A Comparison of Profitability and Economic Efficiencies Between Management-Intensive Grazing and Conventionally Managed Dairies in Michigan

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ABSTRACT

A retrospective cohort study was designed to determine differences in profitability, asset efficiency, operating efficiency, and labor efficiency between Michigan dairy farms implementing management-intensive grazing (MIG) and conventionally managed dairy farms. Financial information and labor use data for the calendar year 1994 were collected with surveys and personal interviews from 35 MIG dairies and 18 conventionally managed dairies. Because the geographic distribution of MIG and conventionally managed farms in this study did not include Michigan's "dairy belt," extrapolation of these results to an average Michigan or Midwest dairy should be made with care. Within the areas represented, however, multivariate linear regression indicated that MIG dairies had more economic profit than conventionally managed dairies. They captured this profit by being more efficient in asset use, operating practices, and labor use. These results suggest that MIG could provide a sustainable alternate management tool for portions of Michigan's dairy industry.
(**Key words:** management-intensive grazing, net farm income, operating efficiency, asset efficiency)

Abbreviation key: ATO = asset turnover, **MIG** = management-intensive grazing, **NFI%** = net farm income percent, **aNFI** = accounting net farm income per cow, **eNFI** = economic net farm income per cow, **VFP** = value of farm production per labor hour.

INTRODUCTION

Structural change has occurred within Michigan's dairy industry. The number of operating dairy farms has decreased (13) and herd size and milk production per cow on remaining dairy farms have increased (2, 10). Factors including high debt-to-asset ratios (2, 10) and a reluctance to take on additional debt (1) indicate that a large proportion of Michigan's dairy industry could be in a measure of financial difficulty. Common survival methods in the face of unstable milk markets have been to increase outputs by increasing herd size and increasing milk production per cow. However, the financial uncertainty characterizing many Michigan dairy farms rules out expansion as a method of remaining competitive for a substantial part of the industry (10). Strategies such as management-intensive grazing (**MIG**) are being explored as competitive dairy management alternatives.

Descriptive studies have shown that moderately sized farms (80 to 100 cows) can remain competitive when they reduce net feed and crop expenses, labor expenses, and machinery costs (3, 11, 16). Although MIG has been reported to reduce these costs, milk production per cow often declines concurrently (5,16). Despite lower milk yields, the accompanying lower costs can yield a comparable or even higher net income per cow than conventional drylot or continuous pasture systems (5, 11, 15). One of the few studies that compared a stratified random sample of grazing and nongrazing farms (9) found that grazing farms produced significantly less milk per cow than did the comparison group. However, no significant difference in net income per cow was found between groups.

These previous studies have generally used an accounting measure of profit through calculation of net farm income per cow or per hundredweight. Accounting profit was defined as a return to the producer's labor, management, and assets. Accounting profits are an important first step in the determination of farm level profitability. However, they fail to recognize opportunity costs. Family labor is generally an integral input and ought to be valued. Presumably, these "employees" could be working elsewhere for a wage. Also, the substantial dollar value usually represented by farm equity

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could be invested elsewhere in profit generating enterprises. By charging for both family labor and equity invested, an economic measure of profit more objectively measures the profitability of a farm business. In addition, economic profit is probably a better measure of the sustainability of a dairy. Although a high accounting profit may make a business appear to be quite healthy in the short term, these returns may be generated with unacceptably high levels of contributed labor or capital. Economic profit will capture these inconsistencies.

Dairies can increase profit or reduce resource use while maintaining profits by capturing one or more economic efficiencies. If MIG dairies are more profitable, identification of the particular efficiencies that contribute to profitability could provide important suggestions for more effective farm management practices in the face of constrained resources.

The goal of this project was to examine MIG as a low-input alternative management strategy that would assist the average-sized dairy farm in Michigan (85 cows) in development of a financially stable, competitive, sustainable farm business. Specifically, this paper will examine the accounting and economic profit, capital efficiency, operating efficiency, and labor efficiency of MIG and conventionally managed dairy farms matched on herd size and Michigan region.

