 shows the estimated DMI requirements for: 1,200 lb-cows for a 12 month period after calving, steer and heifer calves by 100 lb weight increments, and 2,000 lb-bulls. Birth weights, weaning weights, and weaning ages determine the adjusted weight (AW_{calves}) for calves at sale time. Replacement heifer AW is estimated to weaning age using the same method as for heifer calves sold. However, their DMI requirements post weaning to 1 year of age are estimated using an ADG indicated above based on birth weight, weaning weight, and weaning age for that period. As such, the total monthly DMI requirements for each herd ('Bench Mark' farm and 'Your Farm') were estimated as follows:

Equation 13:

$$TDMI_{ik} = \sum_{l=1}^{5} DMI_{ikl} \cdot AW_{li} \cdot NA_{l} \cdot D_{i}$$

4 For GHG emissions, fuel use includes both fuel consumed by custom haulers and the operations own hauling activities.

Where:

- $TDMI_{ik}$ is the total DMI requirements for the cow-calf herd using calving season k in month i
- DMI_{ikl} is the DMI requirements for animal group l in month i for a herd using calving season k
- AW_{li} is the adjusted weight of animal group l and month i for calves and replacements only (bulls, mature cows and young cows are assumed to have constant body weight throughout the year)
- NA_l is the number of animals in animal group l
- D_i is the number of days in month i
- l describes animal groups of cows (replacements > 1 yr old, young cows and mature cows), bulls, steer calves, heifer calves and replacement heifers from weaning to 1 year of age

Table 10. Monthly dry matter intake (DMI) requirements for a 45-cow herd using a year-round- and spring-calving season, for five animal groups

Year-Round-Calving

	DMI Requirements by Animal Group (l)					
Month	Cows	Bulls	Replacements	Heifer Calves	Steer Calves	Total ($TDMI_{ik}$)
Jan	34,725	2,306	2,219	594	627	40,471
Feb	32,051	2,083	1,704	546	567	36,951
Mar	36,463	2,306	1,336	815	852	41,773
Apr	35,838	2,232	888	1,037	1,090	41,085
May	37,071	2,306	841	1,088	1,152	42,458
Jun	35,395	2,232	899	1,200	1,250	40,976
Jul	36,120	2,306	1,021	1,497	1,559	42,503
Aug	34,986	2,306	1,085	2,126	2,239	42,742
Sep	32,857	2,232	1,449	1,900	2,009	40,448
Oct	33,631	2,306	1,812	1,408	1,491	40,649
Nov	32,868	2,232	1,951	886	936	38,873
Dec	34,519	2,306	2,085	623	658	40,192
Annual	416,525	27,156	17,290	13,719	14,431	489,122

Spring-Calving

	DMI Requirements by Animal Group (l)					
Month	Cows	Bulls	Replacements	Heifer Calves	Steer Calves	Total ($TDMI_{ik}$)
Jan	29,630	2,306	4,672	-	-	36,609
Feb	28,032	2,083	4,460	-	-	34,576
Mar	30,780	2,306	5,369	-	-	38,455
Apr	30,405	2,232	5,613	-	-	38,250
May	37,293	2,306	-	-	-	39,600
Jun	37,821	2,232	-	-	-	40,053
Jul	39,337	2,306	-	-	-	41,643
Aug	37,549	2,306	-	987	1,046	41,888
Sep	34,484	2,232	-	2,259	2,239	41,214
Oct	34,100	2,306	-	3,770	4,017	44,194
Nov	27,686	2,232	-	5,212	5,563	40,693
Dec	29,120	2,306	4,428	-	-	35,854
Annual	396,236	27,156	24,542	12,228	12,864	473,027

Table 10 shows two examples of the monthly DMI requirements for five animal groups for a 45 cow operation (year-round- and spring-calving distribution). Spring-calving results clearly show the weaning age (November) and birth month (April) for steer and heifer calves as it is assumed all calves are born in one month (April) for the spring-calving distribution. The year round distribution contains DMI requirements for the steer and heifer calves for all months as calves are born and weaned in all months of the year. Dry matter intake requirements for each animal group vary by month. Cow DMI varies based on calving distribution, number of months after calving and number of days in each month. The calving distribution shown in Table 7 combined with the DMI requirements in Table 8 determines the monthly DMI requirements for the cow animal group in Table 10 (year-round). Table 11 shows how the TDMI requirements for the cow animal group are calculated. The AW for the cows is 1,156 lbs (column a) and is constant for all months. Dry matter intake requirements in lbs / day for a 1,200 lb cow for each month after calving (column b) is shown in column c. The year-round-calving distribution from

Table 7 is restated in column f. The number of cows giving birth in each month based on a 45 cow herd using the year-round calving distribution is shown in column h. Calving season adjusted DMI requirements are shown in column g and are the DMI (lbs / day) requirements for the *AW* (1,156 lbs) for the cows in each gestation period for each month. Therefore the total DMI requirements for the cow animal group (column i) for each month is estimated as column g multiplied by column e multiplied by the number of cows (45) in the herd. Steer and heifer calves and replacements less than one year of age have different DMI by month on the basis of when calves are born, birth weight, weaning age (it is assumed that calves under 300 lbs are relying solely on milk to obtain nutritional requirements), weaning weights, and days in each month. As such, FORCAP assumes calves have no DMI requirements until they reach 300 lbs after which DMI requirements are shown in Table 8 for each weight category. Bull DMI requirements vary by number of days in each month only.

Table 11. Example of the dry matter intake (DMI) calculation for the cow animal group for a 45 cow herd using a year-round- calving season

(a) AW	(b) Month After Calving	(c) DMI lbs/ day	(d) Month	(e) D_i	(f) Fraction of Calves Born	(g) Calving Season Adjusted DMI lbs / day	(h) Number of cows giving birth that month	(i) $TDMI_{cows}$
1,156	1	30.8	Jan	31	0.15	21.8	7	34,725
	2	29.4	Feb	28	0.18	22.3	8	32,051
	3	27.9	Mar	31	0.14	22.9	6	36,463
	4	26.7	Apr	30	0.09	23.2	4	35,838
	5	22.4	May	31	0.05	23.3	2	37,071
	6	22.8	Jun	30	0.05	23	2	35,395
	7	23.3	Jul	31	0.03	22.7	1	36,120
	8	24.3	Aug	31	0.03	22	1	34,986
	9	24.1	Sep	30	0.08	21.3	4	32,857
	10	24.6	Oct	31	0.08	21.1	4	33,631
	11	29.2	Nov	30	0.08	21.3	4	32,868
	12	30.6	Dec	31	0.04	21.7	2	34,519

Forage Production

Forage production is site specific and can vary dramatically due to soil characteristics, topography, environmental conditions, management practices, and species composition. This section examines the methods utilized in estimating forage production on hay and pasture land.

Species composition, fertilization, hay and pasture base production and N response, grazing strategy, and fencing and water sources are discussed in detail below. Combining these five parameters a forage balance is estimated to match forage production with animal DMI requirements for each operation. Hay is used to balance the DMI requirements for the cow-calf herd; as such surplus hay is sold or bought based on each operations forage surplus or deficit.

Species Composition

Bermudagrass, tall fescue, clover, and one user defined forage can be selected to represent the species composition of pasture and hay acres. The 'Your Forage Species' tab allows users to select from mixed grass, bahiagrass, orchardgrass, alfalfa, lespedeza, high fertilization alfalfa, or define an alternative forage. If a user chooses to define an alternative forage he/she must enter % of annual growth, crude protein (as percent of DM), and total digestible nutrients (as a % of DM) for each month. Table 12 shows the estimated CP for each of bermudagrass, tall fescue, and clover as a percentage of DM by month (UACES, 2005). The three species are the most common pasture forages in the Ozark Highlands region. 'Bench Mark' farm forage species composition was assumed to vary with quantity of fertilizer applied. Larger percentages of bermudagrass were assumed to be present in forage stands that were receiving greater amounts of fertilizer to take advantage of bermudagrass having the highest N response and base production level compared to other species. Hence, producers would choose to more heavily fertilize pastures which would contain bermudagrass and consequently yield greater growth response (see hay and pasture base production and N response section). Default species composition, on hay and pasture acres by fertilization strategy are shown in Table 13. Users may enter the estimated percentage area of the three species for 'Your Farm'. Individual pastures and paddocks cannot be specified; as such, an average species composition for all hay acres and all pasture acres should be input. The total composition should add to 100% so weeds and volunteers should not be included as a percentage of species composition.

Winter annuals can be selected as an early spring or late fall grazing alternative on pasture acres and is not available for hay acres. Winter annual acres are restricted to total pasture acres multiplied by the percent bermudagrass in the pasture species composition. In other words, winter annuals can only be planted on bermudagrass acres. Winter annuals provide a late fall or spring grazing alternative to producers that sod seed this forage annually and only in pasture areas were competition from cool season grasses would be minimal. Users can select from wheat, ryegrass, and rye.

Table 12. Arkansas feedstuffs database, summary of crude protein (CP) as a percentage of dry matter (DM) for bermudagrass, tall fescue, and clovers

	Bermuda		Tall Fescue		Clovers	
Month	Mean	SD	Mean	SD	Mean	SD
	Crude protein as a percentage of dry matter (DM)					
January	10.50	3.02	14.60	3.78	14.25	3.24
February	13.80	4.91	13.90	3.44	14.25	3.24
March	9.30	3.53	17.20	5.69	17.00	3.24
April	13.30	4.30	22.00	3.31	20.00	3.24
May	17.30	5.06	19.30	2.69	21.00	3.24
June	17.40	3.77	18.70	4.24	18.00	3.24
July	13.80	4.18	15.50	3.19	14.00	3.24
August	14.80	3.36	14.40	5.27	10.00	3.24
September	12.80	3.75	15.70	4.20	12.00	3.24
October	13.90	4.32	19.00	4.26	16.00	3.24
November	12.40	3.59	19.50	4.32	16.00	3.24
December	11.80	4.52	17.10	3.45	14.25	3.24

Table 13. Default percentage of area for bermudagrass, fescue, NE fescue, and clover for hay and pasture species composition for four fertilization strategies

		Default Percentage Species Composition by Area			
Forage	Fertilization Strategy	Bermudagrass	Fescue	User Defined	Clover
Hay	*Lime*	30	60	0	10
	Low	30	60	0	10
	Medium	50	45	0	5
	High	70	20	0	10
Pasture	*Lime*	25	65	0	10
	Low	25	65	0	10
	Medium	30	60	0	10
	High	30	50	0	20

Fertilization

Four default fertilizer options for both pasture and hay acres are available to users: *Lime*, *Low*, *Medium*, and *High* and are defined as: *Lime only* – application of lime at pasture establishment prorated to an annual 0.25 tons / acre on pasture and hay land; *Low – Lime only* + 1.0 and 0.5 tons / acre of poultry litter (3-2-3) on hay and pasture, respectively; *Medium – Lime only* + 2.0 tons / acre of poultry litter (3-2-3) and 100 lbs / acre ammonium nitrate (34-0-0) on hay and 1.0 tons / acre of poultry litter on pasture; and *High – Lime only* + 3.0 tons / acre of poultry litter (3-2-3), and 300 lbs / acre ammonium nitrate (34-0-0) on hay and 2.0 tons / acre of poultry litter, and 100 lbs / acre of ammonium nitrate (34-0-0) on pasture. For the ‘Your Farm’ option users can specify the amount of lime, ammonium nitrate, diammonium phosphate (DAP), potash, and poultry litter applied to pasture and hay acres. Additionally, users can select Urea (46-0-0), 19-19-19, 13-13-13, compost, or create a custom blend of fertilizer for ‘Your Farm’ by defining the percent of elemental N-P-K in their blend, cost per ton, and quantity of the fertilizer applied on pasture and hay acres.

If fertilizer is applied once every four years then divide the desired amount actually applied per acre by four to arrive at the prorated number of applications across all acres although only one quarter of the acres would receive the full application rate on average. This adjustment is needed to arrive at an accurate fuel footprint for applications. For the *Low* and *Medium* fertilizer option it was assumed that poultry litter and ammonium nitrate were applied once per year. The *High* fertilizer application was assumed to occur two times per year for ammonium nitrate and once for poultry litter on hay acres. Pasture acres received one application of ammonium nitrate and poultry litter annually for the *High* fertilizer option. No attempt was made to allow the user to specify timing of applications but the user can specify when they expect growth response as discussed in the following sections.

