COMPARISON OF FARM MANAGEMENT PRACTICES ON CONVENTIONAL, GRAZING AND ORGANIC DAIRY FARMS IN WISCONSIN, AND THEIR IMPACTS ON ECONOMICS AND ENVIRONMENT.

by

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DEDICATION

I dedicate this thesis to my partner Benjamin, who supported me along the way.

To my daughter Margaux, who gave me the strength to finalize this whole project.

To my parents, who always supported my choices and gave me the means to achieve my goals.

To my former advisor, who initiated me into the joy of research.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 2: Survey of management practices on selected dairy farms using conventional, grazing, or organic management system in Wisconsin.

CHAPTER 3: Key Factors associated to herd income over feed cost on conventional, grazing, and organic dairy farms in Wisconsin.

CHAPTER 4: Feeding strategies and manure management for cost effective mitigation of greenhouse gas emissions from dairy farms in Wisconsin

LIST OF FIGURES

CHAPTER 2: Survey of management practices on selected dairy farms using conventional, grazing, or organic management system in Wisconsin.

CHAPTER 3: Key Factors associated to herd income over feed cost on conventional, grazing, and organic dairy farms in Wisconsin.

CHAPTER 4: Feeding strategies and manure management for cost effective mitigation of greenhouse gas emissions from dairy farms in Wisconsin

GENERAL INTRODUCTION

Wisconsin is known as “America’s Dairy Land” since 1930 and it is not without good reasons. In 2013, the dairy industry in Wisconsin contributed $26.5 billion to the state’s economy. With 10,860 licensed dairy farms producing 13.6% of the US milk production and 211 plants contributing to 26% of the cheese production in the United States, Wisconsin was the second state in term of milk production in 2013 and has been leading the cheese production in the country since 1910. Over the past years, the dairy industry employed 146,000 people, that is 40% of all Wisconsin agricultural jobs. The average dairy cow in Wisconsin generated over $21,000 a year in economic activity. Given all those numbers, there is no doubt that the dairy industry is a major actor of the economy in Wisconsin.

However, the dairy sector is subject to a lot of socio-economic challenges. Due to increased volatility in milk prices and inputs costs, as well as emerging concerns from consumers regarding the way food is produced, the face of milk production in Wisconsin has changed over the past decade. While the number of conventional farms keeps decreasing, the number of grazing and organic farms has been increasing to meet consumers’ demand. The emergence of those alternative ways of producing milk has raised new questions and created a need for accurate data on farm management practices on those farms. More specifically, data on management practices are needed to evaluate the impact of farm management systems such as conventional, grazing, and organic on farm productivity, farm economics and farm environmental impact.

Therefore, the objectives of this thesis were:

1.) To describe and compare farm characteristics and management practices on conventional, grazing and organic dairy farms in Wisconsin.

2.) To determine key factors associated to farm profitability on conventional, grazing and organic dairy farms in Wisconsin.

3.) To compare conventional, grazing and organic dairy farms in terms of simulated greenhouse gas emission in Wisconsin using survey data and the Integrated Farm System Model.

The first chapter of this thesis presents a literature review on conventional, grazing and organic dairy management and its association with productivity, economy, and greenhouse gas emissions. The second chapter presents the results of the survey regarding farm characteristics and farm management practices on these 3 dairy farm management systems in Wisconsin in 2010. The third chapter exposes the different factors associated with income over feed costs on conventional, grazing, and organic dairy farms in Wisconsin in 2010. Finally, the fourth chapter highlights the impact of farm management practices on simulated greenhouse gas emission for the 3 average dairy farm systems in Wisconsin in 2010.

CHAPTER 1

LITTERATURE REVIEW

This literature review intends to present differences in farm characteristics and farm management practices among conventional, grazing and organic dairy farms and their impact on farm productivity, farm economy and greenhouse gas emissions. The chapter starts with a description of milk production in Wisconsin as an introduction.

A Milk production in Wisconsin

In 2013, 27,572 million lb of milk were produced in Wisconsin. Almost 90 % of this milk produced went into cheese making, which led to a production of 2,842 million lb of cheese. With 13.6% of the national milk production and 25.5% of the national cheese production, Wisconsin is the second largest milk producer state behind California (20.9%) and the first cheese producer state (USDA/NASS, 2014).

Milk production is a tradition in Wisconsin and cheese has been made since 1830. Nowadays, the dairy industry accounts for nearly 40% of all Wisconsin agriculture jobs, employing 146,000 people on 10,860 dairy farms, 211 plants manufacturing dairy products, and 1,178 licensed cheese makers. In total, the dairy sector contributes annually to 26.5 billion $ to Wisconsin economy: “it is more than apple to Washington or raisins to California” (WMMB, A review of Wisconsin dairy industry, 2010).

The dairy industry in Wisconsin is composed of 10,860 dairy farms across the state, breeding 1,271,000 cows having on average 117 cows per farm producing 21,693 lb of milk per cow per year. Over the last 80 years, the number of farms in Wisconsin dropped from almost 175,000. In the meantime, total milk production went from around 10,000 millions of lb to more than 27,000 millions of lb. The small farms are the first to disappear and the average number of cows per farm went from 28.3 in 1970 to 117 in 2013. The increase in farm size has been faster in the past 10 years. The number of farm with less than 100 cows has decreased between 2003 and 2007 whereas the number of farm with more than 200 cows has increased. Despite these changes most dairy farm operations have remained at a scale such that they are still operated and managed predominantly by farm household members. Wisconsin dairy farms have been defined as "medium-sized, diversified, family-labor farms." Those farms are small enough to be operated predominantly by family labor and they grow most of their own feed for the livestock (Jackson-Smith and Barham, 2000). Individuals and family farms represented 86.8% of the Wisconsin dairy farms in 2013 (USDA, 2014).

The increased in herd size and milk production over the years has been a way for farmers to face unstable milk markets, but those methods don't seem to work well anymore, and therefore, alternatives strategies based on decreasing input instead of increasing output are explored. This is why while the total number of farms keep decreasing, the proportion of dairy operations using intensive grazing method went from 7% in 1993 to 23% in 2003 (Kriegl et al, 2005; Brock and Barham, 2008) and the number of certified organic dairy farms has more than double between 2003 and 2008, representing 479 farms in 2008 (USDA, 2009). Moreover, those alternative ways of farming respond to a consumer demand for pasture-raised and organic dairy products (David and Campbell-Arvai, 2009; Franzluebbers et al, 2012).

The exact number of farms using intensive grazing method in Wisconsin is not easy to determine accurately as there is no list of farmers using Managed Intensive Rotational Grazing (MIRG). Moreover, MIRG has been defined in a variety of ways with no consensus on a specific definition, but only general agreement on the overall concept. In general, MIRG rely on pasture as the primary source of forages for their milking cows during the grazing months, they move their cows to pasture on a regular basis, and manage the pastures to maximize the quality and the quantity of feed. What is not clear is the number of days needed before moving cows to fresh pasture. For some people, cows have to be moved to fresh pasture every day or every 3 days or at least once a week to be considered MIRG. Consequently, the number of farms using MIRG can change based on the assumptions made. The main reasons identified to adopt MIRG by Taylor and Foltz (2006) were farm profitability, animal health, quality of life, type of feed available, and location of land close to milking facilities. Winsten est al (2010), estimated the proportion of farms using MIRG to be about 13% in the Northeastern US in 2006.