MATERIALS AND METHODS

Study Design

A retrospective cohort study was designed to determine differences in profitability and economic efficiencies between MIG and conventionally managed Michigan dairies. Potential MIG farms were identified with 1993 and 1994 Michigan Grazing Conference mailing lists cross-referenced with the 1995 Michigan Department of Agriculture list of Grade-A dairies. Of the studies' MIG herds, a small number were identified by word-of-mouth from cooperating producers, Extension agents, and veterinarians. Producers were then contacted by letter and phone to solicit their voluntary participation in the project and to ensure they fit the MIG herd definition. A MIG herd was defined as obtaining at least 25% of the annual whole herd forage requirement through grazing. Cows must have been grazed or pastured at least 4 mo per year and lactating cattle rotated or changed to new pastures every 3rd d or less. In addition, 1994 had to be at least the 2nd yr the MIG farm fit this definition.

Matches by herd size (five categories) and Michigan Department of Agriculture geographical distribution (nine regions) were made. Herd size strata were: 0 to 39 cows, 40 to 79 cows, 80 to 119 cows, 120 to 249 cows, and 250+ cows. Matching was employed to control for different herd sizes, growing season lengths, and soil types that could, if correlated with the variable of interest, *graze*, confound the estimation of the graze effect.

Conventionally managed dairies were identified by a mailing to the 1184 Grade-A dairies in the counties where MIG farms were located. The mailing included a letter asking for voluntary participation in the project and a self-addressed, stamped reply card on which producers could indicate their willingness to participate, as well as their herd size (one of five categories). Volunteers were matched to a MIG herd. If more than one potential match existed, a single match was randomly selected. Selected producers were telephoned to ensure they met the definition of a conventionally managed farm. A conventionally managed farm was defined as one that utilized at least 95% of its whole herd forage requirement from mechanically harvested forages. In addition, MIG and conventionally managed farms were excluded if more than 10% of their revenue came from sources other than milk or dairy-related livestock sales, if they were increasing their cow herd by greater than 10%, if they were purchasing more than 60% of their forage, or if they were undergoing substantial structural or management change during 1994.

Data Collection

The data collected by this study represent the 1994 calendar year. A preliminary data collection packet was mailed to producers prior to a farm visit. All participating farms were subsequently visited by one of two investigators who collected data. Financial data collected included 1994 beginning and ending inventories of cattle and feed, as well as the value of assets for farm production including land, equipment, and livestock facilities. Market values, as estimated by each producer, were used for all inventories and assets. Farm income and expenses and labor use data, detailed both by laborer and job type, were also collected.

Model Building

For this study, both accounting (**aNFI**) and economic profit (**eNFI**) were modeled as a modified profit function (6) dependent on inputs that included land, labor, capital, and purchased feed expense, and the outputs of milk per cow, total livestock revenue, and other revenue. The stated hypotheses indicate an a priori assumption that financial performance also depends on whether a producer practices MIG.

The various efficiencies were assumed to depend on the same explanatory variables as profitability and were modeled similarly. This work chose to measure three key areas of economic efficiency: capital efficiency (asset turnover; **ATO**), operating efficiency (net farm income percent, **NFI%**), and labor efficiency (value of farm production per labor hour, **VFP**). The definitions of financial indicators employed in this study closely follow those advocated by the Farm Financial Standards Council (4) and are as follows:

Revenue = Gross farm income from milk sales, cattle and crop sales, and government payments;
Expenses = Cash and noncash farm costs, including depreciation calculated for tax purposes;
aNFI = (revenue − expenses + interest expense + inventory changes) ÷ average herd size;
eNFI = ((revenue − expenses) + interest expense + inventory changes − ($7 * unpaid labor hours) − (0.04 * average farm assets)) ÷ average herd size;
ATO = (revenue − purchased feed costs + inventory changes) ÷ average total assets;
NFI% = accounting net farm income ÷ total revenue;
VFP = (revenue − purchased feed costs + inventory changes) ÷ (paid + unpaid labor hours).

To allow comparison with previous work, this study measured both accounting and economic profit through calculation of net farm income per cow. Net farm income per cow was used rather than net farm income because it allowed each farm to be compared on the basis of an individual production unit.

The accounting definition of profit used is similar to the way returns have been measured in most previous studies. By not placing an arbitrary dollar amount on the unpaid labor contribution, accounting profit helps equalize different standards of living. The measure also avoids penalizing dairies with a high debt structure by adding back interest expense.