<u>Hay and Pasture Base Production and N Response</u>

Estimated pasture forage production is composed of two components, a base level of production and an N response. Base levels of forage production are estimated for operations with mid-level soil fertility with moderate slopes. Base production for all forages can be modified by advanced users to more accurately reflect regional or county level yields. Base levels of forage production (*BP*) for each species in lbs per acre of dry matter (DM) were estimated to be: bermudagrass- 3,000; tall fescue – 2,800; clover – 3,000; ryegrass – 2,500; wheat – 1,500; rye – 2,000; orchardgrass – 3,000; mixed grass – 2,500; bahiagrass – 2,500; alfalfa – 6,000; high fertilization alfalfa – 10,000; and lespedeza – 2,000. Nitrogen responses (for both commercial N and N fixation by clovers) in lbs of DM per pound of N applied were: bermudagrass- 32.6; tall fescue – 22; clover – 0; ryegrass – 30; wheat –30; rye – 30; orchardgrass – 26; mixed grass – 32; bahiagrass – 20; alfalfa – 0; high fertilization alfalfa – 0 and lespedeza – 0 (Huneycutt et al., 1988). Forage species selected were constrained to bermudagrass, tall fescue, clover, one other forage, and a winter annual. As such, monthly forage production was estimated by:

Equation 14:

$$MPFP_i = PA \cdot \sum_{j=1}^{4} (MG_{ij} \cdot (BP_j + (N_{app} + N_{clov}) \cdot N_{res\,j}) \cdot SCP_j$$

Where:

$MPFP_i$	is pasture forage production in lbs of DM in month i
PA	is total pasture acres
MG_{ij}	is portion of annual growth for species j in month i
BP_j	is the annual base production for species j
N_{app}	is the elemental quantity of N applied to pasture acres
N_{clov}	is N available to other species produced from clover N fixation
$N_{res\,j}$	is the N growth response for species j
SCP_j	is the fraction of species j of the pasture by area

Winter annual production was estimated in a separate equation as winter annual production was only assumed to occur on a user-specified number of acres whereas bermudagrass, fescue, other forages, and clover production were estimated to occur on all pasture acres.

Nitrogen applied (N_{app}) is calculated from the fertilizer applied as shown above. Nitrogen available to other species from clover production (N_{clov}) was estimated to be one pound of elemental N for each percent of clover in the species composition (West, C., 2012).

Equation 15:

$$MRGP_i = AR \cdot MG_{wa\ i} \cdot (BP_{wa} + (N_{app\ wa}) \cdot N_{res\ wa})$$

Where:

$MRGP_i$	is winter annual production in lbs of DM in month *i*
AR	is winter annual acres planted
$MG_{wa\ i}$	is the percent of winter annual growth in month *i*
BP_{wa}	is the annual base level production for winter annuals in lbs
$N_{app\ wa}$	is the elemental quantity of N applied to winter annual acres
$N_{res\ wa}$	is the N growth response for the specific species of winter annual

Monthly forage growth (*MG*) by species is defined as the percentage of total forage growth for each species in each month of the production year. Table 14 shows the estimated

Table 14. Default percentage of monthly forage growth for bermudagrass, fescue, orchardgrass, and clover and percentage of stockpiled forage consumed for each month

	Estimated Percentage of Annual Growth					Estimated Percentage of Stockpiled Forage Consumed
Month	Bermudagrass	Tall Fescue	Orchardgrass	Clover	Rye	
January	-	-	-	-	5%	20%
February	-	3%	-	-	15%	20%
March	-	7%	15%	5%	35%	-
April	-	20%	25%	20%	20%	-
May	10%	27%	25%	25%	5%	-
June	25%	15%	10%	20%	-	-
July	35%	0%	3%	5%	-	-
August	20%	0%	2%	-	-	-
September	10%	2%	5%	5%	-	-
October	-	13%	10%	15%	-	20%
November	-	11%	5%	5%	10%	20%
December	-	2%	-	-	10%	20%

percentage of monthly forage growth by species and percentage of stockpiled forage utilized in November, December, January and February for the 'Bench Mark' farm. For the 'Your Farm' option, users may enter any percentage for each month (*i*) and species (*j*) with the constraint that the annual total sum to 100% or less for each species. Species that sum to less than 100% may be entered and interpreted as a production year where growth of that species is less than a typical year (for example a drought year). For example, if the sum of percentages for the monthly growth for fescue adds to 85%, the interpretation is that pasture fescue production was 15% less than a typical year. Using this approach the monthly forage balance can be utilized to estimate changes in forage production by species as a result of drought, such as in Arkansas in 2012. Species composition of the pasture (SCP_j) is the percentage of each species present in the pasture stand by area. Monthly forage growth (MG_{ij}) is the percentage of annual growth occurring in month *i* for species *j* (Table 14) by weight and applies to both hay and pasture acres.

Estimated hay production, like pasture forage production is composed of two components, a base level of production and an N response. Base levels of forage production and nitrogen response in lbs of DM per pound of N applied were the same as the pasture forages above. Winter annuals were not assumed to be used in hay production, with the exception of excess forage removed from pasture acres. Hay production was assumed to occur from two cuttings; however the timing of the cuttings is not defined. Again forage selection was limited to bermudagrass, tall fescue, clover and one other forage, as such, annual hay production for was estimated as:

Equation 16:

$$HP=HA \cdot \sum_{j=1}^{4}\sum_{k=1}^{12}(MG_{ij} \cdot (BP_j+(N_{app} + N_{clov}) \cdot N_{resj}) \cdot SCH_j \cdot HE$$

Where:

HP	is annual hay production in lbs of DM
HA	is the total number of hay aces
MG_{ij}	is the percentage of total hay growth in each month *i* for species *j*
BP_j	is the annual base production for species *j*
N_{app}	is the elemental quantity of N applied to pasture acres
N_{clov}	is N available to other species produced from clover
$N_{res\,j}$	is the N growth response for species *j*
SCH_j	is the percentage of species *j* of the hay species composition by area
HE	is the estimated harvest efficiency for the operation

Harvest efficiency is defined as the percentage of forage growth that is removed in the harvesting process as a percentage of total available DM production. Default harvest efficiency was estimated to be 60% (Popp and Nalley, 2011). Using Equation 16, hay production was estimated in total pounds of DM and then converted into 1,000 or 800 lb round bales in

FORCAP so that feeding requirements and hay for sale could be easily quantified. Additionally, this allowed for estimated twine requirements to be calculated per bale.

Additional hay production can be achieved for the both enterprises by harvesting excess pasture forage (when available). Users can set the minimum yield to be harvested from pasture acres. The default is set at 0.5 bales which will vary based on the user selected bale size.

Grazing Strategy

Continuous and rotational grazing strategies are a function of farm size. Continuous grazing strategy is defined as allowing cattle access to all pasture acres in a given paddock. "Benchmark Farms" have the following number of paddocks and acreage, respectively: *Small* – 1 paddock at 120 acres; *Medium* – 2 paddocks of 90 acres each; *Large* – 3 paddocks of 150 acres. The number of paddocks on 'Your Farm' can be user input; however, the acres will be evenly divided among each paddock. Using a continuous grazing strategy provides an estimated grazing efficiency of 50%, which is independent of farm size. Grazing efficiency is defined as the amount of forage consumed as a percentage of above ground production occurring 2 inches above the ground, thus accounting for trampling, selective grazing, and waste (forage consumed divided by total above ground forage growth multiplied by 100). Grazing efficiency for 'Your Farm' can be user entered as any percentage. It is important to note that grazing efficiency has a dramatic influence on the forage availability in pastures and consequently the amount of hay that an operation will feed. Typical grazing efficiencies are 40 to 70% (Allison, 1985).

Rotational grazing divides pastures into equal sized paddocks, restricting forage access to animals, which prevents potential overgrazing and thus improves grazing efficiency. The rotational grazing strategy, for the default, is based on farm size (paddocks, acres) as follows: *Small* – 4, 30; *Medium* – 8, 23; and *Large* – 12, 38. The 'Your Farm' option allows users to input the number of pasture paddocks not the number of acres in each paddock, which is estimated to be the total pasture acres divided by the number of paddocks (all paddocks are of equal size). Using a rotational grazing strategy improves expected grazing efficiency from 50% to 60%. An additional option for those producers using a rotational grazing strategy is strip grazing. Strip grazing involves restricting access to forage by moving a temporary charged wire so that cows only access a day or two days' worth of forage at a time such that all forage is grazed and selective grazing is minimized. This results in an additional 15% improvement in grazing efficiency (75% net grazing efficiency).

Additional grazing options for the 'Bench Mark' farm is grazing winter annuals (wheat, rye, and ryegrass) and practicing stockpiling of pasture forages. The number of pasture acres of winter annuals planted for the each operation is defaulted to 20 for all operation sizes. Producers can specify acreage in winter annuals for both the 'Bench Mark' farm and 'Your Farm' options, so long as the acreage does not exceed the total pasture area in bermudagrass in the operation. Stockpiling forage refers to keeping cows off a pasture paddock in the late-summer and early-fall to allow for standing forage that can be grazed when temperatures no longer support forage production. The forage quality will be lower and some trampling will occur. Hence, a stockpiling loss of 5% is assumed. Stockpiling is effective for increasing grazing days and shortening days on feed and supplements. Forage stockpiling restricts access to a user-specified amount of pasture acres from August and September. Stockpiled forage is then made available in October, November, December, January, and February with the breakdown of default availability shown in Table 14. The total acres subjected to stockpiling cannot exceed half of the total number of pasture acres. Users can specify when they want to use stockpiled forage for their farm.

Fencing and Water Sources

For "Benchmark Farms" farm ponds and watering sites are a function of farm size (*Large* – 5, 1; *Medium* – 3, 1; and *Small* – 1, 1, farm ponds and watering sites, respectively). Farm ponds and watering sites are independent of grazing strategy. The number of farm ponds and watering sites on 'Your Farm' is user defined. Three fencing options are defined: perimeter, cross, and moveable. Perimeter fencing is assumed to be barbed wire while cross fencing and moveable fencing is electric. For each fencing option, users are required to enter the number of strands, and distances between posts. The type of corners (pipe or wood) is selected by the user for perimeter fence and cross fence. Moveable electric fence is only an option for operations using rotational grazing and strip grazing. Number of gates is a function of total pasture acres, number of paddocks, acres per paddock, and grazing strategy selected as follows:

Equation 17:

$$NG = PA / APP \cdot NGS$$

Where:

NG	is the number of gates
PA	is pasture acres
APP	is the acres per pasture paddock
NGS	for continuous grazing strategy, *NGS* is three gates per paddock; for rotational grazing, *NGS* is two gates per paddock

For the 'Your Farm' option number of gates and miles of fence for each fencing option are user-defined.

Forage Balance

The forage balance estimates a monthly starting and ending forage level along with the sources of forage to meet the DMI requirements for the cow-calf herd (Figure 4 and Table 15).

Figure 4. Sample estimated forage balance for 'Your Farm' in FORCAP showing total dry matter intake (DMI) requirements, total pasture forage growth, forage available for hay, and source of forage to meet DMI requirements

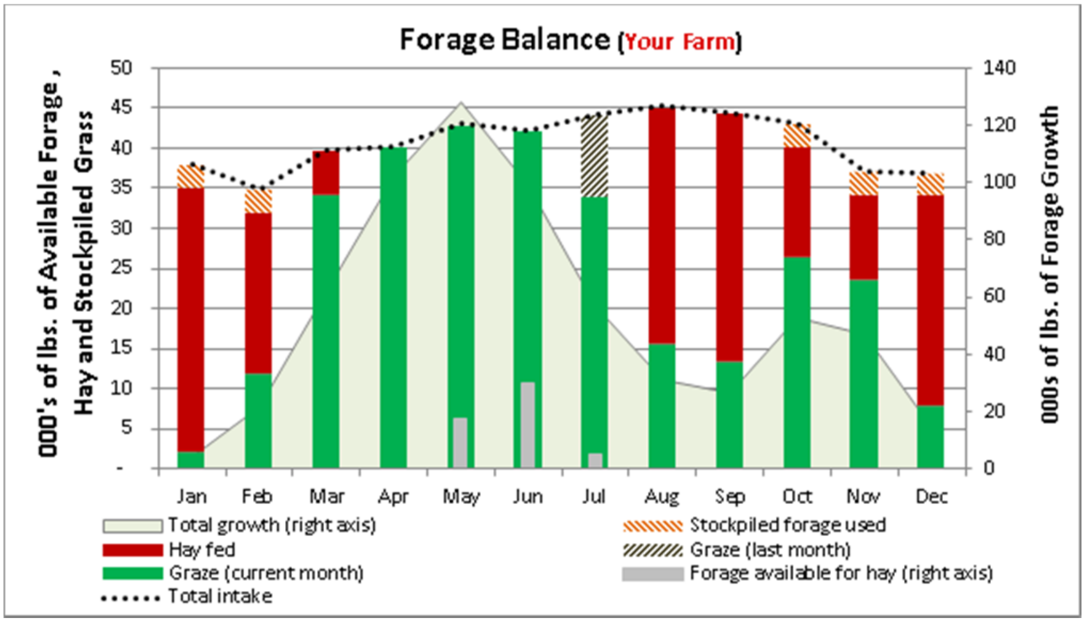


Table 15. An example of the forage balance calculation in FORCAP for a 30-cow herd using a year-round-calving season and default input levels