Wisconsin was the leading organic dairy state in 2008 with more than a quarter of the nation's 87,000 organic dairy cows, 479 organic dairy farms representing 24% of the total number of organic dairy farms in the country, and 12% of the nation's organic milk production. Organic milk's sales reached $57.6 million representing 13.5% of total USA organic dairy sale, just behind California (13.8%) in 2009.

B Definition of farm management systems

Based on the description of the Wisconsin dairy industry and its development in the previous section, this literature review will focus on 3 different management systems: organic, MIRG and conventional. This following paragraph intends to define those 3 systems before they will be compared in the next section.

1 Organic management system

Farms in the organic management system are required to be certified organic. The certification standards were put into place to guarantee the use of "cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity" (USDA-AMS, 2013). They include, for instance, the use of organic feeds by the animals, the development of living conditions that promote health and natural behavior, and the non-use of synthetic products such as pesticides, commercial fertilizers, antibiotics, hormones… More recently, a pasture rule for organic ruminant has been included in the Organic standards in 2010 (USDA-AMS, 2010). From this year on, organic dairy cattle at least 6 mo of age must receive at least 30% of their DMI from pasture during the grazing season, which must be at least 120 days long.

2 *Managed intensive rotational grazing system.*

As stated previously, farms in the MIRG system rely on pasture as the primary source of forages for their milking cows during the grazing months, they move their cows to pasture on a regular basis, and manage the pastures to maximize the quality and the quantity of feed. For the rest of this thesis, farms rotating their lactating cows at least twice a week to a fresh pasture will be considered part of the MIRG system.

3 *Conventional management system.*

Farms in the conventional management system were defined by default based on the definition of the two previous systems. In this study, any farm that was not certified organic and that did not fit in the MIRG system was considered part of the conventional management system.

C Methods used for system comparison

Different methods can be used to compare different farm management systems such as conventional, grazing and organic. Those methods include the comparison of farm results before and after adopting a new management system, the comparison of a large sample of farms in each of the management system studied, the comparison of different management system on an experimental farm using two separated herds, or the use of models to simulate farm results for each of the farm management system (Parker et al, 1992). Each method comes with advantages and drawbacks.

Comparing farm results before and after adopting a new management system allow for control of variables that are not easy to quantify such as the managerial ability of farmers. However, the comparison is made across years.

Comparing farms results based on survey data allow for comparison of a large number of farms. However, this method compares farms that have different amount of resources or managerial ability (Ford and Shonkwiler, 1994; Byma and Tauer, 2010). Moreover, the causality can not be determined with survey results and the direct effect of the management system on the variable of interest cannot be demonstrated.

Comparing farm management system on an experimental farm allow for control of a lot of factors. However, most of the time, the herd is split in 2 separate herds that use the same resources and the comparison between the 2 management systems can only be partial.

Using models to compare results from different farm management systems allow for control of a lot of variables such as the amount of sources or management methods. However, it comes with a lot of assumptions, which can weight on the results.

D Farm characteristics of conventional, grazing and organic dairy farms

1 Comparison of farm characteristics and management practice between conventional and organic dairy farms

a Farm size and breed

When comparing conventional and organic management system in the US, McBride and Green (2007) reported a significant higher number of cows on conventional dairy farms (156 cows vs, 82, respectively). In the Upper Midwest, the difference in number of cows between conventional and organic dairy farms was not significant even though conventional farms had numerically more cows than organic farms (98 vs. 64, respectively). No other study comparing a large sample of organic and conventional farms in the US has been found in the literature. The same trend in number of cows has been reported in other countries whether the difference is significant or not (Roesch et al, 2005 in Switzerland; Langford et al, 2009 in United Kingdom; Muller and Sauerwein, 2010 in Germany).

The information on breed was only reported by Stiglbauer et al. (2013), who observed that cows were more likely to be Jersey or Crossbred on the organic farms compared to cows on the conventional farms. Holsteins cows were predominantly used on conventional dairy farms.

b Milk production

McBride and Greene (2007) reported a 30% lower milk production for organic dairy farms compared to conventional dairy farms. This result has been reported in all the studies comparing organic and conventional management system (Roesch et al, 2005; Sato et al, 2005; Langford et al, 2008; Shabolt et al, 2009; Muller and Sauerwein, 2010; Stiglbauer et al, 2013). It could be attributed to differences in farm management. Organic dairy farms relied less on nutritionist advice (45 vs. 72% of the conventional farms), were less likely to milk 3 times a day, and were not allowed to use rBST while 17% of the farms on the conventional system did (McBride and Greene, 2007; Stiglbauer et al, 2013). Moreover, organic dairy farmers were feeding less concentrate (Langford et al, 2009; Stiglbauer et al, 2013).

No significant differences in bulk tank SCC between organic and conventional management system have been recently reported in the literature (Sato et al, 2005; Muller and Sauerwein, 2010; Stiglbauer et al, 2013).

c Facilities

No differences between housing and milking facilities between organic and conventional management system were reported (Sato et al, 2005; Brock and Barham, 2008; Lanfgord et al, 2009; Stiglbauer et al, 2013). The main housing type for both systems (conventional and organic) used in the upper Midwest for lactating cows was a tie stall barn and a pipeline milking system (Sato et al, 2005; Brock and Barham, 2008). The only difference reported was a higher proportion of conventional farms having freestall barn compared to the organic farms (21.3% vs. 4.6%, respectively. Brock and Barham, 2008).

d Farmer's characteristics

McBride and Greene (2007) reported no differences in farmer's characteristics, such as age or education, whether they belong to the organic or conventional management system. Differences in farmer's characteristics between organic and conventional dairy farms have not bee found elsewhere in the literature.

2 Comparison of farm characteristics and management practices between conventional and grazing dairy farms

a Farm size

All studies comparing conventional dairy farms with grazing dairy farms in the US reported a greater number of cows and larger farmland on the conventional farms (Winsten et al, 2000; Parsons et al, 2004; Foltz and Lang, 2005; Gillespie et al, 2009; Winsten et al, 2010; Hanson et al, 2013). Overall, farms in the MIRG system had 25% less cows 15% less acreage than farms in the conventional management system in the northeast.

b Milk production

Reported milk production was between 10% to 35% lower on the grazing farms compared to farms in the conventional management system (Winsten et al, 2000; Parsons et al, 2004; Foltz and Lang, 2005; Gillespie et al, 2009; Winsten et al, 2010; Hanson et al, 2013).

As for the organic management system, differences in milk production between conventional and grazing farms can be attributed to differences in farm management. Farmers in the conventional management system were more likely to use rBST (Gloy et al, 2002; Parsons et al, 2004; Brock and Barham, 2008; Gillespie et al, 2009; Winsten et al, 2010), to participate in the DHIA program (Parsons et al, 2004; Gillespie et al, 2009), to use a TMR and feed more concentrates (Brock, and Barham, 2008; Winsten et al, 2010), or to use a nutritionist (Winsten et al, 2010); all of which led to higher production in the conventional systems.

c Facilities

As for the conventional and the organic dairy farms in Wisconsin, the main type of housing used by the grazing dairy farms was a tie stall barn with a pipeline milking system (Brock and Barham, 2008). Farms in the conventional and grazing management system were respectively 69.3 and 68.3% to have this type of housing and milking facilities. No difference in term of housing or milking facilities was reported in the literature between farms in the conventional management system and farms in the MIRG system.

d Farmer's characteristics

Depending on the sample, farmers in the grazing management system were found to be younger and more educated than farmers in the conventional management system (Kriegl and Bauman, 1999; Parsons et al, 2004; Hanson et al, 2013), more educated than conventional farmers with no difference in age (Foltz and Lang, 2005), or with no difference in age or education (Gloy et al, 2002).