The economic measure of profit included the opportunity costs of operator labor and capital. This study charged for family labor at slightly higher than minimum wage ($7 per hour). Other Michigan work (14) has used a similar per hour charge for unpaid operator and family labor contributions.

A charge of 4% on farm assets was utilized to capture the opportunity cost of invested capital. To avoid penalizing farms with a higher debt structure, the charge was made on the value of assets rather than equity. Four percent was derived by approximation of the inflation-adjusted average 1994 return to 30-yr United States Treasury bonds (18).

Asset turnover was chosen as the measure of capital efficiency. A higher value implies better efficiency, indicating that the farm is generating more revenue per dollar of assets. Asset turnover was chosen instead of return on assets because return on assets, by definition, must include a subjective valuation of contributed labor and management. Net farm income percent was chosen as the measure of operating efficiency. Again, a higher value indicates better efficiency and shows that the farm is generating more net income per dollar of farm production and that costs per unit of value of farm production are lower. Net farm income percent utilized accounting profit because it is customarily used by farm management analysts. Finally, value of farm production per labor hour was chosen as the measure of labor efficiency. Hundredweight per worker is another common measure of dairy labor efficiency. Some dairies used in this study operated additional, although limited, alternative enterprises that contributed to farm revenue. Using the value of farm production rather than hundredweight per worker allows a fairer comparison of farms that purchase or grow different proportions of their feed.

Analysis

To begin, univariate statistics, including means and standard deviations, were calculated for independent, dependent, and other descriptive variables of interest for both MIG and conventionally managed herds. The mean of each variable for the two distributions was then compared by Student's *t*-test. Results were considered significant at the $P < 0.05$ level.

Multivariate linear regression models using a log-log functional form were then constructed and analyzed by ordinary least squares in STATA 5.0 (17). These models were tested for the presence of heteroscedasticity. When necessary, variance estimators developed by White (19), which are robust to heteroscedasticity, were used. All explanatory variables, except *graze*, were divided by average herd size to place them on a per cow basis. Regression analysis was carried out with the following five models to measure accounting profit, economic profit, capital efficiency, operating efficiency and labor efficiency, respectively:

$$\text{aNFI} = \beta_{01} + \beta_{11}\,graze + \beta_{21}\,assets + \beta_{31}\,acres + \beta_{41}\,unpdlab + \beta_{51}\,pdlab + \beta_{61}\,purchfd + \beta_{71}\,milk + \beta_{81}\,lvstckrev + \beta_{91}\,othrev + e_1$$

$$\text{eNFI} = \beta_{02} + \beta_{12}\,graze + \beta_{22}\,assets + \beta_{32}\,acres + \beta_{42}\,unpdlab + \beta_{52}\,pdlab + \beta_{62}\,purchfd + \beta_{72}\,milk + \beta_{82}\,lvstckrev + \beta_{92}\,othrev + e_2$$

$$\text{ATO} = \beta_{03} + \beta_{13}\,graze + \beta_{23}\,acres + \beta_{33}\,unpdlab + \beta_{43}\,pdlab + \beta_{53}\,purchfd + \beta_{63}\,milk + \beta_{73}\,lvstckrev + \beta_{83}\,othrev + e_3$$

$$\text{NFI\%} = \beta_{04} + \beta_{14}\,graze + \beta_{24}\,assets + \beta_{34}\,acres + \beta_{44}\,unpdlab + \beta_{54}\,pdlab + \beta_{64}\,purchfd + \beta_{74}\,milk + \beta_{84}\,lvstckrev + \beta_{94}\,othrev + e_4$$

$$\text{VFP} = \beta_{05} + \beta_{15}\,graze + \beta_{25}\,assets + \beta_{35}\,acres + \beta_{45}\,purchfd + \beta_{55}\,milk + \beta_{65}\,lvstckrev + \beta_{75}\,othrev + e_5$$

where

graze = a binary dummy variable with a MIG farm = 1 and a conventionally managed farm = 0;
assets = average farm assets;
acres = sum of farm-owned and rented acres;
unpdlab = total contributed family labor hours;
pdlab = total hired labor hours;
purchfd = total purchased feed expense;
milk = total milk sold;
lvstckrev = revenue from all livestock sales;
othrev = revenue from all other farm sources;
β_{ij} = regression parameter i in equation j;
e_j = stochastic error term in equation j.