					Source of DMI			
Month	Ending Forage Balance (EFB$_i$)	Beginning Forage Balance (EFB_{i-1})	Current Production (FP_i)	Grazed Forage (GF_i)	Stockpiled Forage Consumed (MSP_i)	Forage Transfer (FT_i)	Hay Fed (HF_i)	Total DMI Required ($TDMI_{ik}$)
January	-	-	-	-	-	-	40,471	40,471
February	-	-	6,458	6,458	-	-	30,493	36,951
March	-	-	16,420	16,420	-	-	25,353	41,773
April	7,371	-	48,456	41,085	-	-	-	41,085
May	32,102	6,634	74,560	42,458	-	-	-	42,458
June	20,926	28,891	61,902	40,976	-	-	-	40,976
July	-	18,833	35,244	35,244	-	7,259	-	42,503
August	-	-	19,368	19,368	-	-	23,374	42,742
September	-	-	15,340	15,340	-	-	25,108	40,448
October	-	-	32,036	32,036	-	-	8,612	40,649
November	-	-	25,031	25,031	-	-	13,842	38,873
December	-	-	4,306	4,306	-	-	35,887	40,192
Total	60,398	54,358	339,120	278,722	-	7,259	203,141	489,122

The month-end quantity of forage is dependent on the starting forage quantity available (the ending forage balance of the previous month less a transfer loss of 10%), forage growth in the month, grazing efficiency, stockpiled forage used in the current month, and dry matter intake requirements from the cow-calf herd.

Equation 18a:

$BFB_i = EFB_{i-1} \cdot (1 - FTL)$ -- for all $i \neq$ March when $BFB = 0$ or growth starts

Equation 18b:

$EFB_i = FP_i + MSP_i + FT_i + HF_i - TDMI_i$ -- ending forage is a function of forage production, stockpiled forage used, grazable forage transferred, hay fed and nutrient requirements.

Equation 18c:

$FP_i = (MPFP_i + MRPG_i) \cdot GE$ -- monthly forage production from pasture and ryegrass adjusted for grazing efficiency

Equation 18d:

$HF_i = TDMI_i - (GF_i + MSP_i + BFB_i)$ -- hay feeding only occurs if nutrient needs can't be met from forage production, beginning forage balance and stockpiled forage made available

Equation 18e:

$MSP_i = SPU_i \cdot TSP \cdot GE \cdot SPL$ -- stockpiled forage fed is the user-specified, monthly allocation of annual total stockpiled forages set aside and adjusted for grazing efficiency and stockpile losses if needed

Where:

FTL	is the estimated forage loss, in percent, as a result of forage being transferred from one month to the next
EFB_i	is the ending forage balance for month *i* in lbs
BFB_i	is the beginning forage balance for month *i* in lbs
FP_i	is forage growth on pasture for month *i* in lbs
MSP_i	is stockpiled forage consumed in month *i* in lbs subject to limits in Eq. 19
FT_i	is forage grazed from previous month's growth in lbs subject to limits in Eq. 19
HF_i	is hay fed in month *i* in lbs subject to limits in Eq. 19 via FT_i
$TDMI_i$	are the herd's DMI needs for month *i* in lbs
$MPFP_i$	is pasture forage production in lbs of DM for month *i*
$MRPG_i$	is ryegrass production in lbs of DM for month *i*
GE	is grazing efficiency in percent and measures the amount of forage consumed by animals as a percentage of total above ground biomass production

GF_i	is the forage grazed from current production in month i in lbs
SPU_i	is the user-specified percent of annual stockpiled forages used in month i
TSP	is the pasture forage growth set aside from August to December to allow accumulation of standing forage for delayed consumption (defined below)
SPL	is the estimated forage loss from stockpiling in percent

The herd's $TDMI_i$ needs are met first by grazing the current month's production (FP_i), followed by stockpiled forages (MSP_i) and finally forage transfers from the previous month if available (FT_i). What forage source is used to meet $TDMI_i$ thus depends on the ending forage balance of the previous month, current production and whether the user specified stockpiled forage availability as follows:

Equation 19a:

If $EFB_{i-1} > TDMI_i$
  If $EFB_{i-1} > TDMI_i / (1 - FTL)$
    $EFB_{i-1} = TDMI_i / (1 - FTL)$
  Else
    $EFB_{i-1} = FP_{i-1} - TDMI_{i-1}$
Else
  $EFB_i = FP_i + MSP_i + FT_i + HF_i - TDMI_i$

-- check for possibility of forage transfer and limit forage transfer from previous month to this month's nutrient needs adjusted for transfer loss (can't transfer more than one month). Also limit forage transfer to excess of current month's production and apply loss to next month's starting balance (e.g. $BFB_i = EFB_{i-1} \cdot (1 - FTL)$)

Equation 19b:

If $TDMI_i > FP_i$
  $GF_i = FP_i$
Else
  $GF_i = TDMI_i$

-- animals prefer current month's production for grazing and will choose it over stock-piled or transferred forage. It is limited to the amount of nutrients needed by the herd in that month.

Equation 19c:

If $TDMI_i - FP_i > 0$ and $MSP_i > TDMI_i - FP_i$
  $MSP_i = TDMI_i - FP_i$
Else
  $MSP_i = SPU_i \cdot TSP \cdot GE \cdot SPL$

-- if current production is insufficient to meet herd needs, stockpiled forage is next in line and limited to the lesser of herd needs or amount made available. It cannot be trans-ferred as the user specifies monthly use.

Equation 19d:

If $BFB_i > 0$ and $TDMI_i - GF_i - MSP_i - HF_i > 0$
  $FT_i = TDMI_i - GF_i - MSP_i - HF_i$
Else
  $FT_i = 0$

-- transfer forage use by animals is limited to availability of transferred forage (BFB) at the start of the month less consumption of preferred forage (GF), stockpiled forage (MSP) and hay (HF) as needed.

Where:

EFB_i	is the ending forage balance for month *i* in lbs
BFB_i	is the beginning forage balance for month *i* in lbs
FP_i	is forage growth on pasture for month *i* in lbs
$TDMI_i$	are the calving season and gestation stage adjusted DMI requirements for the cow-calf herd in month *i* in lbs
GF_i	is grazed forage from current production in month *i* in lbs
FT_i	is forage consumed in month $_i$ that was transferred in from the previous month in lbs
MSP_i	is the user-specified amount of forage made available from stockpiled sources in month *i* in lbs

Grazed forage and forage transfer are two sources to meet $TDMI_{i.}$ The other two sources are hay fed and stockpiled forage. Total stockpiled forage available (*TSP*) was estimated from the number of stockpiled acres as follows:

Equation 20:

$$TSP = \sum_{j=1}^{4}\sum_{i=1}^{5} MPFP_{ij} \cdot TSA$$

Where:

TSP	is the total stockpiled forage available
$MPFP_{ij}$	is the monthly pasture forage production of species *j* in month *i*
TSA	is the total number of stockpiled pasture acres ($TSA < PA$)

Forage can be stockpiled from August to November and removes the number of acres stockpiled from the monthly pasture forage production ($MPFP_i$) made available for grazing for four species (bermudagrass, fescue, cool season grass, and clover). Stockpiled acres can then be utilized to meet herd DMI requirements in October, November, December, January, and February (Table 14). Winter annuals are not assumed to be available for stockpiling and would be consumed when produced.

In summary, hay is the feed source of last resort and grazed forage is consumed in the following order of preference: current production, stockpiled forage and finally forage transferred from the previous month. A sample of how *TDMIi* requirements are met, is provided in Table 15 and a decision tree is provided in Figure 5. Note that current production and stockpiled forage are under the control of the decision maker and hence precede forage transfers.

Figure 5. Flowchart of logic for feeding available forage production, stockpiled forages, forage transferred from the prior month and hay

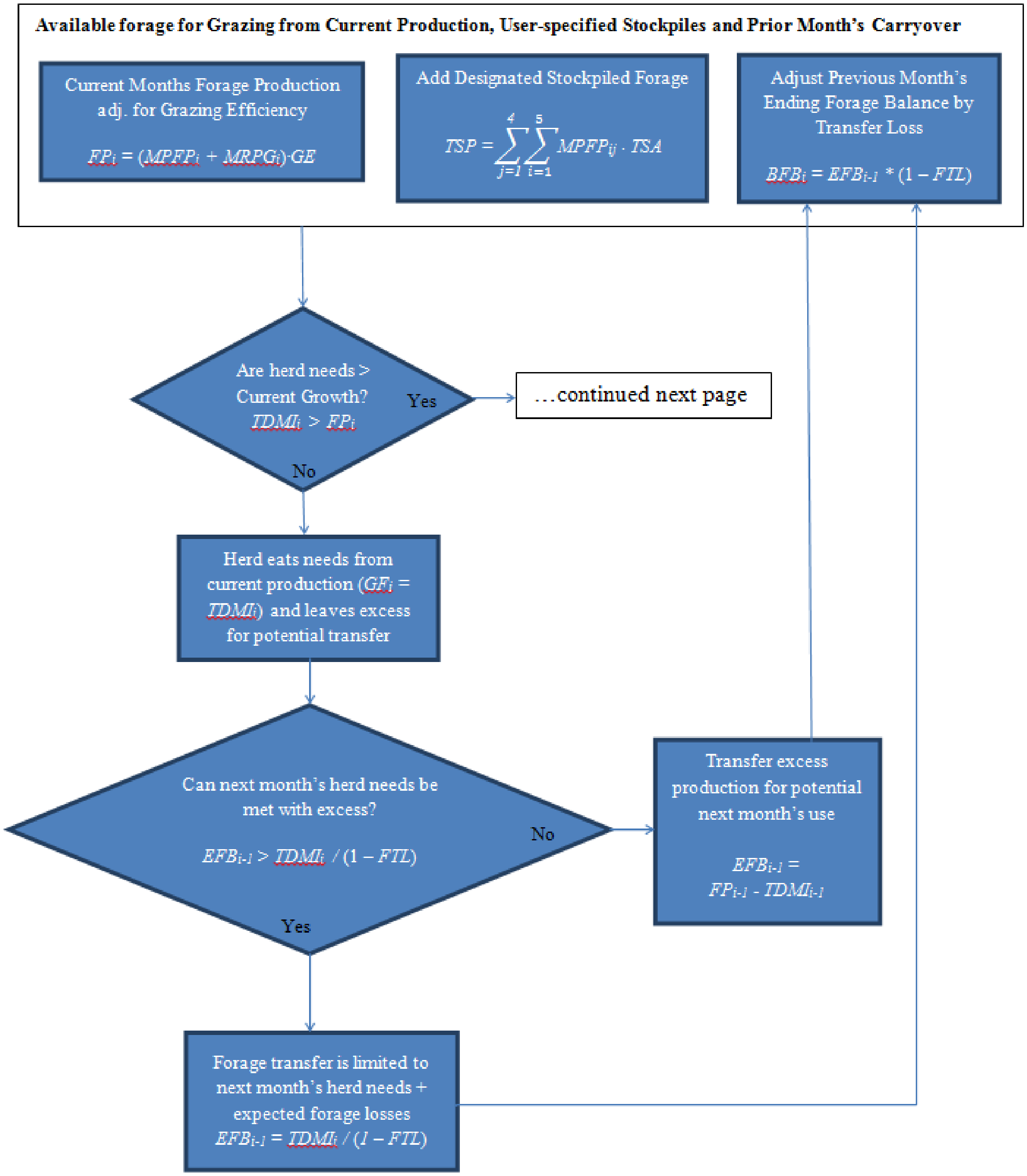
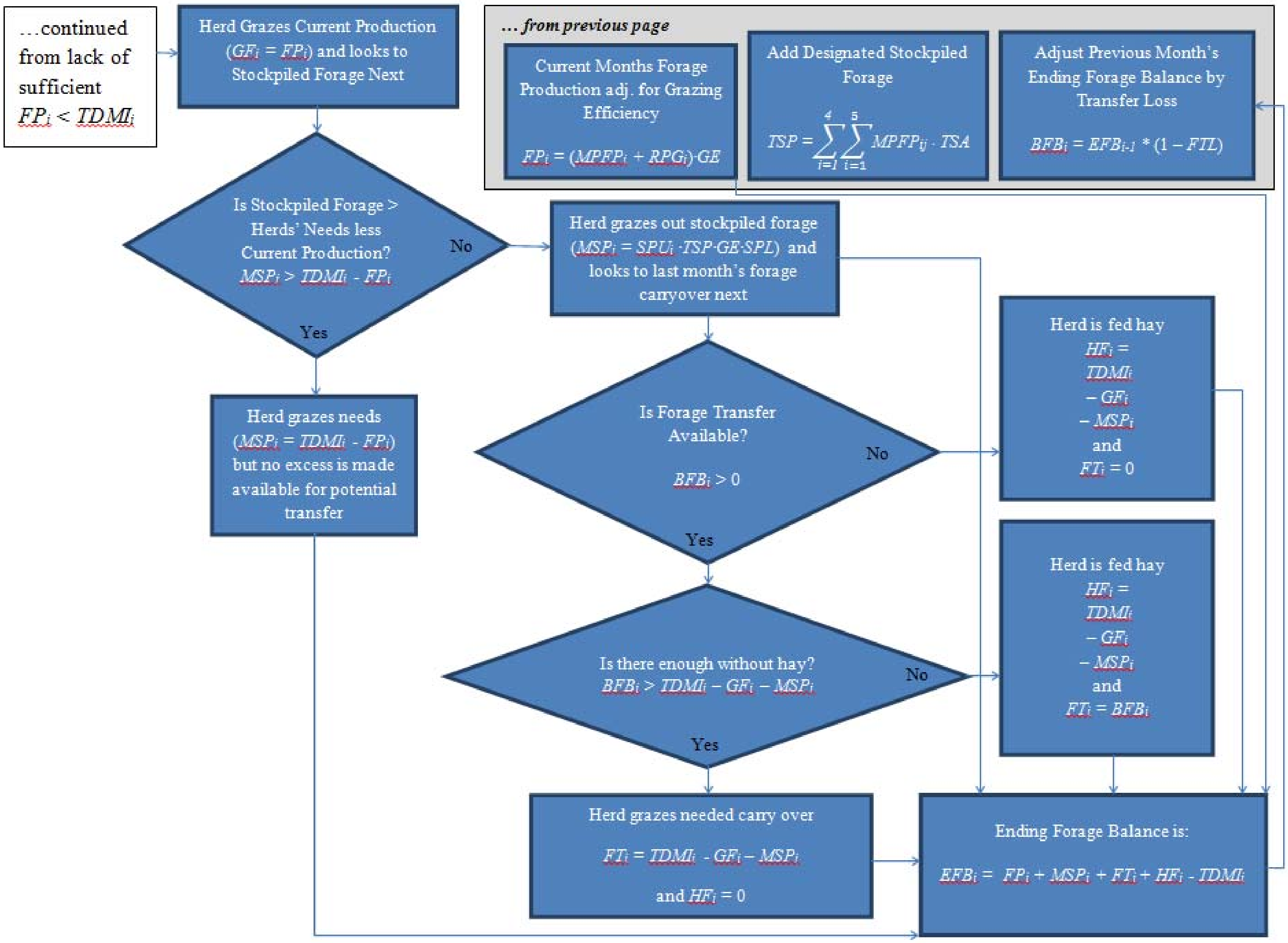