Overall, farm characteristics in organic, grazing and conventional dairy farms in the upper Midwest were close in term of housing and milking facilities (Brock and Barham, 2008).

The main sources of differences between those 3 systems were the management methods and especially the use of technologies such as rbST, the use of a nutritionist, or more use of concentrate fed in the conventional systems leading to a lower milk production on organic and grazing dairy farms.

E Economic performances of conventional, grazing and organic dairy farms

1 Economic performances of conventional and organic dairy farms

Very few studies comparing economic performances of conventional and organic dairy farms in the US and more specifically in the upper Midwest have been found.

McBride and Greene (2007) compared financial performances of conventional and organic dairy farms in the US using data from the 2005 Agricultural Resources Management Survey (ARMS). They reported the same income over feed cost (IOFC) on conventional and organic dairy farms ($8.87/cwt vs. $9.1/cwt, respectively). However, the repartition of income and cost was different between the 2 management systems. Income expressed per unit of milk produced was a lot higher on organic dairy farms due to the price premium for organic milk ($24.35/cwt compared to $16.99/cwt on the conventional farms). Nonetheless, feed costs (homegrown and purchased) were $4.66/cwt higher on the organic farms leading to the same IOFC as for the conventional farms. Differences in farm management characteristics could explain differences in feed costs between conventional and organic farms as the use of a nutritionist was associated to lower cost of production and the use of pasture was associated to an increase in cost of production in this study (McBride and Greene, 2007).

Rotz et al (2008), found different results using the Integrated Farm System Model (IFSM). They compared 2 organic and conventional farms having the same number of cows and the same land area. They reported a higher net farm income for the organic farms compared to the conventional farms ($14.9/cwt vs $3.3/cwt, respectively). Moreover, they showed that net farm income was less variable across year on the organic farms compared to the conventional farms. In their study, they assumed that milk production on organic farm was only 5% lower than the milk production on the conventional farm (Rotz et al, 2008).

2 Economic performances of conventional and grazing dairy farms

Previous studies have mainly used survey data to compare the economic impact of grazing (Hanson et al, 1998; Dartt et al, 1999; Kriegl and Bauman, 1999; Winsten et al, 2000; Gloy et al, 2002b; Foltz and Lang, 2005; Gillespie et al 2009; Meul et al, 2012; Hanson et al, 2013), some have used simulation models (Parker et al, 1992; Elbehri and Ford, 1995; Soder and Rotz, 2001) and others have used experimental data (Rust et al, 1995; White et al, 2002; Tozer et al, 2003).

Overall, when revenue is expressed per unit of milk produced, grazing farms were found to be either more profitable than conventional farms (Hanson et al, 1998; Dartt et al, 1999; Kriegl and Bauman, 1999; Winsten et al, 2000; Gloy et al, 2002b; Gillespie et al 2009; Nerhing and al, 2009; Meul et al, 2012; Hanson et al, 2013; Parker et al, 1992; Elbehri and Ford, 1995; Soder and Rotz, 2001; Rust et al, 1995; Tozer et al, 2003) or at least as profitable as the conventional dairy farms (Foltz and Lang, 2005; White et al, 2002).

Raw survey data showed a higher profitability on grazing dairy farms compared to conventional dairy farms (Dartt et al, 1999; Winsten et al, 2000; Gloy et al, 2002; Gillespie et al, 2009; Nehring et al, 2009; Hanson et al, 2013). Usually, the higher net farm income on grazing farms was attributed to lower costs and higher non-milk revenue that compensated for the lower milk production compared to conventional dairy farms. Given the differences in farms structure that exist between conventional and grazing management system, some of the authors have developed models to study the impact of grazing alone. That way, Gloy et al (2002) were able to show that other things being equal, grazing generated more profit than their conventional counterpart. The same way, Foltz and Lang (2005) were able to isolate the effect of using grazing on farm profitability. They showed that grazing farms did not have a higher farm profitability compared to conventional farms. However, their results suggested that farm profitability of grazing farms could be increased when the intensity of grazing increases and especially when cows were moved to fresh pasture more rapidly. These results were previously reported by Hanson et al (1998) who showed a higher profitability for more farmers who were grazing more intensively. Finally, Nehring et al (2009) studied the effect of farm size on profitability. They were able to demonstrate that grazing farms were more profitable than conventional farms of the same size. However, as the size of conventional farms increased, the difference in profitability between the 2 management systems disappeared.

In those studies, variables that were identified as having a significant impact on profitability were the age of the farmer (Foltz and Lang, 2005; Gillespie et al, 2009), the number of cows (Winsten et al, 2000; Gillespie et al, 2009), milk production per cow (Winsten et al, 2000), and the amount of non-milk revenue (Foltz and Lang, 2005). Many other variables have also been found to impact farm profitability. On a grazing farm, the breed could impact substantially profitability. White et al (2002) and Bailey et al (2005) reported a higher IOFC for Holstein cows versus Jersey cows. Prendiville et al (2011) reported a higher profitability with crossbred cows (Jersey x Hosltein) compared to pure Holstein or pure Jersey cows. Profitability could also be impacted by pasture management such as the percentage of pasture reseeded each year (Shalloo et al, 2011) or the amount of supplementation. Soder and Rotz (2001) evaluated the impact of different level of supplementation on farm profitability using the IFSM. They found the grazing farm to be at least as profitable as the conventional farm when cows were supplemented with a minimum of 3 kg of DM/cow per day of concentrate. In an experiment, Tozer et al (2004) reported an increase in net return as supplementation increased up to 10 kg DM/cow per day of concentrate. Stocking rate has also been shown to affect farm profitability (Fales et al, 1995; MacDonald et al, 2011; Vibart et al, 2012). Increasing stocking rate decreased profitability per cow but increased profitability per unit of land. Finally, the use of technologies such as rBST (Tauer, 2006), milking parlor (Tauer, 1998), artificial insemination (Kelly et al, 2012) and nutritionist (Tauer and Mishra, 2006) could impact dairy farm profitability.

In order to better control for variables that could have an impact on profitability and study the effect of grazing itself, other authors have used experimental data or simulation model to compare the economic performances of grazing and conventional management system. Over 2 trials, White et al (2002) and Tozer et al (2003) found no differences in farm profitability between grazing and conventional management system. They concluded that costs and income from milk were both lower on the grazing farm management system leading to no differences in IOFC compared to conventional dairy farms. Results from those experiments revealed that grazing management system was less sensitive to feed prices, as it requires fewer inputs. Consequently, when feed prices were high and milk prices were low, the grazing management system was more profitable. When comparing grazing and conventional farms with the same land area and the same number of cows producing the same amount of milk, Elbehri and Ford (1995) and Parker et al (1992) reported a higher farm profitability for the grazing management system. The higher profitability for the grazing management system was maintained even with a 5% reduction in milk production on the grazing farm (Elbehri et al, 1995).