To more accurately model dairy farms, inputs were disaggregated from the simple capital and labor inputs found in a traditional profit function. Because the effect of acres on profitability or efficiency may not be captured by asset value as measured in dollars, both total asset value in dollars and total acres were included as separate independent variables. The number of unpaid and paid labor hours were included as separate independent variables because increasing hours of one or the other were expected to have opposite effects on profitability and efficiency. Finally, purchased feed was included because it represents a substantial portion of farm expense and was expected to be correlated with *graze*. When explanatory variables are omitted, the result is that their effects are included in the error term. If these omitted variables are correlated with any of the explanatory variables in the model, the parameter estimates of those variables will be biased because of omitted variable bias (7).

Following the general structure of the profit function, three measures of output—milk per cow, total livestock-revenue, and other farm revenue—were also included in the models. Milk per cow was used rather than milk income, because the milk price received was often unavailable. Total livestock revenue and other revenue were both included because of a priori expectations that they could be important in explaining profitability.

Interpreting the coefficient on the *graze* variable included in the previous five models would allow an intercept-shifting difference to be detected. However, it is possible that the profitability and efficiency on MIG and conventionally managed farms were explained by differing slopes as well. To detect slope differences, interaction terms were created between *graze* and each of the other explanatory variables present in the five models. These terms were added, one at a time, to each model. If an interaction term was found to be significant at $P \le 0.15$ when included in a model individually, this interaction term was used in the final profitability or efficiency model. Ideally, all interaction terms would be added to a regression simultaneously. However, the relatively low number of degrees of freedom necessitated adding interaction terms individually.

Finally, external validity was reviewed to ensure that the "No" and "Yes" respondents to the mailing designed to recruit conventionally managed farms did not differ significantly by region or herd size. The review was completed through chi-square analyses of response ("No" or "Yes") by herd size, region, and herd size within region.

RESULTS

Univariate Analysis

Ninety-seven of the 1184 Grade-A dairies (8%) contacted by mail volunteered to participate in the study. Of the respondents who did volunteer to participate, only 24 matched a MIG farm and agreed to participate after a follow-up phone call. Three MIG and six conventionally managed farms were subsequently excluded from the data set for not meeting stated definitions, leaving 35 MIG farms and 18 conventionally managed farms for analysis. Twelve of the 18 conventional herds were matched successfully to MIG herds on both region and herd size. Five were matched to MIG herds on herd size alone. Each of these pairs were in neighboring regions and were not more than three counties apart. One pair was matched only on region, but had a similar herd size. Figure 1 shows the Michigan counties in which participating MIG and conventionally managed farms were located.

Mean and standard deviation calculations for dependent and independent variables, as well as other variables of interest, are reported in Table 1. As measured by Student's *t*-test, significant differences between MIG and conventionally managed dairies were found only in the total livestock revenue per cow and nondairy livestock revenue per cow. When we examined the external validity of the response to the recruitment mailing to conventionally managed dairies, chi-square analysis indicated no difference between "No" and "Yes"

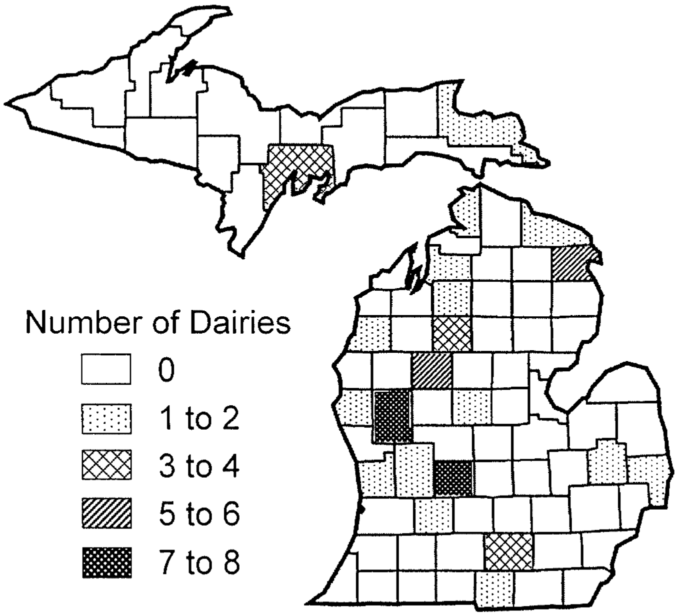

Figure 1. Location of MIG and conventionally managed dairies participating in study by Michigan county, 1994.

respondents by herd size, region, or herd size within region.