Figure 5. (cont'd) Flowchart of logic for feeding available forage production, stockpiled forages, forage transferred from the prior month and hay



Using the monthly $TDMI_i$ and HF_i an estimate of monthly days on feed (EDF_i) was determined as follows:

Equation 21:

$$EDF_i = {HR_i}/{TDMI_i} \cdot D_i$$

Where:

EDF_i	is the estimated number of days on feed in month *i*
HR_i	is hay required in month *i* in lbs of DM
$TDMI_i$	is the total DMI requirements for the cow-calf herd in month *i*
D_i	is the number of days in month *i*

Days on feed represent an estimate as some DMI requirements will be met from grazing and hay fed for any given month.

This logic was later amended to allow for removal of unused forage as hay. This amount of hay harvested was limited to portions of forage that would go unused as forages can only be transferred one month. The producer is assumed to realize this and harvest if a minimum threshold of harvestable hay was available at the end of each month. This minimum threshold is user specifiable and suggested at ½ bale per acre. Further, this harvesting is only possible if more than one pasture paddock is available. It is important to note that this activity is modeled in such as fashion as to not affect the forage balance for grazing.

IV. GHG Emissions

FORCAP tracks three primary GHG's from cow-calf and forage production (CO_2, CH_4, and N_2O). For comparison purposes, CH_4 and N_2O are converted to their CO_2 equivalents based on their 100 year global warming potential (GWP) of 25 and 298 times that of CO_2, respectively (IPCC, 2007). Greenhouse gas emissions are estimated from cattle, forage, and agricultural inputs.

Animal Emissions

Greenhouse gas emissions from animals were calculated from three sources: i) carbon dioxide from animal respiration; ii) methane emissions from enteric fermentation; and iii) nitrous oxide from urine and manure. Total CO_2 eq. emissions for each animal group are estimated from monthly values and then summed across months to estimate total annual animal emissions for each animal group.

Carbon dioxide from respiration was calculated utilizing an equation from Kirchgessner et al. (1991) as follows:

Equation 22:

$ECO_{2\ animal}$	$= -1.4 + 0.42 \cdot M_{DMI} + 0.045 \cdot M_{bw}^{0.75}$

Where:

$ECO_{2\ animal}$	is defined as emissions of CO_2 from animal respiration (kg CO_2 cow^{-1} day^{-1})
M_{DMI}	is defined as daily intake of feed dry matter for each animal (kg DM cow^{-1} day^{-1})
M_{bw}	is defined as the animal's body weight in kg

ECO_2 animal emissions were converted to imperial units for consistency within FORCAP by converting BW and DMI into kg, applying **Equation 22** and then converting $ECO_{2\ animal}$ from kg to pounds. Total ECO_2 per year were thus a function of monthly liveweight and DMI for all animals in each animal group on the farm times the number of days at that weight for that month and summed across all months. Cow monthly weights were assumed to be constant and were estimated as *AW* (Equation 8) described in the herd characteristics section. Dry matter intake requirements changed with gestation stage as indicated in the herd characteristics-dry matter intake requirements section. Steer and heifer calves and replacement heifer's weights and DMI requirements were based on month of birth, birth weight, weaning age, and weaning weights determined by the user or default values recorded above. Steer and heifer calf and replacement weights were the weight recorded for the last day of the month. As such, ECO_2 emissions changed on a monthly basis as animal weights and DMI requirements changed monthly.

Methane emissions from enteric fermentation were estimated using the IPCC tier II equation for animal maintenance and CH_4 emissions:

Equation 23:

CH_{4E} =	$(C_f \cdot M_{bw}^{0.75} \cdot Y_m) / 55.65$ MJ / kg CH_4

Where:

CH_{4E}	are daily CH_4 emissions in kg per head based on mega joules (MJ) of energy intake per head per day required for maintenance of each animal
C_f	is the emissions factor for each animal category (lactating cows 0.335 and 0.322 for all other animal groups)
M_{bw}	is the liveweight of the animal in kg
Y_m	is the methane conversion rate which is the fraction of gross energy in feed converted to methane (estimated at 0.06 for all cattle)
55.65 MJ / kg CH_4	is defined as the stoichiometric conversion constant of 55.65 MJ per kg of CH_4

Total annual CH_{4E} emissions were estimated by summing the monthly emissions for each animal group based on number of days in each month and *AW* of each animal group. Similar to animal respiration, varying monthly live weight of steer and heifer calves and replacements while keeping bull and cow weights constant was used to estimate enteric fermentation for each animal group. Nitrous Oxide emissions from animal urine and manure were estimated utilizing the following IPCC equation:

Equation 24:

$$N_2O = (CP_{intake} \cdot N_{CP} \cdot M_{bw}) \cdot (1- N_{retention}) \cdot N_2O_{Nex}$$

Where:

N_2O	is N_2O in kg per day by an animal weighing M_{BW} in kg.
CP_{intake}	is defined as the animal's crude protein intake per day. Intake varied by animal group and ration as a percentage of DMI shown in Table 12. Note that CP content varies by forage species consumed and by month of consumption.
N_{CP}	is defined as the N intake as a percentage of crude protein by stoichiometric conversion and held constant at 0.16
M_{bw}	is the liveweight of the animal in kg
$N_{retention}$	is defined as the fraction of N retained by the animal and set at 7% regardless of animal age, gender or weight
N_2O_{Nex}	is defined as the amount of N_2O emissions per kg of N excreted and assumed constant at 2% regardless of season.

Similar to CH_4 emissions, daily emissions by adjusted animal weight by month were summed across days on farm for the year and converted to lbs at their CO_2 equivalent by adjusting for GWP. Total animal emissions were estimated by summing CH_4, CO_2, and N_2O emissions for each of five animal groups (cows[5], bulls, replacement heifers, heifer calves for sale, and steer calves for sale). Animal emissions are shown in CO_2 eq. for the farming operation, lbs / acre, and lbs / liveweight leaving the farm.

Monensin has been shown to reduce CH_4 emissions in cattle by reducing the CH_4 emitted from microbes in the rumen and improving feed efficiency. FORCAP can estimate feeding monensin to cows, bulls, and replacement heifers to reduce CH_4 emissions. An average CH_4 emissions reduction from six studies (Odongo et al. 2007; Thorton and Owens, 1981; O'Kelly and Spiers, 1992; Guan et al. 2006; Hamilton et al., 2010; and Singh and Mohini, 1999) with nine estimates was 18.35% when high and low values were removed and is based on feeding monensin at the recommended rate. No reduction in calf CH_4 emissions was assumed. At this time feed efficiency is not changed as a result of feeding monensin. Note that monensin is a relatively cheap feed additive and the GHG impact on a whole farm basis is relatively small at the farm scale as modeled.

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5 A weighted average for young cows and mature cows were used to estimate the emissions for all bred cows.

Forage Emissions

Carbon dioxide equivalent emissions assimilated in forage are estimated for both hay and pasture production. These emissions should not be considered as sequestered for extended periods; the forage temporarily stores C that will eventually be released to the atmosphere. Carbon stored in grazed (GF_{CO2}) and hay (HF_{CO2}) forages provides an estimate of the carbon exported from the farm via live animal weight or in hay sold. Forage emissions represent the amount of CO_2 equivalent C contained in forages, as follows:

Equation 25:

$$GF_{CO2} = \sum_{i=1}^{12}\sum_{j=1}^{4} MPFP_{ij} \cdot GE \cdot C_j \cdot PA \cdot (44/12) \cdot F_p$$

Where:

$MPFP_{ij}$	is pasture forage production for month *i* and species *j* in lbs of DM
GE	is the operation's estimated grazing efficiency in percent
C_j	is the estimated carbon content of species *j* in percent
PA	is the number of pasture acres in the operation
44/12	is the stoichiometeric conversion of CE to CO_2 eq.
F_p	is a constant conversion factor that estimates the fraction of initial carbon captured via photosynthesis in forage removed from grazing that is exported from the farm via live animal weight (the factor can take on any value between 0 and 1 and is defaulted to 1/8)

Equation 26:

$$HF_{CO2} = \sum_{j=1}^{4} HP_j \cdot C_j \cdot HA \cdot (44/12) \cdot F_h$$

Where:

HP_j	is the annual hay production from species *j* in lbs of DM per acre (total hay growth x haying efficiency)
C_j	is the estimated carbon content of species *j* in percent
HA	is the number of hay acres in the operation
44/12	is the stoichiometeric conversion of CE to CO_2 eq.
F_h	is a constant conversion factor that estimates the fraction of initial carbon captured via photosynthesis in hay forage less harvest waste that is exported from the farm via animal weight and hay sold (the factor can take on any value between 0 and 1; defaulted to 1/8)

Note that these are negative emissions as they represent the amount of carbon stored in biogenic material and should not be considered carbon sequestered for extended periods of time. The GF_{CO2} and HF_{CO2} provide estimates of carbon temporarily stored in forage and animal weight that is exported from the farm. Conversion factors F_p and F_h can be any number between 0 and 1. Zero indicates that carbon temporarily stored in forage is not accounted for in GHG emission calculations. If the conversion factors are positive then a fraction of carbon from forage removed via grazing or harvest is assumed to be captured short term in live animal weight sold or hay sold from the operation. The default values for F_p and F_h were set to 0.125 on an *ad hoc* basis.