Results from the literature review showed that, on average, economic performances of organic and grazing dairy farms were, most of the time, better than economic performances of conventional farms. However, several variables could impact the profitability and therefore only management system (organic, grazing or conventional) cannot be used as the only variable explaining farm profitability.

F Assessment of greenhouse gas emission on Conventional, Grazing, and Organic dairy farms.

Greenhouse gas emissions on a dairy farm include emissions of carbon dioxide, methane and nitrous oxide. The emissions of carbon dioxide are mainly due to the combustion of fossil fuel, animal respiration and land use change (Chianese et al, 2009a). Regarding methane emissions, the main sources on a dairy farm are enteric fermentation and manure (during storage, application, when deposited on pasture or on the barn floor) (Chianese et al, 2009b). Finally, the main sources of nitrous oxide emissions on a dairy farm include the nitrification/denitrification process in the soil and manure (Chianese et al, 2009c).

1 Comparison of greenhouse gas emissions on conventional and organic dairy farms

The assessment of greenhouse gas emissions at the farm level was made through simulations. When results were expressed on kg CO2eq per kg milk produced, total greenhouse gas emissions were higher on the organic farms compared to the conventional farms (Cederberg et al, 2000; de Boer, 2003; Thomassen et al, 2008; Kristensen et al, 2011). Even though nitrous oxide emissions and carbon dioxide emission were lower on the organic farms compared to the conventional farms due to a lower usage of fossil fuel and commercial fertilizers, the higher methane emission from ruminant fermentation more than offset these reductions yielding higher greenhouse gas emissions on the organic farm.

The sources of greenhouse gas emissions were different on the organic and conventional dairy systems. For the organic farms, most of the emissions occurred on farm whereas for the conventional farms a higher portion of total emissions occurred off-farm to account for the manufacture of fertilizers and the transport of purchased feed (Thomassen et al, 2008; Kristensen et al, 2011).

2 Comparison of greenhouse gas emissions on conventional and grazing dairy farms

Total greenhouse gas emissions from the grazing farm were found to be lower than emissions from the conventional farm (Arsenault et al, 2009; Belflower et al, 2012; O'Brien et al, 2012), even when emissions were expressed per unit of milk produced, taking into account the lower productivity of grazing farms compared to conventional farms. The differences in total greenhouse gases between the 2 management systems were attributed to differences in the inputs usage. More specifically, grazing farms were using less fertilizer and were purchasing less concentrates (O'Brien et al, 2012).

3 Factors affecting greenhouse gas emissions

a Nutritional factors

Multiple nutritional factors affect greenhouse gas emission and especially methane emission. Those factors include feed conversion efficiency, the use of high quality forage, the increase in grain supplementation, and the use of sBST or Monensin.

Methane emissions are related to feed intake. Consequently, if feed conversion efficiency is improved through animal breeding or nutritional management, then methane emissions could be reduced.

The use of high quality grasses or forage legumes have been found to reduce enteric fermentation of dairy cows (Yusuf et al, 2012) by reducing the retention time in the rumen and the proportion of dietary energy converted to methane (Eckard et al, 2010).

Methane emission from dairy cows per unit of milk produced decreased as the forage to grain ratio decreased (Lovett et al, 2005; Aguerre et al, 2011). The reduction in methane emission when grain supplementation increased was possible because the percentage of energy converted to methane was reduced with higher supplementation (Yusuf et al, 2012). Chianese et al (2009b) also reported a 16% increase in methane emissions when the use of forage to feed the lactating cow was increased.

Odongo et al (2007) showed that the use of Monensin could reduce methane emission at the animal level by 7% when associated to a TMR. The same way, Capper et al (2008) showed that the use of rBST could reduce greenhouse gas emissions by 8.8%.

b Animal productivity

Results from the literature show that methane emissions could be reduced by unit of milk produced when animal productivity is improved (Boadi et al, 2004). Milk production increases faster than GHG emissions, especially methane emissions, yielding a lower rate of emission per unit of milk when productivity is increased. Zehetmeier et al (2012), reported the same results with a reduction of 36% of total GHG emissions when milk production is increased by 67% (from 6,0000kg/cow per year to 10,000kg/cow per year). The same way, Chianese et al (2009a) reported an increase of 20% of total GHGE when Holstein cows were replaced by Jersey cows due to the increase in number of cows needed to produce the same amount of milk.

c Animal health

Hospido and Sonesson (2005) assessed the effect of lowering the incidence rate of mastitis on the environmental impact of the farm. They concluded that lowering the incidence rate of mastitis from 25 to 18% would reduce greenhouse gas emissions by 2.5% by decreasing the number of productive cows, the amount of milk replacer purchased, the antibiotics to treat mastitis, and the number of culled cows.

d Crop management practices

Chianese et al (2009c) reported a 7% reduction of nitrous oxide emission by reducing the use of inorganic fertilizer and accounting for manure nitrogen. This reduction yielded an overall GHG emission from the farm that was 1% lower.

e Level of analysis

When assessing the impact of different factors on greenhouse gas emission, it is important to take into account the level of analysis. Vellinga and Hoving (2010) and Van Middelaar et al (2013) showed that the use of corn silage would reduce greenhouse gas emissions at the animal level. However, changes in land use when pastures were converted to corn could offset the benefits of this potential mitigation strategy.

This literature review highlighted differences in farms characteristics and farm management practices on organic, grazing and conventional dairy farms and their impacts on farm profitability and GHG emissions. Relatively few information were available to compare farms characteristics and farms management practices of organic, grazing and conventional dairy farms, especially in the Midwest. This information is of great value for researchers and dairy professionals such as nutritionists or extension specialists.

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CHAPTER 2

SURVEY OF MANAGEMENT PRACTICES ON SELECTED DAIRY FARMS USING CONVENTIONAL, GRAZING OR ORGANIC MANAGEMENT SYSTEM IN WISCONSIN.

INTERPRETIVE SUMMARY

Survey of management practices on selected dairy farms using conventional, grazing or organic management system in Wisconsin. By Dutreuil et al. A survey was conducted on conventional, grazing and organic dairy farms to describe their characteristics and their management practices. Farms were managed by similar individuals. However, differences in feeding management were observed, as well as differences in milk production among the 3 management systems. Moreover, large variations were observed inside each of the management system.

Survey of management practices on selected dairy farms using conventional, grazing or organic management system in Wisconsin.

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A ABSTRACT

The objective of this study was to describe characteristics and management practices on Wisconsin dairy farms. A comprehensive survey questionnaire was developed to collect information on farm business structure, people working on the farm, dairy herd management practices, feeding management practices, pasture management practices, crop management practices, manure management practices, economics and quality of life for Conventional, Grazing and Organic dairy producers in Wisconsin in 2010. Conventional and Organic surveyed farms were found to be representative of Wisconsin dairy farms but no conclusion could be made on the representativity of surveyed Grazing dairy farms. Results showed no differences in farm managers' characteristics or farm business structure between Conventional, Grazing and Organic management systems. As expected, farms in the Conventional management system operated more cropland with more cows, producing more milk than farms in the Grazing and Organic management systems. Overall, farm managers in the Conventional management system were feeding a larger amount of feed, were more likely to use feed additive such as BST, Monensin or dietary fat, to have Holstein cows, and to rely on synchronization reproductive programs. However, despite all those differences between the 3 management systems, a large variation was observed inside each of the 3 groups, indicating that other criteria than the management system could be used to classify farms in a more homogeneous way.