Multivariate Regression Analysis

Because of the detection of significant heteroscedasticity, variance estimators robust to heteroscedasticity (19) were used for all five models. The results of the aNFI, eNFI, ATO, NFI%, and VFP regressions are shown in Table 2. The F-tests indicate that all five models explained a significant amount of variation in the dependent variable. The positive sign on the *graze* parameter estimate in each model indicated that MIG was associated with increased profitability and efficiencies. The remaining explanatory variables had expected signs and magnitudes.

The aNFI model indicated that no significant difference in accounting profit existed between MIG and conventionally managed dairies. No interactions between *graze* and the other explanatory variables were found to have a significant impact on accounting profit. However, the eNFI model found that graziers tended (P = 0.058) to generate more economic profit than conventionally managed farmers. In addition, two interaction terms, *graze*lvstckrev* and *graze*othrev*, were found to be slope shifters. These interaction terms implied that the impacts of *lvstckrev* and *othrev* on eNFI may have been different on MIG and conventionally managed dairies. In this case, neither of these variables or the interaction terms were significant.

The magnitudes of the coefficients on *graze* and the interaction terms must be interpreted with care because of the binary nature of *graze* and because the dependent variable is natural logarithm transformed. The full effect of MIG on eNFI was captured by adding the coefficient of each interaction term multiplied by the MIG mean of the appropriate continuous variable to the coefficient of graze. Performing this calculation

TABLE 1. Means and standard deviations of selected variables of interest for conventionally managed and management intensive grazing Michigan dairy farms, 1994.[1]

	MIG (n = 35)		Convention (n = 18)	
Variable	Mean	SD	Mean	SD
aNFI ($)	429	381	412	466
eNFI ($)	(450)	503	(512)	646
ATO (%)	31	11	28	9
NFI% (%)	19	16	16	17
VFP ($)	18.07	8.31	19.10	12.64
Assets per cow ($)	6495	3513	6479	1827
Acres per cow	5.9	3.3	5.2	2.3
Unpaid labor per cow (hr)	89.0	50.9	95.0	62.1
Paid labor per cow (hr)	19.2	21.9	24.9	34.5
Purchased feed cost per cow ($)	528	304	482	239
Milk per cow (lb)	13,992	3974	15,090	4241
Total livestock revenue per cow ($)	262[a]	170	173[b]	140
Other revenue per cow ($)	122	116	88	94
Nondairy livestock revenue per cow ($)	44.1[a]	95.2	1.3[b]	5.6
Total assets ($)	414,259	232,899	502,207	287,839
Vet and medicine cost per cow ($)	50.2	34.2	64.6	41.1
Herd size	70.1	38.3	80.2	45.3

[a,b]Significantly different at $P < 0.05$ using Student's *t*-test.

[1]aNFI = Accounting net farm income, eNFI = economic net farm income, ATO = asset turnover, NFI% = net farm income percent, and VFP = value of farm production per labor hour.

TABLE 2. Results of regression of explanatory variables on aNFI, eNFI, ATO, NFI%, and VFP for conventionally managed and MIG Michigan dairy farms, 1994.[1]