Agricultural Inputs

Direct and indirect emissions are estimated for agricultural input use. Direct emissions are those realized from the use of inputs on the farm, for example diesel fuel used by a tractor. Indirect emissions are emissions from the upstream production of an input, such as emissions from the extraction and processing of potash. Carbon dioxide equivalent GHG emissions from fertilizer, diesel fuel, and twine are currently estimated in FORCAP.

Fertilizer emission factors in CE (both direct and indirect) are: nitrogen – 1.30 lbs of C / lb of N applied; nitrogen N_2O emissions – 1.27 lbs of C / lbs of N applied; phosphate – 0.20 lbs of C / lb of P applied; potash – 0.16 lbs of C / lb of K applied; and lime – 0.06 lbs of C / lb of lime pellets applied (Lal 2004). Nitrogen (N_2O) emissions are N_2O emissions released to the atmosphere through the nitrification and denitrification process that results from applying nitrogen fertilizer to agricultural soils. Nitrogen, phosphate, potash, and lime emissions are indirect emissions from the upstream production of the fertilizers. Fertilizer emissions are estimated by the quantity of each fertilizer applied multiplied by the CE emissions factor and converted to its CO_2 equivalent. Included in the fertilizer quantities are elemental amounts of N, P, and K from poultry litter application. Only direct and indirect N is tracked for custom fertilizers.

Emissions from hay bales purchased from another farm are not attributed to the operation as those emissions charged are assumed to be charged to the other farm. Twine emissions were estimated at 6.1 lbs of CE per lb of plastic twine used (Lal 2004). Farm implements were assumed to use diesel fuel with an emission factor of 7.0 lbs of CE (Lal 2004). Pasture maintenance, mowing, raking, baling and staging are assigned a fuel use of 4.5 gallons per acre per year. Diesel fuel for checking cattle is estimated at 1 gallon per day and feeding is charged at 1 gal per 70 cows per days the cow herd is fed hay. To estimate total agricultural input emissions, the emission factors above were multiplied by the quantities of the input used and converted from CE to CO_2 eq. For example, an operation that produces 100 bales of hay would have twine emissions of 746 lbs of CO_2 equivalent emissions or 100 bales multiplied by 6.1 lbs CE per lb of plastic multiplied by 1/3 lbs of plastic twine per bale multiplied by 44/12, the stoichiometric conversion of CE to CO_2. Currently no emissions are estimated in FORCAP for mineral, supplemental feed, vaccinations, or other agricultural inputs. The GHG emissions ramifications of input use from these sources are considered marginal (less than 5% of total farm emissions). Hay harvest from pastures as well as custom fertilizer applications are tracked in emissions estimates. GHG emissions by source are summarized in a spreadsheet tab and are reported as emissions by farm, per acre as well as per lb of animal liveweight sold.

V. Budget and Economic Analysis

Input prices, parameters, production methods, and site characteristics selected by the user are utilized to generate a basic farm budget. Budgets will be discussed in two sections. First, capital requirements for the three 'Bench Mark' farm sizes and 'Your Farm' estimate ownership charges for equipment, buildings, farm infrastructure (fencing, corals, and watering systems) and breeding stock. Second, gross receipts and direct costs are estimated from input / output prices and quantities used or produced.

Capital Requirements

Default capital requirements are shown in Tables 16 to 18 for the three benchmark farm sizes. Users may enter the list prices, useful life, salvage value, and repair factor for equipment, buildings, and fencing infrastructure to estimate ownership charges used on 'Your Farm'. List price is defined as the estimated current price of the capital input. Years of useful life is the number of years the input is estimated to be productive. Salvage value is the amount the capital input can be sold for at the end of its useful life in today's dollars. Repair factor is an estimate of the total cost of repairs and maintenance over the useful life of the asset. Annual repair and maintenance is estimated as follows:

Equation 27:

$$RM = RF \cdot LP / YUL$$

Where:

RM	is the annual repair and maintenance cost for the capital asset in $
RF	is the repair factor for the capital asset as described above
LP	is the list price of the capital asset in $
YUL	is the years of useful life of the capital asset

Capital recovery is estimated as follows:

Equation 28:

$$CR = (LP - SV) \cdot (CRR / (1 - (1 + CRR)^{-YUL})) + SV \cdot CRR$$

Where:

CR	is the annual estimated capital recovery cost for the capital asset in $
LP	is the list price of the capital asset in $
SV	is the salvage value of the capital asset at the end of its useful life in $
CRR	is the capital recovery rate selected as an input cost
YUL	is the years of useful life of the capital asset

For all equipment, buildings, and fencing the user can select if the asset is charged annual personal property taxes and / or insurance premiums. Property taxes and insurance are estimated from the rate defined on the input page and the list price of the asset (LP x Tax rate or Insurance rate). Breeding stock capital requirements are estimated from the estimated market value for mature cows, young cows, replacement heifers, and bulls. Of note, user-entered capital requirements are for the 'Your Farm' option only while the 'Bench Mark' farm uses default values based on farm size selection in the 'Farm' tab. Capital investment includes machinery, buildings, and breeding livestock. Land value is not entered for capital requirements as some producers may rent land. Net returns calculated are thus to land, owner labor, and management.

Table 16. Annual capital recovery (depreciation and interest), repair and maintenance, property taxes and insurance for fixed investments for *Small* Benchmark farms

Description	List Price in $ (*LP*)	Years of Useful Life in Years (*YUL*)	Salvage Value in $ (*SV*)	Capital Recovery in $ (*CR*)	Repair Factor (*RF*)	Repair and Maintenance in $ (*RM*)	Taxes in $	Insurance in $
Hay Barn (1,000 sqft.)	5,000	20	800	377	0.4	100	25	40
Shed (800 sqft.)	4,000	20	750	298	0.4	80	20	32
45-50 hp Tractor w Loader	24,000	10	7,500	2,512	0.25	600	120	192
Corral and Chute	3,000	10	800	325	0.25	75	15	24
Brush Mower	8,000	10	800	972	0.25	200	40	64
Miscellaneous Items	2,000	10	0	259	0.5	100	10	16
Stock Trailer	3,500	10	1500	334	0.2	70	17.5	28
Fencing & Watering	13,458	20	0	1,080	0.5	336	na	108
Total	62,958			6,157		1,561	248	504

Table 17. Annual capital recovery (depreciation and interest), repair and maintenance, property taxes and insurance for fixed investments for *Medium* benchmark farms

Description	List Price in $ (*LP*)	Years of Useful Life in Years (*YUL*)	Salvage Value in $ (*SV*)	Capital Recovery in $ (*CR*)	Repair Factor (*RF*)	Repair and Maintenance in $ (*RM*)	Taxes in $	Insurance in $
Hay Barn (1,000 sqft.)	5,000	20	800	377	0.40	100	25	40
Shed (800 sqft.)	4,000	20	750	298	0.40	80	20	32
50-75 hp Tractor	30,000	10	10,000	3,090	0.25	750	150	240
Disk Mower	8,000	7	4,000	891	0.35	400	40	64
Hay Baler	20,000	10	7,500	1,994	0.10	200	100	160
Hay Rake	4,000	10	750	458	0.20	80	20	32
Stock Trailer	3,500	10	1,500	334	0.20	70	18	28
Hay Wagon	3,000	10	500	349	0.20	60	15	24
Brush Mower	8,000	10	800	972	0.25	200	40	64
Corral and Chute	3,500	10	1,000	374	0.15	53	18	28
Miscellaneous Items	2,000	10	0	259	0.50	100	10	16
Fencing & Watering	24,293	20	0	1,949	0.10	121	na	194
Total	115,293			11,346		2,214	455	922

Table 18. Annual capital recovery (depreciation and interest), repair and maintenance, property taxes and insurance for fixed investments for *Large* benchmark farms

Description	List Price in $ (*LP*)	Years of Useful Life in Years (*YUL*)	Salvage Value in $ (*SV*)	Capital Recovery in $ (*CR*)	Repair Factor (*RF*)	Repair and Maintenance in $ (*RM*)	Taxes in $	Insurance in $
Hay Barn (1,500 sqft.)	7,500	20	1,250	564	0.40	150	38	60
Shed (800 sqft.)	4,000	20	750	298	0.40	80	20	32
90 - 110 hp Tractor	50,000	10	35,000	3,693	0.12	600	250	400
Hay Baler	22,000	10	8,000	2,213	0.10	220	110	176
Hay Rake	4,000	10	750	458	0.20	80	20	32
Disk Mower	8,000	7	4,000	891	0.15	171	40	64
Tedder	5,000	10	750	588	0.20	100	25	40
Stock Trailer	12,500	10	7,000	1,062	0.10	125	63	100
Hay Wagon	5,500	10	500	673	0.20	110	28	44
Brush Mower	8,000	10	800	972	0.25	200	40	64
Corral and Chute	5,000	10	1,250	548	0.15	75	25	40
Miscellaneous Items	2,500	10	0	324	0.50	125	13	20
Fencing & Watering	45,185	20	0	3,626	0.10	226	na	361
Total	179,185		60,050	15,910		2,262	670	1,433

Revenues and Expenses

Enterprise budgets feature estimated gross receipts, direct costs, operating interest, and ownership charges as they vary on the basis of input parameters selected for the ‘Bench Mark’ farm and ‘Your Farm’ operations. Gross receipts are from the sale of steer and heifer calves, culled cows, culled bulls, and excess hay (bales or head sold multiplied by the current market price for the weight categories (Figure 3 and Table 5) with time of sale dictated by calving season and weaning age except for cull animals sold at annual average price). Direct costs include fertilizer, feed, marketing, and miscellaneous inputs and are summarized on the ‘Budget’ tab (Figure 6). Quantity detail on fertilizer, other feed, veterinary & medicine, yardage, insurance, checkoff, repair and maintenance, reseeding and ownership charges are not provided in the ‘Budget’ tab as the page was designed as a summary page. Operating interest is charged on half the direct costs assuming that financing on input purchases is provided by line of credit. With timing of purchases unknown, average investment in total direct cost over the course of one year is estimated to be half of those costs and is a common procedure when developing enterprise budgets. Subtracting specified costs from receipts provides and estimated return to land, management, owner’s equity, and labor for each operation. This return statistic is provided for the farm, as returns per calving cow, and per acre of hay and pasture land basis. Enterprise budgets were designed to provide helpful information to i) entrants to provide an approximation of capital requirements and an estimate of annual costs and returns; ii) lenders to provide information for evaluating loan applications; iii) current producers to provide a basis for evaluating the performance of their operation and potential financial changes as a result of the change in inputs and production methods; and iv) an estimate of how sensitive return estimates are to livestock price fluctuations.

VI. Conclusions

FORCAP provides user flexibility to reflect site-specific operation characteristics, inputs, and production methods. Users can compare their operation to a benchmark operation using similar production methods and site characteristics. Additionally, default values can be adjusted by advanced users to reflect regional- or county-level differences when conducting comparisons. FORCAP provides a method for cow-calf producers, extension agents, and researchers to evaluate the NR and GHG emission changes associated with different site characteristics, production methods, and inputs. While the interaction among many variables was programmed into FORCAP, the user is ultimately responsible to determine whether changes in outcomes are appropriate. The possibility exists to change the weaning age, for example, without modifying weaning weights and hence unrealistic average daily gain numbers may result.