Key words: Conventional, Grazing, Organic, Farm characteristics, dairy.

B INTRODUCTION

Maintaining the viability of dairy farms is a key objective for Wisconsin, a state that ranks second in the US with 14% of national milk production (USDA, 2013) and for which the dairy industry generated $26.5 billion in 2012. Up until few decades ago, the main survival methods to face unstable milk prices and to guarantee the economic durability of dairy farms have been to increase herd size and/or milk production per cow. However, those strategies do not seem to work well anymore and public concerns regarding food safety, preservation of the environment and animal welfare have been raised (Sundrum, 2001). Alternative methods of production have emerged to meet consumers' demand. Those methods include the utilization of managed grazing and the transition to organic milk production. While the number of Conventional farms keeps decreasing, the number of farms using managed grazing or organic production has increased over the past 10 years (Kriegl and McNair, 2005 and Green, 2006). The emergence of those alternative ways of producing milk has created a need for new references for researchers and farmers and those who advise them. There is a lack of information regarding farms characteristics and farmers management practices on Wisconsin Conventional, Grazing and Organic farms that would allow consultants to be more efficient when advising farmers and to adjust their guidance based on the need of the farmer. This information is also lacking for researchers who need accurate data to develop models.

The objective of this paper was to describe characteristics and management practices of dairy farms in Wisconsin in 2010 and to determine if these practices were different between the 3 management systems studied (Conventional, Grazing and Organic). Those references could be used by dairy farmers, advisors and consultants, and researchers. Many more data that can be reported here were collected; hence, communication with authors is encouraged.

C MATERIALS AND METHODS

1 Sampling

Farms were selected from the Wisconsin's official lists of certified milk producers and organic milk producers of 2009 as well as a list of graziers compiled from extension agents from the University of Wisconsin. Each selected farmers received, by mail, an envelope containing an introductory letter, a description of the project, and a pre-stamped postcard to indicate their willingness to participate in the study. Farmers were offered US $100 reward after completing the survey. Farmers who did not send their pre-stamped postcards back after 2 weeks received a reminder letter. Farmers who were willing to participate in the study were then contacted by phone to schedule a face-to-face interview. Dairy farms were classified across 3 different management systems: organic, grazing and conventional. The organic system included farms which were certified organic; the grazing system included farms which used grazing as a major source of feed during the grazing season (i.e., at least 30% of the dry matter intake of the lactating cows from pasture during the grazing season) and which rotated their cows to fresh pasture at least every 3 days (qualified as managed intensive grazing); and the conventional system included farms which were the non-organic, non-grazing farms. A total of 114 farms were surveyed between January 2011 and January 2012, that is 28 conventional farms, 28 grazing farms, and 58 organic farms. A geographical repartition of farms surveyed can be found in Figure 1.

2 Questionnaire

The survey questionnaire contained 98 questions, distributed over 9 sections as follow:

- Section I: "Farm business structure". This section included questions regarding the farm business structure, the number of decisions maker on the farm and the land tenure characteristics.
- Section II: "People on the farm". This section included questions on demographics for people living on the farm (age, education, work off farm, gender, and relationships), as

well as questions regarding on-farm and hired labor (number of persons, tasks, hours worked).

- Section III: “Dairy herd management”. This section included questions on dairy herd (number of cows and heifers, breeds), milk production (monthly milk price, milk quantity, fat and protein content, and SCC), and reproduction (methods used, success rate, age at first calving, and culling).
- Section IV: “Feeding management”. In this section, the monthly diet of lactating cows and the amount of feed purchased was recorded. It also included questions regarding the use of a nutritionist or other assistance to balance the ration and the use of additives such as BST or Monensin.
- Section V: “Pasture management”. This section was answered only by grazing and organic dairy farmers and included questions grasses and legumes species grown, grazing season length, pasture rotation and stocking rate on pasture.
- Section VI: “Land management and cropping operations”. This section included questions on crops grown (hectares, type of harvests, and yields).
- Section VII: “Manure and nutrient management”. This section included questions regarding manure collection, manure storage, manure application and crop fertilization.
- Section VIII: “Economic information”. This section included questions on dairy animals sold and purchased, crop sold, government payments, income from off-farm work and health insurance.
- Section IX: “Assessment of farm management and quality of life”. This section included questions on farmers’ satisfaction regarding the farm operation, their quality of life on the farm, and their income.

Section V will not be summarized here as it was addressed to only part of the sample (farms in the Grazing management system and some farms in the Organic management system). The same way, section VII will not be analyzed here because the results of this section will be the subject of another publication. All date sensitive questions pertained to year 2010.

3 Statistical analysis

All data were coded in Excel and analyzed with R (version 3.0.2; http://www.R-project.org) to describe characteristics and assess differences in management practices among the 3 management systems: Conventional, Grazing and Organic. Significance level was set at 0.05 and tendencies were detected between 0.05 and 0.1.

The data on size of the farm (number of cows and ha) and the milk production per cow in our sample were compared to the data from the census of agriculture in 2010 to assess their representativeness.

D RESULTS AND DISCUSSION

1 Representativeness of the farms

Our sample of organic farms was found to be representative of organic farms in the state of Wisconsin in 2010 as they had about the same mean number of cows (74 and 61, for our sample and the census of agriculture, respectively), producing similar amount of milk (6,380 and 6,277 kg/cow per yr for our sample and the census of agriculture, respectively) on similar mean land size (145 and 142 ha, for our sample and the census of agriculture, respectively). The conventional farms in our sample had a similar number of cows than the conventional farms in the 2010 census of agriculture (128 and 135 cows, respectively), producing similar mean amounts of milk (9,768 and 9,338 kg/cow per yr, respectively) but had less available land for cropland or pasture (181 and 215 ha, respectively). The grazing farms in our sample were found to have more cows (+37 cows) producing more milk (1,069kg/cow per yr) on more land (+59 ha) than the grazing farms in the census of agriculture in 2010. However, the sample size for grazing farms in the census of agriculture was small (n = 14) and they defined their sample as not representative of grazing farms in Wisconsin. Consequently, we were not able to assess the representativeness of the grazing farms in our sample.

2 Farmers' characteristics

The characteristics of dairy farmers in Wisconsin did not differ among the 3 management systems (Table 1). Farm managers were on average 50.3 (±12.1) years old and had 23.2 (±12.3) years of experience on the farm. They were more likely to be male, to have been raised on farm, to be married and to have children. Even though numerically a higher percentage of farm managers using managed grazing had completed at least a 4 years degree of education (39.3% vs. 21.4% and 24.1% for the farm managers using the conventional or the organic management system, respectively), the difference was not statistically significant (Table 2). The same way, Gloy et al (2002) found no difference in age and level of education between farmers in the Conventional and Grazing management system.