Dependent variable	Explanatory variable[2]	b_i	SE[3]	p value	Regression statistics	
aNFI	*graze*	0.356	0.278	0.21	R^2	0.364
	assets	0.182	0.392	0.65	Prob > F	0.012
	acres	–0.718	0.434	0.11		
	unpdlab	0.884	0.560	0.12		
	pdlab	0.119	0.082	0.15		
	purchfd	–0.436	0.160	0.01		
	milk	2.248	0.662	<0.01		
	lvstckrev	0.083	0.098	0.40		
	othrev	–0.184	0.098	0.07		
	Intercept	–17.135	6.964	0.02		
eNFI	*graze*	1.459	0.745	0.06	R^2	0.550
	*graze*lvstckrev*	–0.104	0.128	0.42	Prob > F	0.002
	*graze*othrev*	–0.205	0.178	0.26		
	assets	–0.083	0.132	0.53		
	acres	–0.220	0.112	0.06		
	unpdlab	–0.398	0.204	0.06		
	pdlab	0.014	0.039	0.71		
	purchfd	–0.107	0.088	0.23		
	milk	0.458	0.236	0.06		
	lvstckrev	0.131	0.116	0.27		
	othrev	0.150	0.181	0.41		
	Intercept	5.106	1.963	0.01		
ATO	*graze*	0.259	0.132	0.06	R^2	0.295
	*graze*pdlab*	–0.073	0.044	0.11	Prob > F	<0.001
	acres	–0.157	0.110	0.16		
	unpdlab	–0.097	0.076	0.21		
	pdlab	0.018	0.031	0.56		
	purchfd	–0.151	0.055	0.79		
	milk	0.541	0.204	0.01		
	lvstckrev	0.017	0.057	0.77		
	othrev	0.008	0.036	0.82		
	Intercept	–5.897	1.726	<0.01		
NFI%	*graze*	1.759	0.821	0.04	R^2	0.333
	*graze*lvstckrev*	–0.219	0.163	0.19	Prob > F	0.053
	*graze*othrev*	–0.096	0.136	0.48		
	assets	0.269	0.305	0.38		
	acres	–0.356	0.221	0.12		
	unpdlab	0.190	0.231	0.42		
	pdlab	0.032	0.060	0.59		
	purchfd	–0.290	0.160	0.08		
	milk	1.301	0.562	0.03		
	lvstckrev	0.229	0.139	0.11		
	othrev	–0.128	0.089	0.16		
	Intercept	–15.488	5.472	<0.01		
VFP	*graze*	10.472	3.899	0.01	R^2	0.603
	*graze*acres*	0.576	0.278	0.04	Prob > F	<0.001
	*graze*purchfd*	0.040	0.157	0.80		
	*graze*milk*	–1.195	0.482	0.02		
	assets	0.036	0.156	0.82		
	acres	–0.788	0.233	<0.01		
	purchfd	–0.369	0.082	<0.01		
	milk	2.028	0.314	<0.01		
	lvstckrev	0.115	0.036	<0.01		
	othrev	0.006	0.031	0.85		
	Intercept	–14.172	3.312	<0.01		

[1]aNFI = accounting net farm income, eNFI = economic net farm income, ATO = asset turnover, NFI% = net farm income percent, and VFP = value of farm production per labor hour.

[2]Except for *graze*, all explanatory variables are on a per-cow basis and natural logarithm transformed.

[3]Standard errors are robust to serial correlation and heteroscedasticity.

and then applying the method described by Halvorsen and Palmquist (8) for interpretation of binary explanatory variables with regard to natural logarithmically transformed dependent variables indicated that MIG dairies tended to have 7% higher economic profit than conventionally managed dairies.

Interpretation of the *graze* variable in the ATO model indicated that MIG dairies tended ($P = 0.057$) to be more capital efficient than conventionally managed dairies. One interaction term was included, *graze*pdlab*, which indicated that the relationship between *pdlab* and asset efficiency was different on MIG dairies and conventionally managed dairies. However, neither *pdlab* nor *graze*pdlab* were found to be significant. Applying the method described above indicates that MIG dairies tended to be 11% more asset efficient than conventionally managed dairies.

The NFI% model showed that MIG dairies had significantly higher operating efficiency. The two interaction terms, *graze*lvstckrev* and *graze*othrev*, both had negative signs. However, neither *lvstckrev*, *othrev*, nor the interaction terms were significant. The MIG dairies appeared to have a 26% higher net farm income percent than conventionally managed dairies.

Again applying the above methods to the VFP model indicated that MIG dairies were 32% more labor efficient than were conventionally managed dairies. Two of the three interaction terms, *graze*acres* and *graze*milk*, were significant. The parameter estimates *acres*, *purchfd*, and *milk* were also significant. The signs on *acres* and *purchfd* were both negative, indicating that when these inputs increased, labor efficiency decreased on conventionally managed dairies. The positive sign on *milk* indicated that higher milk production on conventionally managed farms was related to increased labor efficiency. Summing the coefficients on the interaction terms with the appropriate parameter estimates yielded the impact of these variables on labor efficiency for MIG dairies. It appeared that, similar to their effect on the conventionally managed farms, increased purchased feed cost and increased acres were both related to decreased labor efficiency on MIG dairies. Higher milk production was associated with higher labor efficiency on MIG dairies, although to a smaller degree than on conventionally managed farms.