Not discussed in this reference manual are ramifications of changing genetics. The user manual describes this model feature. Changing genetics potential affects weaning weights, birth

Figure 6. Sample FORCAP 'Budget' tab summarizing revenue and expenses for 'Your Farm' and the 'Bench Mark' farm

DIVISION OF AGRICULTURE RESEARCH & EXTENSION University of Arkansas System

Comparison of Production Cost and Returns to Land, Labor and Management

FORCAP FORAGE & CATTLE PLANNER

	Bench Mark Weight (in lb if app.)	Unit	Quantity	Price or Cost/Unit	Total	VS.	Total	Your Farm Weight (in lb if app.)	Quantity	Price or Cost/Unit
GROSS RECEIPTS					**Total**		**Total**			
Steer Calves	555	lb	12	$1.59	$10,591.81		*$20,889.48*	555	*22*	*$1.71*
Heifer Calves	520	lb	7	$1.42	$5,178.93		*$11,087.44*	520	*14*	*$1.52*
Cull Cows	1,117	lb	5	$0.76	$4,264.15		*$6,416.47*	1,117	*7*	*$0.82*
Cull Bulls	2,000	lb	0.50	$0.92	$922.82		*$945.38*	2,000	0.50	*$0.95*
Excess Hay (if any)	800	bale	153	$40.00	$6,120.00		*$1,760.00*	800	*44*	$40.00
TOTAL RECEIPTS					**$27,077.71**		*$41,098.76*			
DIRECT COSTS										
FERTILIZER										
Fertilizer Costs		$/farm	1	$8,718	$8,718.00		*$9,966.75*		1	*$9,967*
FEEDING AND OPERATING										
Purchased Hay	800	bale	0	$45.00	$0.00		$0.00	800	0	$45.00
Corn		lbs	2,494	$0.15	$369.01		*$580.43*		*3,924*	$0.15
Salt and Minerals	50	$/bag	35	$20.00	$700.00		*$1,792.00*	50	*56*	*$32.00*
Other Feed		$/farm	1	$50	$50.00		$50.00		1	$50
Veterinary & Drug Charges		$/farm	1	$1,186	$1,186.04		*$1,702.05*		1	*$1,702*
MARKETING										
Sales commission		$/sales	1	3.5%	$733.52		*$1,376.86*		1	3.5%
Yardage, Insurance, and Checkoff		$/farm	1	$67	$67.38		*$119.63*		1	*$120*
Cattle Purchasing Costs		$/farm	1	$75	$75.00		$75.00		1	$75.00
Custom Hauling		$/farm	1	$0	$0.00		$0.00		1	$0
MISCELLANEOUS										
Twine		$/bale	362	$1.00	$361.83		*$441.05*		*441*	$1.00
Fuel		$/gal	1072	$3.50	$3,751.47		*$3,233.33*		*924*	$3.50
Herd Sire(s)		$/hd	0.50	$2,000	$1,000.00		$1,000.00		0.50	$2,000
Farm Vehicle		$/month	12	$30	$360.00		*$600.00*		12	*$50*
Other (pasture reseeding + winterannuals if any)		$/farm	1	$3,570	$3,570.00		$3,570.00		1	$3,570
Repair and Maintenance		$/farm	1	$2,194.28	$2,194.28		*$2,213.22*		1	*$2,213*
TOTAL DIRECT COSTS (TDC)					**$23,136.52**		*$26,720.32*			
OPERATING INTEREST (on 1/2 of TDC)		rate	1	6%	$694.10		*$801.61*		1	6%
RETURNS ABOVE DIRECT COSTS				farm total	**$3,247.09**		*$13,576.83*			
				$/calving cow	**$108.24**		*$271.54*			
				$/acre	**$13.53**		*$56.57*			
OWNERSHIP CHARGES										
Capital Recovery		$/farm	1	$11,030	$11,030.24		*$11,334.20*		1	*$11,334*
Opportunity Cost on Breeding Stock		rate	1	5%	$1,737.50		*$2,745.00*		1	5%
Property Taxes		$/farm	1	$629	$628.75		*$729.50*		1	*$730*
Insurance		$/farm	1	$891	$890.85		*$921.15*		1	*$921*
TOTAL OWNERSHIP CHARGES					**$14,287.34**		*$15,729.85*			
RETURNS TO LAND, OWNER'S EQUITY, AND LABOR				farm total	**-$11,040.25**		*-$2,153.03*			
				$/calving cow	**-$368.01**		*-$43.06*			
				$/acre	**-$46.00**		*-$8.97*			

Cattle Price Sensitivity Analysis

	- 20%	- 10%	- 5%	Curent Prices	+ 5%	+ 10%	+ 20%
RETURNS ABOVE DIRECT COSTS	$5,984	$9,781	$11,679	$13,577	$15,475	$17,373	$21,169
RETURNS TO LAND, OWNER'S EQUITY, AND LABOR	-$9,196	-$5,675	-$3,914	-$2,153	-$392	$1,369	$4,890

weights and attendant birthing difficulty as well as sale prices. A sensitivity analysis of various model parameters is included in the Technical Appendix to this manual.

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VIII. Technical Appendix

NR and GHG Sensitivity to Parameter Changes

Changing parameters in FORCAP affects the NR and GHG emission estimates. As such, sensitivity analyses were conducted on cow DMI requirements, pasture species composition, cow body weight, breeding failures, and base production of bermudagrass, fescue, and clover.

Change in Cow DMI Requirements

Dry matter intake requirements for the cow animal group were changed by +/- 1, 5, and 10%, from the NRC DMI requirements for a 1,200 lb cow for a 12 month gestation cycle to determine the impact on NR and GHG emissions estimated by FORCAP for *Large*, *Medium*, and *Small* farm sizes using *None*, *Lime*, *Low*, *Medium*, and *High* fertilization strategies. Appendix Tables 1 to 6 show changes in NR and GHG emissions by farm size and fertilization strategy. The results are specific to an operation using 2012 prices, year-round-calving season, rotational grazing strategy (with strip grazing), no winter annual acres, and no acres stockpiled. All other parameters were set to the defaults described above in the reference manual.

Appendix Tables 1-3 show NR, $/calving cow, change in NR from the base, and change in NR for a 1% change in DMI requirements. As anticipated, a decrease in DMI requirements resulted in an increase in NR (reduced feed requirements resulted in lower costs). Change in NR ($) for a 1% change in DMI requirements for *Large* operations varied from $235 to $863, varying primarily by fertilization strategy (Appendix Table 1). In general, as fertilization strategy increased, from *None* to *High,* NR ($) per 1% change in DMI increased and the range of change widened. For example, using a *High* fertilization strategy resulted in a $759 to $863 ($104 range) change in NR for a 1% change in DMI while a *Lime* fertilization strategy resulted in a $235 to $251 ($16 range) change in NR. Higher fertilization resulted in greater stocking rate increases which in turn led to a greater total amount of DMI required to maintain the herd. While per cow DMI does not change in FORCAP herd numbers do vary by fertilization strategy.

Change in NR for *Medium* operations (Appendix Table 2) showed a similar pattern as *Large* operations. Small operations (Appendix Table 3) showed an increase in NR for a 1% change in DMI as fertilization strategy increased, however the range did not increase as fertilization strategy increased [*None* $49-$95 ($46); *Lime* $49-$95 ($46); *Low* $97-$144 ($47); *Medium* $145-$201 ($56); and *High* $193-$239 ($46)]. Percentage change in NR from the baseline was consistent across fertilization strategies for *Small* and *Medium* operations (1 to 3% change in NR for a 1% change in DMI requirements). Large operations had a much larger range (3 to 48%), however this was a reflection of the lower absolute value of the baseline NR rather than increased volatility, as evidenced by the change in actual dollars between scenarios and the baselines.

Greenhouse gas emissions were less sensitive to changes in DMI requirements, 1% or less change in GHG emissions for a 1% change in DMI requirements, for *Large*, *Medium*, and *Small* sized farms (Appendix Tables 4 to 6). Pounds of GHG emissions per lb of live-weight sold from the farm varied from 10 to 20 lbs. This change in lbs of GHG emissions per lb of live-weight was driven by fertilization strategy regardless of farm size. Greater emissions per lb of live weight were recorded for Small and Medium sized farms than large sized farms.

Appendix Table 1. Change in net returns (NR) for +/- 1%, 5%, or 10% change in dry matter intake requirements (DMI) in FORCAP by pasture fertilization strategy for *Large* farm size

Fertilizer Strategy		Baseline	% Change in Cow DMI Requirements from the Base Cow DMI Requirements -1	-5	-10	1	5	10
None	NR ($)	1,917	2,168	3,091	4,306	1,666	704	(467)
	$ / Calving Cow	**26**	**29**	**41**	**57**	**22**	**9**	**(6)**
	NR Change from Base ($)	-	251	1,174	2,389	(251)	(1,212)	(2,384)
	Change in NR from 1% Change in DMI ($)	**-**	**251**	**235**	**239**	**251**	**242**	**238**
	Change in NR from Base (%)	-	13	61	125	(13)	(63)	(124)
	Change in NR from 1% Change in DMI (%)	**-**	**13**	**12**	**12**	**13**	**13**	**12**
Lime	NR ($)	526	777	1,700	2,915	276	(686)	(1,857)
	$ / Calving Cow	**7**	**10**	**23**	**39**	**4**	**(9)**	**(25)**
	NR Change from Base ($)	-	251	1,174	2,389	(251)	(1,212)	(2,384)
	Change in NR from 1% Change in DMI ($)	**-**	**251**	**235**	**239**	**251**	**242**	**238**
	Change in NR from Base (%)	-	48	223	454	(48)	(230)	(453)
	Change in NR from 1% Change in DMI (%)	**-**	**48**	**45**	**45**	**48**	**46**	**45**
Low	NR ($)	(4,829)	(4,303)	(2,335)	(170)	(5,309)	(7,227)	(9,766)
	$ / Calving Cow	**(43)**	**(38)**	**(21)**	**(2)**	**(47)**	**(65)**	**(87)**
	NR Change from Base ($)	-	526	2,494	4,659	(480)	(2,398)	(4,936)
	Change in NR from 1% Change in DMI ($)	**-**	**526**	**499**	**466**	**480**	**480**	**494**
	Change in NR from Base (%)	-	11	52	96	(10)	(50)	(102)
	Change in NR from 1% Change in DMI (%)	**-**	**11**	**10**	**10**	**10**	**10**	**10**
Medium	NR ($)	(7,081)	(6,457)	(3,867)	(650)	(7,751)	(10,339)	(14,492)
	$ / Calving Cow	**(47)**	**(43)**	**(26)**	**(4)**	**(52)**	**(69)**	**(97)**
	NR Change from Base ($)	-	624	3,214	6,430	(670)	(3,258)	(7,411)
	Change in NR from 1% Change in DMI ($)	**-**	**624**	**643**	**643**	**670**	**652**	**741**
	Change in NR from Base (%)	-	9	45	91	(9)	(46)	(105)
	Change in NR from 1% Change in DMI (%)	**-**	**9**	**9**	**9**	**9**	**9**	**10**
High	NR ($)	(25,005)	(24,142)	(20,736)	(17,412)	(25,868)	(29,129)	(32,966)
	$ / Calving Cow	**(139)**	**(134)**	**(115)**	**(97)**	**(144)**	**(162)**	**(183)**
	NR Change from Base ($)	-	863	4,269	7,593	(863)	(4,124)	(7,960)
	Change in NR from 1% Change in DMI ($)	**-**	**863**	**854**	**759**	**863**	**825**	**796**
	Change in NR from Base (%)	-	3	17	30	(3)	(16)	(32)
	Change in NR from 1% Change in DMI (%)	**-**	**3**	**3**	**3**	**3**	**3**	**3**

Appendix Table 2. Change in net returns (NR) for +/- 1%, 5%, or 10% change in dry matter intake requirements (DMI) in FORCAP by pasture fertilization strategy for *Medium* farm size

Fertilizer Strategy		Baseline	% Change in Cow DMI Requirements from the Base Cow DMI Requirements -1	-5	-10	1	5	10
None	NR ($)	(7,994)	(7,910)	(7,533)	(7,032)	(8,078)	(8,455)	(8,915)
	$ / Calving Cow	**(266)**	**(264)**	**(251)**	**(234)**	**(269)**	**(282)**	**(297)**
	NR Change from Base ($)	-	84	461	962	(84)	(460)	(920)
	Change in NR from 1% Change in DMI ($)	**-**	**84**	**92**	**96**	**84**	**92**	**92**
	Change in NR from Base (%)	-	1	6	12	(1)	(6)	(12)
	Change in NR from 1% Change in DMI (%)	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Lime	NR ($)	(8,550)	(8,466)	(8,090)	(7,588)	(8,635)	(9,011)	(9,471)
	$ / Calving Cow	**(285)**	**(282)**	**(270)**	**(253)**	**(288)**	**(300)**	**(316)**
	NR Change from Base ($)	-	84	461	962	(84)	(460)	(920)
	Change in NR from 1% Change in DMI ($)	**-**	**84**	**92**	**96**	**84**	**92**	**92**
	Change in NR from Base (%)	-	1	5	11	(1)	(5)	(11)
	Change in NR from 1% Change in DMI (%)	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Low	NR ($)	(8,617)	(8,425)	(7,610)	(6,697)	(8,809)	(9,576)	(10,629)
	$ / Calving Cow	**(191)**	**(187)**	**(169)**	**(149)**	**(196)**	**(213)**	**(236)**
	NR Change from Base ($)	-	192	1,007	1,920	(192)	(959)	(2,012)
	Change in NR from 1% Change in DMI ($)	**-**	**192**	**201**	**192**	**192**	**192**	**201**
	Change in NR from Base (%)	-	2	12	22	(2)	(11)	(23)
	Change in NR from 1% Change in DMI (%)	**-**	**2**	**2**	**2**	**2**	**2**	**2**
Medium	NR ($)	(11,194)	(10,954)	(9,900)	(8,605)	(11,481)	(12,629)	(14,299)
	$ / Calving Cow	**(187)**	**(183)**	**(165)**	**(143)**	**(191)**	**(210)**	**(238)**
	NR Change from Base ($)	-	240	1,294	2,590	(287)	(1,435)	(3,105)
	Change in NR from 1% Change in DMI ($)	**-**	**240**	**259**	**259**	**287**	**287**	**310**
	Change in NR from Base (%)	-	2	12	23	(3)	(13)	(28)
	Change in NR from 1% Change in DMI (%)	**-**	**2**	**2**	**2**	**3**	**3**	**3**
High	NR ($)	(17,823)	(17,487)	(16,191)	(14,842)	(18,206)	(19,501)	(21,036)
	$ / Calving Cow	**(248)**	**(243)**	**(225)**	**(206)**	**(253)**	**(271)**	**(292)**
	NR Change from Base ($)	-	336	1,633	2,981	(382)	(1,678)	(3,212)
	Change in NR from 1% Change in DMI ($)	**-**	**336**	**327**	**298**	**382**	**336**	**321**
	Change in NR from Base (%)	-	2	9	17	(2)	(9)	(18)
	Change in NR from 1% Change in DMI (%)	**-**	**2**	**2**	**2**	**2**	**2**	**2**