The only statistical difference observed among the 3 management systems was the percentage of farm managers working off-farm, which was higher for the organic management system compared to the conventional and grazing management systems (22.4% versus 7.1% and

3.6%, respectively, Table 1). The 2 conventional farm managers who worked off farm were working 8 and 10 hr per wk respectively. In 2010, they earned between $1,000 and $1,999 and between $10,000 and $14,999 per year, respectively, but did not get health insurance. No information was available for the farm manager in the grazing management system regarding off-farm work. The 13 Organic farm managers who worked off-farm were working 28.8 (± 15.6) hr per wk on average. They earned on average $21,500/yr and about half of them received health insurance.

For the farm managers who were married, their spouses were on average 48.7 (±11.0) yr old and 42% of them were working off-farm (Table 1). A higher percentage of spouses in the grazing management system compared to the conventional and organic management systems completed at least a 4 yr degree of education (61.9% versus 26.1% and 28.6%, respectively) (data not shown).

On average, farm managers in the grazing management system started using managed intensive rotational grazing methods for 14.7 yr (±4.6) whereas farm managers using organic production method have been farming organically for 17.3 yr (±11.7) and were certified organic in 2003.

3 Farm business

Farms in the 3 management systems had the same type of business structure with overall 80.7% of the farms being individual or family farms and 14.0% being a partnership (Table 3).

The number of decision makers on the farm was higher for the organic management system compared to the grazing or conventional management systems (2.31 vs. 1.89 and 1.93, respectively, p-value=0.04763).

4 Labor sources and amount

The average number of household members, including principal decision makers, working on the farm was 3.3, 2.7, and 3.4 for the farms in the Conventional, Grazing, and Organic management system, respectively, with no statistical difference among the 3 systems (p-value=0.08023).

Farmers in the Organic management system tend to rely less on hired labor than farmers in the Conventional or Grazing management system with only 67% of them relying on hired help compared to 82% and 89% for the farmers in the Conventional and Grazing management system, respectively (p-value=0.05717). For the farms relying on hired help, the proportion of paid work in the total number of hours allocated to the dairy farms was 0.24, 0.15 and 0.17 for the Conventional, Grazing and Organic management system, respectively, with no statistical difference among the 3 management systems (p-value=0.9469). On the Conventional farms, people were hired mainly to do field work, to milk the cows, and to handle manure (Figure 2). On the Grazing farms, people were hired mainly to do field work, to milk the cows, and to do pasture work. On the Organic farms, people were hired mainly to milk the cows, to do field work, and to handle manure.

The total number of hours supplied to the dairy farm for the year averaged 12,165 (±9,456.8), 6,793 (±4,073.3), and 7,809 (±4,484.2) for the Conventional, Grazing, and Organic management system respectively with a large variation among farms (Table 4). This number is much higher for the Conventional management system compared to the 2 other systems (p-value=0.01843). However, when expressed on a per cow or per 45.4 kg milk basis, farms in the Conventional management system are more labor efficient than farms in the Organic management system. And the Grazing farms are more labor efficient than the Conventional (Table 4).

5 Land and land tenure characteristics

The average farm in the Conventional, Grazing and Organic management system operated 181, 137, and 145 ha respectively (excluding land in the Conservation Reserved Program, Table 5). Most of this land was owned with the rented land representing only 31%, 29%, and 33% of the land operated for the farms in the Conventional, Grazing, and Organic management system, respectively. There was no statistical difference among the 3 management systems in term of total land operated due to the large variation between each farm within each management system. However, farms in the Conventional management system owned more ha of cropland and less ha of pasture than the 2 other management systems. As a result, the proportion of cropland in the total land operated was higher for the farms in the Conventional management system (0.73 versus 0.42 and 0.52 for the farms in the Grazing and Organic management system respectively, $p\text{-value}<0.01$) and the proportion of pasture in the total land operated was lower for the farms in the Conventional management system (0.17 versus 0.41 and 0.36 for the farms in the Grazing and Organic management system respectively, $p\text{-value}<0.01$) (data not shown). The same way, Parsons et al (2004) reported more ha of cropland and less ha of pasture for farms in the Conventional management system compared to farm in the Intensive grazing management system.

When expressed on a per cow basis, farms in the Conventional, Grazing and Organic management system had on average 1.50, 0.96, and 1.16 ha/cow of cropland and 0.61, 0.59, and 0.75 ha/cow of pasture, respectively.

6 Herd management practices

a Herd structure

Farms in the Conventional management system had on average 128 dairy cows, 112 heifers, and 1 dairy bull. About one third of the cows were in first lactation (Table 6).
Farms in the Grazing management system had on average 94 dairy cows, 77 heifers and 3 dairy bulls. The herd structure was really close to the one for the farms in the Conventional management system with 30% of the cows in first lactation and 53% of the cows in their second, third or fourth lactation (Table 6).

Farms in the Organic management system had the least number of animals compared to the 2 other management systems with on average 74 cows, 64 heifers, and 1 dairy bull.
Differences in cow numbers between the 3 management systems in Wisconsin have been previously reported whether the difference was statistically significant (Sato et al, 2005) or not (Gloy et al, 2002, Hanson et al, 2013).

b Breed

For all the farms in the 3 management systems, Holstein was the predominant breed. However, the proportion of Holstein cows in each management system was different, representing 87, 47, and 53% of all the cows on the farms in the Conventional, Grazing and Organic management system, respectively (p-value<0.01, Table 7).

Grazing and Organic management system farms had crossbreds as the second main breed representing 39 and 30% of the cows, respectively.

The rest of the breeds used on the 3 management systems were either Jersey, Milking shorthorn, Normande or Brown Swiss (Table 7).

Crossbred cows were used by 36%, 89% and 76% of the farmers in the Conventional, Grazing and Organic management system, respectively.

Conventional farms with crossbred cows (n=10) had on average 44 crossbred cows representing 25% of the cows in the herd. Grazing farms with crossbred cows had on average 45 crossbred cows representing 44% of the cows in the herd. Organic farms with crossbred cows had on average 27 crossbred cows representing 40% of the cows in the herd.

Breeds used in the crossbreeding program were mainly Holstein and Jersey cows on the 3 management systems with a large variety of breeds for the farms in the Organic management system (Figure 3). Each farm was using on average 3 breeds in the crossbreeding program with no difference between management systems.

Preferences for non-Holstein and mixed breed of farm managers in the Organic and Grazing management system have been documented in previous studies (Weigel and Barlass; Sato et al, 2005).

c Milk production

Cows were milked 2.11, 2.02, and 1.96 times on average on the farms using the Conventional, Grazing and Organic management system, respectively (p-value=0.0177). The large majority of farmers milked the cows twice a day (89.3%, 92.8%, and 91.4% for the farmers in the Conventional, Grazing and Organic management system, respectively). Farmers in the Conventional management system were more likely milking cows 3 times a day compared to the farmers in the Grazing and Organic management system (10.7% vs. 3.6% and 0%, respectively). These results corroborate findings from Gillespie et al (2009) who reported a higher percentage of farmers in the Conventional management system milking 3 times compared to farmers in the Grazing management system at the national level. Farmers in the Organic management system were more likely milking cows once a day (8.6%).