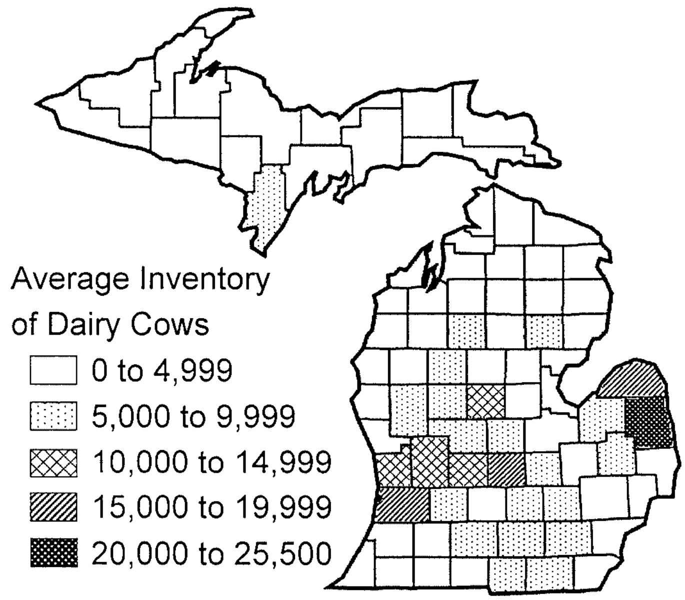

Figure 2. Average inventory of dairy cows by Michigan county, 1994, Michigan Agricultural Statistics Service.

DISCUSSION

Univariate Analysis

The univariate results presented in Table 1 revealed interesting characteristics of this study population. Milk production for MIG farms was similar to that of conventionally managed farms. This milk production level is consistent with previous descriptive work (5, 16). In addition, average milk production per cow for the study population as a whole (14,365 ± 4060, ± SD) was similar to the 1994 state average of 16,905 lb (12).

The sample obtained for this study was well dispersed throughout Michigan; however, it did not represent the state's "dairy belt" geographically. This band of counties across the central to southern portion of Michigan's lower peninsula is characterized by flat, well-drained ground that is moderately to highly productive for row crops and forages. In 1994, approximately 53% of Michigan's dairy cows were located within this belt (Figure 2), but only about 30% of the cows in this study were located here. Most MIG dairies were located in areas of marginal to poor soil that favor forage growth over grain production. Because conventionally managed dairies were matched to MIG dairies on region, they, too, were located out of Michigan's dairy belt.

Univariate analysis showed that MIG dairies in this study had similar asset values per cow and acres per cow as conventionally managed dairies. Although MIG is generally considered a "low-input" system, these descriptive results are consistent with those found in other studies (3, 4). Management intensively grazed dairies had significantly more livestock revenue per cow than did conventionally managed dairies. Although both management types tended to generate similar revenues through sales of cull cows, calves, and heifers, MIG dairies generated significantly more revenue than conventionally managed dairies through sales of other livestock, including beef cattle, pigs, chickens, and dairy steers. Despite excluding both MIG and conventionally managed farms that generated greater than 10% of their revenue from cropping enterprises or non-dairy livestock sales from the study, we found that MIG dairies still exhibited greater diversity in revenue sources.

This study found no difference in veterinary and medicine costs or purchased feed costs between MIG and conventionally managed dairies. Previous descriptive studies (11, 16) found that an important part of cost savings on MIG dairies was through decreased feed expense. The magnitude of purchased feed cost found in this study was similar to that found previously (16). Because individual farms purchased differing proportions of their total feed requirements, it is not surprising that MIG and conventionally managed dairies had similar purchased feed costs.

Multivariate Regression Analysis

The results from the two profitability models, aNFI and eNFI, seemed at first somewhat conflicting. However, the economic net income measure, by charging for unpaid family labor and farm assets, captured the labor and asset efficiencies exhibited by MIG dairies. This allowed for the tendency for MIG dairies to be more economically profitable than conventionally managed farms. If eNFI is considered a more accurate long-term measure of profitability, the difference found in the eNFI model, but not in the aNFI model indicated that MIG dairies were somewhat more sustainable than were the conventionally managed farms in this study. Considering that the mean eNFI for both farm types were substantially negative, however, it could be questioned whether having a slightly less negative profitability measure made MIG dairies more sustainable in a practical sense.