Appendix Table 3. Change in net returns (NR) for + or – 1%, 5%, or 10% change in dry matter intake requirements (DMI) in FORCAP by pasture fertilization strategy for *Small* farm size

Fertilizer Strategy		Baseline	% Change in Cow DMI Requirements from the Base Cow DMI Requirements -1	-5	-10	1	5	10
None	NR ($)	(7,273)	(7,177)	(6,888)	(6,549)	(7,322)	(7,657)	(7,995)
	$ / Calving Cow	**(364)**	**(359)**	**(344)**	**(327)**	**(366)**	**(383)**	**(400)**
	NR Change from Base ($)	-	95	385	724	(49)	(385)	(723)
	Change in NR from 1% Change in DMI ($)	**-**	**95**	**77**	**72**	**49**	**77**	**72**
	Change in NR from Base (%)	-	1	5	10	(1)	(5)	(10)
	Change in NR from 1% Change in DMI (%)	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Lime	NR ($)	(7,643)	(7,548)	(7,258)	(6,920)	(7,692)	(8,028)	(8,366)
	$ / Calving Cow	**(382)**	**(377)**	**(363)**	**(346)**	**(385)**	**(401)**	**(418)**
	NR Change from Base ($)	-	95	385	724	(49)	(385)	(723)
	Change in NR from 1% Change in DMI ($)	**-**	**95**	**77**	**72**	**49**	**77**	**72**
	Change in NR from Base (%)	-	1	5	9	(1)	(5)	(9)
	Change in NR from 1% Change in DMI (%)	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Low	NR ($)	(9,651)	(9,508)	(8,981)	(8,356)	(9,748)	(10,275)	(11,087)
	$ / Calving Cow	**(322)**	**(317)**	**(299)**	**(279)**	**(325)**	**(342)**	**(370)**
	NR Change from Base ($)	-	143	670	1,295	(97)	(624)	(1,435)
	Change in NR from 1% Change in DMI ($)	**-**	**143**	**134**	**130**	**97**	**125**	**144**
	Change in NR from Base (%)	-	1	7	13	(1)	(6)	(15)
	Change in NR from 1% Change in DMI (%)	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Medium	NR ($)	(8,518)	(8,374)	(7,702)	(6,839)	(8,709)	(9,428)	(10,525)
	$ / Calving Cow	**(213)**	**(209)**	**(193)**	**(171)**	**(218)**	**(236)**	**(263)**
	NR Change from Base ($)	-	145	816	1,680	(191)	(909)	(2,007)
	Change in NR from 1% Change in DMI ($)	**-**	**145**	**163**	**168**	**191**	**182**	**201**
	Change in NR from Base (%)	-	2	10	20	(2)	(11)	(24)
	Change in NR from 1% Change in DMI (%)	**-**	**2**	**2**	**2**	**2**	**2**	**2**
High	NR ($)	(13,485)	(13,245)	(12,382)	(11,514)	(13,678)	(14,588)	(15,595)
	$ / Calving Cow	**(281)**	**(276)**	**(258)**	**(240)**	**(285)**	**(304)**	**(325)**
	NR Change from Base ($)	-	239	1,103	1,971	(193)	(1,103)	(2,111)
	Change in NR from 1% Change in DMI ($)	**-**	**239**	**221**	**197**	**193**	**221**	**211**
	Change in NR from Base (%)	-	2	8	15	(1)	(8)	(16)
	Change in NR from 1% Change in DMI (%)	**-**	**2**	**2**	**1**	**1**	**2**	**2**

Appendix Table 4. Change in greenhouse gas emissions (GHG) for +/- 1%, 5%, or 10% change in dry matter intake requirements (DMI) in FORCAP by pasture fertilization strategy for *Large* farm size

Fertilizer Strategy		Baseline	% Change in Cow DMI Requirements from the Base Cow DMI Requirements -1	-5	-10	1	5	10
None	GHG (lbs)	489,522	485,632	470,074	450,624	493,411	508,967	528,409
	GHG / lb of Live-weight	**11**	**11**	**10**	**10**	**11**	**11**	**12**
	GHG Change in lbs	-	(3,889)	(19,447)	(38,898)	3,889	19,445	38,888
	GHG (lbs) from a 1% Change in DMI	**-**	**3,889**	**3,889**	**3,890**	**3,889**	**3,889**	**3,889**
	Change in GHG from Base (%)	-	(1)	(4)	(8)	1	4	8
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Lime	GHG (lbs)	538,430	534,541	518,983	499,532	542,319	557,875	577,318
	GHG / lb of Live-weight	**12**	**12**	**11**	**11**	**12**	**12**	**13**
	GHG Change in lbs	-	(3,889)	(19,447)	(38,898)	3,889	19,445	38,888
	GHG (lbs) from a 1% Change in DMI	**-**	**3,889**	**3,889**	**3,890**	**3,889**	**3,889**	**3,889**
	Change in GHG from Base (%)	-	(1)	(4)	(7)	1	4	7
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Low	GHG (lbs)	987,325	981,551	958,452	929,588	993,098	1,016,190	1,045,058
	GHG / lb of Live-weight	**13**	**13**	**13**	**12**	**13**	**14**	**14**
	GHG Change in lbs	-	(5,774)	(28,873)	(57,736)	5,773	28,866	57,734
	GHG (lbs) from a 1% Change in DMI	**-**	**5,774**	**5,775**	**5,774**	**5,773**	**5,773**	**5,773**
	Change in GHG from Base (%)	-	(1)	(3)	(6)	1	3	6
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Medium	GHG (lbs)	1,440,951	1,433,194	1,402,166	1,363,377	1,448,707	1,479,730	1,518,538
	GHG / lb of Live-weight	**14**	**14**	**14**	**14**	**14**	**15**	**15**
	GHG Change in lbs	-	(7,756)	(38,784)	(77,574)	7,756	38,780	77,588
	GHG (lbs) from a 1% Change in DMI	**-**	**7,756**	**7,757**	**7,757**	**7,756**	**7,756**	**7,759**
	Change in GHG from Base (%)	-	(1)	(3)	(5)	1	3	5
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
High	GHG (lbs)	2,030,607	2,021,302	1,984,084	1,937,596	2,039,912	2,077,119	2,123,611
	GHG / lb of Live-weight	**15**	**15**	**15**	**15**	**15**	**16**	**16**
	GHG Change in lbs	-	(9,305)	(46,523)	(93,011)	9,304	46,511	93,004
	GHG (lbs) from a 1% Change in DMI	**-**	**9,305**	**9,305**	**9,301**	**9,304**	**9,302**	**9,300**
	Change in GHG from Base (%)	-	(0)	(2)	(5)	0	2	5
	GHG (%) Change from 1% Change in DMI	**-**	**0**	**0**	**0**	**0**	**0**	**0**

Appendix Table 5. Change in greenhouse gas emissions (GHG) for +/- 1%, 5%, or 10% change in dry matter intake requirements (DMI) in FORCAP by pasture fertilization strategy for *Medium* farm size

Fertilizer Strategy		Baseline	% Change in Cow DMI Requirements from the Base Cow DMI Requirements -1	-5	-10	1	5	10
None	GHG (lbs)	200,356	198,813	192,645	184,933	201,898	208,065	215,775
	GHG / lb of Live-weight	**11**	**11**	**10**	**10**	**11**	**11**	**12**
	GHG Change in lbs	-	(1,542)	(7,711)	(15,423)	1,542	7,710	15,419
	GHG (lbs) from a 1% Change in DMI	**-**	**1,542**	**1,542**	**1,542**	**1,542**	**1,542**	**1,542**
	Change in GHG from Base (%)	-	(1)	(4)	(8)	1	4	8
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Lime	GHG (lbs)	219,919	218,377	212,208	204,496	221,461	227,629	235,338
	GHG / lb of Live-weight	**12**	**12**	**11**	**11**	**12**	**12**	**13**
	GHG Change in lbs	-	(1,542)	(7,711)	(15,423)	1,542	7,710	15,419
	GHG (lbs) from a 1% Change in DMI	**-**	**1,542**	**1,542**	**1,542**	**1,542**	**1,542**	**1,542**
	Change in GHG from Base (%)	-	(1)	(4)	(7)	1	4	7
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Low	GHG (lbs)	398,766	396,441	387,140	375,515	401,091	410,390	422,015
	GHG / lb of Live-weight	**14**	**14**	**14**	**14**	**15**	**15**	**15**
	GHG Change in lbs	-	(2,325)	(11,626)	(23,251)	2,325	11,624	23,250
	GHG (lbs) from a 1% Change in DMI	**-**	**2,325**	**2,325**	**2,325**	**2,325**	**2,325**	**2,325**
	Change in GHG from Base (%)	-	(1)	(3)	(6)	1	3	6
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Medium	GHG (lbs)	583,153	580,046	567,618	552,080	586,260	598,692	614,237
	GHG / lb of Live-weight	**16**	**15**	**15**	**15**	**16**	**16**	**16**
	GHG Change in lbs	-	(3,107)	(15,536)	(31,073)	3,107	15,538	31,083
	GHG (lbs) from a 1% Change in DMI	**-**	**3,107**	**3,107**	**3,107**	**3,107**	**3,108**	**3,108**
	Change in GHG from Base (%)	-	(1)	(3)	(5)	1	3	5
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
	GHG (lbs)	813,137	809,411	794,507	775,889	816,864	831,765	850,385
	GHG / lb of Live-weight	**18**	**18**	**18**	**18**	**18**	**19**	**19**
	GHG Change in lbs	-	(3,726)	(18,631)	(37,249)	3,726	18,628	37,247
	GHG (lbs) from a 1% Change in DMI	**-**	**3,726**	**3,726**	**3,725**	**3,726**	**3,726**	**3,725**
	Change in GHG from Base (%)	-	(0)	(2)	(5)	0	2	5
	GHG (%) Change from 1% Change in DMI	**-**	**0**	**0**	**0**	**0**	**0**	**0**

Appendix Table 6. Change in greenhouse gas emissions (GHG) for +/- 1%, 5%, or 10% change in dry matter intake requirements (DMI) in FORCAP by pasture fertilization strategy for *Small* farm size