Cows in the Conventional management system were producing more milk than cows in the Organic management system with 10,112 kg/cow per yr vs. 6,213 kg/cow per yr on average, cows in the Grazing management system had an intermediate milk production of 7,533 kg/cow per yr (p-value<0.01). Lower milk production for farms in the Grazing (Gloy et al, 2002; Parsons et al, 2004) or Organic (Sato et al, 2005) management systems have been previously reported. In terms of composition, milk from farms in the Organic and Grazing management system had a higher fat (p-value<0.01) and protein content (p-value=0.0015; Figure 4). The average fat and protein content for the year were 3.71% and 3.03%, 3.98% and 3.17%, and 4.01% and 3.11% for farms in the Conventional, Grazing and Organic management system, respectively. No difference between groups was observed regarding the average SCC for the year (286,000, 254,000 and 261,000 cells/mL for farms in the Conventional, Grazing and Organic management system, respectively. p-value=0.6721) and the same fluctuations during the year occurred on farms in the 3 management systems (Figure 5). Sato et al (2005) found no difference in average SCC between Organic and Conventional dairy farms with numbers really close to the one observed in our sample (263,000 and 285,000 cells/ml for farms in the Organic and Conventional management system, respectively).

The large majority of farmers were not able to report the milk urea nitrogen content monthly either because they do not use this information on the farm or because they do not keep this information once they have it. Only 12 farmers were able to report milk urea nitrogen content and only for some months of the year. Therefore, results regarding milk urea nitrogen are not described here. The same way, quantity of milk used on-farm and not sold was difficult to assess for most of the surveyed farmers and therefore not presented here.

The average milk price received in 2010 was lower for farms in the Conventional and Grazing management system compared to farms in the Organic management system ($15.78/45.4 kg and $16.62/45.4 kg vs. $25.4/45.4 kg for the Conventional, Grazing and Organic management system, respectively, p-value<0.001). However, milk price followed the same tendency for the 3 management systems during the year 2010 (Figure 6). Milk prices reported by farm managers in the Conventional and Grazing management systems were close to prices observed by the Wisconsin Department of Agriculture in 2010 ($16.10/45.4 kg, USDA-NASS, 2011). Farmers were asked to report the minimum milk price they needed to remain economically viable. Farmers in the Conventional, Grazing and Organic management system reported a minimum milk price ($/45.4 kg) of $17.14, $14.81, and $24.22, respectively. Is it interesting to notice that the minimum price needed reported by Grazing and Organic farmers was lower than the average price received in 2010, whereas it was higher for farmers in the

Conventional management system, which would explain the difference of satisfaction regarding milk price received among the 3 management systems (Table 9).

A numerically higher percentage of farmers in the Conventional management system were using DHIA services than in the Grazing and Organic management systems (71.4% vs. 56.0% and 53.3%, respectively), even though this difference was not significant (p-value=0.293).

d Reproduction

Dairy farmers in Wisconsin were mainly milking year round with 96.4%, 60.7%, and 75.9% of the farmers in the Conventional, Grazing and Organic management system having cows calving year round and 0%, 17.9%, and 3.4% of them having cows calving over two distinct seasons, respectively. Only 3.6%, 21.4%, and 20.7% of the farmers in the Conventional, Grazing and Organic management system were completely seasonal, closing the milking parlor at least one day of the year.

Farmers in the Conventional, Grazing and Organic management system reported an average of 330, 331, and 323 days of lactation (p-value=0.2200) with a calving interval of 395, 398, and 392 days (p-value=0.3882), respectively.

The main method of reproduction used on Wisconsin farms was artificial insemination for the 3 management systems with 75%, 86% and 81% of users in the Conventional, Grazing and Organic management system, respectively (Figure 7). In previous study at the national level, Gillespie et al (2009) found no differences in the use of artificial insemination between farmers in the Conventional and Grazing management system. Synchronization reproductive programs were used almost exclusively by the farmers in the Conventional management system since only

14% of the farmers in the Grazing management system used it and, as excepted since they cannot use hormones, none in the Organic management system. The success rate at the first insemination service reported by the farmers was higher for the Organic management system (54.9%), intermediate for the Grazing management system (48.9%) and lower for the Conventional management system (42.5%, p-value<0.01).

No significant difference was observed for the age at first calving between the 3 management system with farmers in the Conventional, Grazing and Organic management system reporting an average age of 25.6, 25.2, and 26.3 months at first calving, respectively (p-value=0.2107).

e Longevity

Farmers in the Conventional and Grazing management system were culling cows after 4 lactations on average, whereas farmers in the Organic management system were culling cows after 4.5 lactations (p-value=0.0126).

On average, farmers in the Conventional, Grazing and Organic management system were culling 31%, 26% and 21% of their cows annually, respectively (p-value<0.001). Farmers in the 3 management systems reported mastitis, low fertility, and death as the main reasons for culling a cow (Figure 8). Only 2 statistical differences were observed regarding the reasons for culling. First, the proportion of cows culled for injuries was lower on the farms in the Organic management system compared to farms in the Conventional or Grazing management system (4% vs. 11% and 13%, respectively, p-value=0.0132). Second, the proportion of cows culled for mastitis was higher on the farms in the Organic management system compared to farms in the

Conventional or Grazing management system (27% vs. 21% and 20%, respectively. p-value=0.0439).

Mastitis and lameness, 2 important reasons for culling a cow on the 3 management systems, were also identified as a health issue by the farmers (Figure 9). In the Conventional, Grazing and Organic management system 64.3%, 46.4%, and 60.3% of the farmers identified mastitis as an issue on their farms, respectively, and 57.1%, 28.6%, and 46.6% identified lameness as an issue on their farm, respectively. Twisted stomach was identified as an issue mainly by farmers in the Conventional system (p-value<0.001).

7 Feeding practices

Feeding for the lactating cows was less variable during the year for the farms in the Conventional management system compared to farms in the Grazing and Organic management system (Figures 10). Only 12 farmers out of 28 in the Conventional management system were using grazing for the lactating cows (42.9%). The amount of concentrate and corn silage offered to the cows during the year remained the same on the farms in the Conventional management system. When lactating cows were grazing, pasture was replacing preserved grass (hay or silage). Overall, lactating cows in the Conventional management system were offered more feed than lactating cows in the Grazing and Organic management systems. On farms in the Grazing and Organic management systems, the amount of corn silage and preserved grass offered was reduced during the grazing season.

As expected, farmers in the Organic management system were not using any feed additive such as BST, Monensin, dietary fat or amino acid supplement. However, BST was used by 29% and 4% of the farmers in the Conventional and Grazing management system, respectively; Monensin was used by 61% and 21% of the farmers in the Conventional and Grazing management system, respectively; Dietary fat was used by 50% and 32% of the farmers in the Conventional and Grazing management system, respectively and amino acid supplements were used by 21% and 7% of the farmers in the Conventional and Grazing management systems, respectively. The fact that farmers in the Conventional management system were more likely to use BST was reported before by Gloy et al (2002) and Parsons et al (2004).

A TMR was used by 54%, 39%, and 33% of the farmers in the Conventional, Grazing and Organic management system, respectively, with no sifnigicant difference between groups (p-value=0.1832). Previously and in neighboroud states, Parsons et al (2004) reported that farmers in the Conventional management system were more likely to use TMR than farmers in the Grazing management system. For the farmers using grazing, TMR was used only outside the grazing season.