Higher capital efficiency indicated that MIG farms generated significantly more farm production per dollar of assets than did conventionally managed farms. The 11% increase in this efficiency, though small, was consequential. An increased asset efficiency of 11% for conventionally managed farms, holding all else constant, would bring up their 28% mean ATO to the level of the MIG farms' at 31%. It should be noted that the mean ATOs found in this study are consistent with that of 29% found for Michigan dairies with a herd size of 40 to 79 cows in 1991 (10). Increased asset efficiency has been among anecdotal claims for MIG dairying through decreased machinery needed to harvest and store feeds and handle manure.

The NFI% model indicated that MIG dairies had both significantly and practically higher operating efficiency. The 26% higher NFI% for MIG dairies indicated by the model implies that, holding all else constant, the mean NFI% of 16% for the conventionally managed dairies would increase to about 20% if they practiced MIG. Cost containment has been found in many descriptive studies as the primary method by which graziers obtained higher profit than conventionally managed farms. The operating efficiency exhibited by graziers in this work, although a broader measure than cost efficiency, seemed to support this contention.

Results of the VFP model suggest that labor efficiency was 32% higher for MIG dairies than for conventionally managed dairies. This result is both significant and practical. The result also points out a difference that was not found in univariate analysis. In fact, if examining the data in Table 1 as the sole source of information, one could assume that conventionally managed dairies had similar levels of labor efficiency. These regression results indicate that, if sufficient data are available, researchers must move beyond descriptive and univariate analysis to ensure that they gain a clear understanding of the systems they are studying.

Two of the three interaction terms appropriate in the VFP model, *graze*acres* and *graze*milk* were significant, although the third, *graze*purchfd*, was not. The three related explanatory variables, *acres, purchfd*, and *milk* were also significant. The negative signs on *acres* and *purchfd* and on the sums of *acres* and *graze*acres*, and *purchfd* and *graze*purchfd*, indicate that on both MIG and conventionally managed farms, increased acres or increased purchased feed costs are related to decreased labor efficiency. The slopes are slightly different, indicating that increased inputs on MIG dairies were related to slightly smaller decreases in labor efficiency. That increased acres would suggest decreased labor efficiency indicated that farms in this sample with lower acres per cow were more labor efficient. Increased purchased feed cost, while holding all else, especially milk production, constant, would lead to a decreased value of farm production. This would, in turn, lead to a smaller value for VFP. Finally, it is worth noting that despite the increased diversity of the MIG operations, as represented by the significantly higher livestock revenue, they still obtained a significantly higher labor efficiency.

The positive signs on *milk* and the sum *milk* and *graze*milk* implied that as MIG and conventionally managed dairies increased milk production per cow, labor efficiency increased. However, the increased efficiency on MIG farms was a little less than half as much as the gain on conventionally managed farms. The results in this study suggest that methods necessary to increase milk production require more labor on MIG dairies than on conventionally managed dairies. The labor efficiency found in this work supports many anecdotal claims that MIG is a labor-saving technology.

As stated above, firm profitability is generally increased by capturing one or more efficiencies. The results found in this study appeared to support this idea as MIG farms tended to have higher economic profit and asset efficiency and were significantly more operating and labor efficient. Measurement of both economic and simple accounting profit was key in explaining the relationship between profit and efficiency.

CONCLUSIONS

In univariate analysis, little difference was found between Michigan MIG and conventionally managed dairy farms in their profitability and efficiency. However, multivariate regression results indicated that MIG farms tended to have higher economic profit and higher capital efficiency and were significantly more operating and labor efficient. The profitability and efficiency results from this study support several previous descriptive papers characterizing differences in financial performance between MIG and conventionally managed dairies. Because the geographic distribution of MIG and conventionally managed farms in this study did not include the main Michigan "dairy belt," extrapolation of these results to an average Michigan or Midwest dairy would be tenuous at best. Regardless, these results suggest that management-intensive grazing could provide a sustainable alternative management tool for portions of Michigan's dairy industry.

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