Fertilizer Strategy		Baseline	% Change in Cow DMI Requirements from the Base Cow DMI Requirements -1	-5	-10	1	5	10
None	GHG (lbs)	140,056	139,020	134,878	129,699	141,092	145,234	150,411
	GHG / lb of Live-weight	**12**	**12**	**12**	**11**	**12**	**13**	**13**
	GHG Change in lbs	-	(1,036)	(5,178)	(10,357)	1,036	5,178	10,355
	GHG (lbs) from a 1% Change in DMI	**-**	**1,036**	**1,036**	**1,036**	**1,036**	**1,036**	**1,035**
	Change in GHG from Base (%)	-	(1)	(4)	(7)	1	4	7
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Lime	GHG (lbs)	153,098	152,063	147,920	142,741	154,134	158,276	163,453
	GHG / lb of Live-weight	**14**	**13**	**13**	**13**	**14**	**14**	**14**
	GHG Change in lbs	-	(1,036)	(5,178)	(10,357)	1,036	5,178	10,355
	GHG (lbs) from a 1% Change in DMI	**-**	**1,036**	**1,036**	**1,036**	**1,036**	**1,036**	**1,035**
	Change in GHG from Base (%)	-	(1)	(3)	(7)	1	3	7
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Low	GHG (lbs)	276,943	275,400	269,231	261,517	278,485	284,654	292,370
	GHG / lb of Live-weight	**15**	**15**	**15**	**14**	**15**	**15**	**16**
	GHG Change in lbs	-	(1,542)	(7,712)	(15,426)	1,542	7,711	15,428
	GHG (lbs) from a 1% Change in DMI	**-**	**1,542**	**1,542**	**1,543**	**1,542**	**1,542**	**1,543**
	Change in GHG from Base (%)	-	(1)	(3)	(6)	1	3	6
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
Medium	GHG (lbs)	394,951	392,902	384,707	374,461	397,000	405,196	415,447
	GHG / lb of Live-weight	**16**	**15**	**15**	**15**	**16**	**16**	**16**
	GHG Change in lbs	-	(2,049)	(10,245)	(20,491)	2,049	10,245	20,496
	GHG (lbs) from a 1% Change in DMI	**-**	**2,049**	**2,049**	**2,049**	**2,049**	**2,049**	**2,050**
	Change in GHG from Base (%)	-	(1)	(3)	(5)	1	3	5
	GHG (%) Change from 1% Change in DMI	**-**	**1**	**1**	**1**	**1**	**1**	**1**
High	GHG (lbs)	548,106	545,637	535,762	523,424	550,575	560,450	572,788
	GHG / lb of Live-weight	**19**	**19**	**18**	**18**	**19**	**19**	**20**
	GHG Change in lbs	-	(2,469)	(12,344)	(24,681)	2,469	12,344	24,682
	GHG (lbs) from a 1% Change in DMI	**-**	**2,469**	**2,469**	**2,468**	**2,469**	**2,469**	**2,468**
	Change in GHG from Base (%)	-	(0)	(2)	(5)	0	2	5
	GHG (%) Change from 1% Change in DMI	**-**	**0**	**0**	**0**	**0**	**0**	**0**

Change in Pasture Species Composition

A *Large* sized farm using a *Medium* fertilization strategy was selected to estimate sensitivity to changes in pasture species composition on NR and GHG emissions (Appendix Table 7). Species composition was changed +/- 1, 5, and 10 % for bermudagrass, fescue, and clover. Increasing the percentage of fescue and decreasing the percentage of clover in the pasture species composition by 5% and 10% from the base species composition (30% bermudagrass, 60% fescue, and 10% clover) increased NR by 14% and 29%, respectively. This is likely a function of greater fescue productivity when compared to clover under the *Medium* fertilizer application level (i.e. clover base production is surpassed by fescue base production plus N response). Again these results are specific to the parameters set forth above. If a lower fertilization level were chosen then a species composition containing more clover (to provide N fixation for use by other species) may have been more beneficial. Increasing the percent species composition in bermudagrass above the base decreased NR regardless of whether clover or fescue received the increase (species composition was required to add to 100%). This is likely a result of bermudagrass production occurring primarily in the mid-summer months when dry matter production was in excess of herd DMI requirements. Thus the forage would be largely unused and provide no benefit to NR (not that hay production on pastures was not implemented in these model runs). Increasing clover species composition 1%, in place of bermudagrass, increased NR. However, increasing clover species composition by 5% and 10% resulted in decreased NR. This suggests that a 10% clover species composition for the *Large* sized operation using a *Medium* fertilization strategy, while holding fescue species composition at 60%, may be close to the optimal clover species composition in the sense that extra N fixation with higher percentage of clover in the mix does not lead to overall enhanced seasonal forage production that the herd can use at specific times in the production cycle. The greatest NR for a *Large* operation using a *Medium* fertilization strategy was obtained with a 30-70-0 (bermudagrass-fescue-clover) species mix. Increasing fescue at the expense of clover led to the most profitable seasonal forage distribution due to increased fescue production (base plus N response) exceeding the benefit of clover production (base production) plus N fixation available to fescue and bermudagrass.

Appendix Table 7. Estimated change in net returns ($) and GHG emissions (lbs) for a *Large* farm using a *Medium* fertilization strategy from changing pasture species composition

Bermuda-Fescue-Clover	NR ($)	GHG (lbs)	Change NR (%)	Change in GHG (%)
Base 30-60-10	(7,081)	1,424,095	-	-
29-61-10	(6,796)	1,424,665	4	0.0
25-65-10	(8,400)	1,427,056	(19)	0.2
20-70-10	(9,861)	1,430,023	(39)	0.4
31-59-10	(7,413)	1,423,525	(5)	(0.0)
35-55-10	(8,647)	1,421,245	(22)	(0.2)
40-50-10	(10,119)	1,418,392	(43)	(0.4)
29-60-11	(6,986)	1,425,502	1	0.1
25-60-15	(9,209)	1,431,237	(30)	0.5
20-60-20	(11,857)	1,438,399	(67)	1.0
31-60-9	(7,176)	1,422,687	(1)	(0.1)
35-60-5	(7,601)	1,417,056	(7)	(0.5)
40-60-0	(8,028)	1,410,014	(13)	(1.0)
30-59-11	(7,318)	1,424,932	(3)	0.1
30-55-15	(8,126)	1,428,284	(15)	0.3
30-50-20	(9,125)	1,432,473	(29)	0.6
30-61-9	(6,890)	1,423,257	3	(0.1)
30-65-5	(6,082)	1,419,906	14	(0.3)
30-70-0	(5,037)	1,415,716	29	(0.6)

Change in Mature Cow Weight and Breeding Failures

Mature cow body weight (BW) and breeding failures (BF) were chosen as two herd parameters to estimate sensitivity in NR and GHG emissions. Appendix Table 8 shows the changes in NR and GHG emissions for a *Large* farm using a *Medium* pasture fertilization strategy by varying only mature cow BW. Body weight was increased or decreased in 100 lb increments. Increasing BW by 1% resulted in a 6.5 to 7.6% decrease in NR and a 0.7% increase in GHG emissions. Weaning weights and birth weights were held constant so caution needs to be taken in interpreting this sensitivity analysis (large cows, holding herd sire genetics constant, will most often produce calves with larger birth and weaning weights). Increasing BW increased DMI requirements and hence a decline in profitability occurred. Greenhouse gas emissions per lb of live-weight increased from 14.2 to 15.5 lbs of GHG emissions as BW increased from 1,250 to 1,550 lbs. A 1% decrease in BW resulted in a NR increase of 5.4 to 5.9%. GHG emissions also decreased with decreases in BW. This was to be expected as decreased DMI and energy intake would result in decreased emissions while holding calf birth weight and weaning weight constant. Overall a change in 1% of cow BW resulted in a 5.4 to 7.6% change in NR a 0.7% change in in GHG emissions, thus indicating that small changes in cow BW have a larger relative impact on NR than GHG emissions.

Appendix Table 8. Estimated change in net returns ($), GHG emissions (lbs), and GHG emissions per lb of live-weight sold for a *Large* farm using a *Medium* fertilization strategy from a change in mature cow BW (lbs)

Mature Cow BW (lbs)	NR ($)	GHG (lbs)	GHG lbs/ lb of Live Weight Sold	% Change in NR	% Change in GHG	% Change in NR for a 1% Change in BW	% Change in GHG Emissions from a 1% Change in BW
1,250	(7,081)	1,424,095	14.2	-	-	-	-
1,350	(10,746)	1,504,565	14.7	(52)	6	6.5	0.7
1,450	(15,350)	1,584,599	15.1	(117)	11	7.3	0.7
1,550	(19,969)	1,664,197	15.5	(182)	17	7.6	0.7
1,150	(3,742)	1,343,128	13.7	47	(6)	5.9	0.7
1,050	(477)	1,261,609	13.2	93	(11)	5.8	0.7
950	2,064	1,179,519	12.6	129	(17)	5.4	0.7

Appendix Table 9. Estimated change in net returns ($) and GHG emissions (lbs) for a *Large* farm using a *Medium* fertilization strategy from a change in breeding failures

Breeding Failures (%)	NR ($)	GHG (lbs)	% Change in NR from Baseline	% Change in GHG from Baseline	Change in NR for a 1% Increase in BF	Change in GHG Emissions from a 1% Increase in BF
14	(7,081)	1,424,095	-	-	-	-
13	(5,634)	1,425,968	20.4	(0.1)	0.2	0.0
9	(1,154)	1,431,587	83.7	(0.5)	0.9	0.0
4	3,280	1,437,207	146.3	(0.9)	1.5	0.0
15	(8,563)	1,422,144	(20.9)	0.1	0.2	0.0
19	(9,549)	1,385,498	(34.9)	2.7	0.4	0.0
24	(15,362)	1,377,283	(116.9)	3.3	1.5	0.0

Increasing or decreasing breeding failures by 1% resulted in a 0.2 to 1.5% change in NR and a less than 0.1% change in GHG emissions (Appendix Table 9). Increased breeding failures reduce the number of calves produced on the operation on an annual basis. Additionally, greater numbers of culled cows would occur as open cows are assumed to be culled in FORCAP. This increase in culled cows would have partially offsetting NR implications. Culled cow sales would increase revenue however, heifer calves would need to be retained or replacements purchased increasing costs. Greenhouse gas emission changes were relatively small (less than 0.1%). Greater GHG emissions were reported for lower breeding failures and decreased GHG emissions for higher breeding failures. Lower BF would result in greater number of calves on the farm and thus higher animal emissions; this would partially be offset by the reduction in emissions realized by the weight difference between culled cows and replacement breeding stock.

Change in Pasture Base Production

Base production for each forage species (bermudagrass – 3,000; fescue – 2,800; and clover – 3,000) was changed by + / - 5% to determine the impact on NR for all three farm sizes and four fertilization strategies (Appendix Table 10). Changes in NR are shown as percentage change from the baseline in dollars per farm. Increasing base production levels for each species increased NR from 0 to 177%. Similar to the changes observed with the DMI requirements, as reported above, the greater percentage increases for the farm level analysis are a function of numerically smaller baseline NR values for the *Large* farm sizes. Changing fescue base production increased or decreased NR for all scenarios by a greater percentage than changing clover or bermudagrass base production. Fescue was assumed to comprise the largest portion of pasture area and as such a greater impact on NR was anticipated. Additionally, fescue production occurs during periods when clover (fall only) and bermudagrass are dormant thus, increasing the value of production from a timing standpoint (ie hay would not have to be purchased at key times in the fall or spring). As such, users should be cognizant of the timing of forage production (percentage of base production in each month) for each species in the forage balance section of FORCAP as this will have an impact on overall profitability. It is important to note that, changing fertilizer strategy would undoubtedly have an impact on the relative changes in base production for each species.

Appendix Table 10. Estimated change in net returns ($) for *Large*, *Medium*, and *Small* farms using *Lime*, *Low*, *Medium*, and *High* fertilization strategies for a +/- 5% change in bermudagrass, fescue, and clover base production

Size	Fertilizer Strategy	Baseline NR ($)	Number of Cows	% Change in NR from 5% Change in Species Base Production					
				B+5	B-5	F+5	F-5	C+5	C-5
Large	*Lime*	526	75	58	(58)	177	(178)	22	(22)
	Low	(4,829)	112	18	(18)	19	(18)	4	(3)
	Medium	(7,081)	150	5	(6)	19	(19)	3	(3)
	High	(25,005)	180	2	(2)	5	(5)	1	(1)
Medium	*Lime*	(8,550)	30	1	(1)	4	(4)	0	(0)
	Low	(8,617)	45	4	(4)	4	(4)	1	(1)
	Medium	(11,194)	60	1	(2)	5	(5)	1	(1)
	High	(17,823)	72	1	(2)	3	(3)	1	(1)
Small	*Lime*	(7,643)	20	1	(1)	2	(2)	0	(0)
	Low	(9,651)	30	2	(1)	1	(1)	0	0
	Medium	(8,518)	40	0	(0)	2	(3)	0	(1)
	High	(13,485)	48	1	(0)	1	(1)	1	(0)

Summary of Sensitivity Analyses

FORCAP provides GHG and NR estimates using default parameters or user-entered variables. As shown in this appendix, changing default parameters or variables can have a dramatic impact on estimated NR and GHG emissions. As such, it is important for users to enter the most accurate information available to them and be aware that NR and GHG emission estimates can vary substantially based on what has been selected or entered. By changing one variable or parameter at a time relative comparisons between GHG emissions and NR can be conducted.

Additionally, FORCAP allows for comparisons among user-entered inputs. When making these types of comparisons potential parameter specification errors take on a lesser role as the same default parameter values would be used across user-specified variables (i.e. DMI intake values are the same whether the user chooses spring-, fall- or year-round-calving, alternative weaning weights, etc.).