Farmers in the Conventional management system were less inclined to try new feeds than farmers in the Grazing or Organic management system. Eightysix percent of farm managers in the Conventional management system reported “almost never” trying alternative feeds vs. 54% and 67% of farmers in the Grazing and Organic management system, respectively (Figure 11). For farmers in the 3 management systems, the 3 reasons more frequently mentioned for trying alternative feeds were related to feed costs (“finding a cheaper alternative to corn” and “a way to reduce feed costs”) or “ a way to provide additional nutrient such as fat, mineral, vitamin.” Another reason mentioned only by farmers in the Conventional and Grazing management system was “finding a cheaper alternative to soybean meal.” The use of alternative feeds as a way to reduced nutrient excretion was only mentionned by 1 farmer in the Grazing management system and 1 farmer in the Organic management system. One farmer in the Conventional management system mentionned using alternative feeds to improve cow performance, 2 farmers in the Grazing management system were using alternative feeds to improve animal health and milk components, and 1 farmer in the Organic management system was doing it to extend the grazing season.

Farmers in the Conventional, Grazing and Organic management system were 57.1%, 53.6%, and 46.5% to receive animal nutrition advice from one source in 2010, respectively. Only 14.3%, 14.3%, and 19% of the farmers in the Conventional, Grazing and Organic management system did not receive any animal nutrition advice, respectively. The rest of the farmers in each of the 3 management system received animal nutrition advice from more than one source. The main sources of animal nutrition advice were the nutritionist or the feed company representative for farmers in the 3 management systems (Figure 12). None farm manager in the conventional system used nutritional advice from a county extension agent and very few of them used advice from a neighboring farmer. Very few farm managers in the Grazing management system received animal nutrition advice from a neighboring farmer or a veterinarian. However, farmers in the Organic management system received animal nutrition advice from all kind of sources.

8 Crop management

The main crops grown on Wisconsin dairy farms in 2010 were corn and alfalfa on the farms in the 3 management systems studied (Figure 13). A larger percentage of farmers in the Conventional management system were growing corn compared to farmers in the Grazing of Organic management system (93% vs. 68% and 63%, respectively, p-value=0.0189). Overall, 63% of the farmers in the Conventional management system were growing corn for grain and silage, 11% of them for silage only and 19% of them for grain only. On farms in the Grazing management system, those percentages were 22, 32 and 14, respectively and on the Organic farms, they were 35, 12 and 16, respectively. Corn silage yields reported by farmers were numerically higher on the Conventional management system (17.09 t DM/ha vs. 16.11 t DM/ha and 14.41 t DM/ha on Grazing and Organic management systems, respectively). However, due to large variation among farms, the difference was not statistically significant (p-value=0.1664). For corn grain, yields were significantly higher on farms in the Conventional management system compared to farms in the Grazing and Organic management system (8.66 t/ha vs. 7.59 t/ha and 7.44 t/ha, respectively. p-value=0.0275).

As for corn, farmers in the Conventional management system were more likely to grow alfalfa compared to farmers in the Grazing and Organic management system (96% vs. 75% and 70%, respectively, p-value=0.0260). Farmers in the Grazing management system reported a numerically higher yield for alfalfa with 8.58 t DM/ha compared to 7.97 t DM/ha and 8.16 t DM/ha for farmers in the Conventional and Organic management systems, respectively. However, this difference was not statistically significant (p-value=0.5388).

Only 19%, 14% and 12% of the farmers in the Conventional, Grazing and Organic management systems cropped soybean in 2010, respectively.

Other crops grown on the farms in the 3 management systems included some cereals such as barley, wheat or triticale or a mixture of cereals and peas (oats and peas, barley and peas, triticale and peas).

9 Farm management assessment and quality of life

When farmers in the 3 management systems were asked to assess the difficulty of some aspects of dairy farming, the one that appeared the most difficult was to find labor for the farm for farmers in the 3 management systems (Table 8). In all the factors presented to farmers, the assessment of 4 factors appeared significantly different between the 3 management systems. Farm managers from the Grazing management system found it easier to keep animal healthy compared to farm managers in the 2 other management systems; farm managers in the Organic management system found it more difficult to manage weed and pest, to manage soil fertility and to find a knowledgeable veterinarian compared to farmers in the 2 other management systems. The aspect of farming that appeared the easiest for the 3 management systems was to find grain for the farm.

More differences among the 3 management systems were observed when farmers were asked to assess their satisfaction regarding some aspects of farming. The overall satisfaction regarding the quality of life tended to be higher on farms in the Grazing and Organic management systems compared to farms in the Conventional management system (5.78 and 5.59 vs. 5.07, respectively. p-value=0.0586). Farmers in the Grazing management system were more satisfied with their stress level, the health of the herd, the physical demand of farm work, the price received for milk, and the net farm income (Table 9). Satisfaction regarding the lifestyle for the family on the farm as well as the opportunities for children to join the farm was not perceived differently among the 3 management systems. Overall, the aspect of farming for which farmers were to most satisfied was the health of the herd. The one for which farmers were the least satisfied was the time off from farm work.

E CONCLUSION

The key objective of this paper was to describe characteristics and management practices on Conventional, Grazing and Organic dairy farms in Wisconsin in 2010. Results draw a good picture of milk production in Wisconsin at that time. Farms in the Conventional, Grazing and Organic management systems were managed by individuals of comparable age, with similar level of education and the similar years of experience farming. However, profound differences on feeding strategies between the 3 management systems were observed. Further analysis could help associating those differences in feeding strategies to the differences in milk production and productivity observed. Overall, a large variation was observed inside each of the 3 management systems studied, suggesting that a typology should be done inside the Conventional, Grazing and Organic management system to define groups that are more homogeneous.

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Table 1 : Characteristics of Wisconsin farm managers using conventional, grazing or organic management system in 2010

	Conventional	Grazing	Organic	p-value
n	28	28	58	NA
Age of the farm manager (yr)	47.8 (11.83)	48.3 (11.52)	52.6 (12.39)	0.1987
Gender (% male)	89.3%	96.4%	93.1%	0.5805
Percentage raised on farm	92.9 %	89.3 %	86.0 %	0.5100
Years of experience on the farm	22.9 (13.16)	22.6 (11.71)	23.7 (12.30)	0.9190
Percentage working off-farm	7.1%	3.6%	22.4%	0.0309
Percentage being married	82.1%	75.0%	84.5%	0.5690
Age of the spouse (yr)	46.9 (10.74)	46.9 (11.74)	50.4 (10.83)	0.3533
Percentage of spouse working off-farm	56.5%	47.6%	32.7%	0.1338
Percentage having children	57.1 %	46.4 %	58.6 %	0.5520

Table 2 : Frequency of education level among Wisconsin dairy farm managers using conventional, grazing or organic management system in 2010.

	Conventional	Grazing	Organic
Less than high school	0.0% (0)	0.0% (0)	1.7% (1)
High school	39.3% (11)	28.6% (8)	32.8% (19)
Tech school	35.7% (10)	17.8% (5)	36.2% (21)
University short course	3.6% (1)	14.3% (4)	5.2% (3)
Complete 4 yr degree	17.8% (5)	39.3% (11)	15.5% (9)
Graduate school	3.6% (1)	0.0% (0)	8.6% (5)

Chi-squared=14.55, p-value=0.1493

Table 3: Business structure of Wisconsin surveyed dairy farms in 2010.

	Conventional	Grazing	Organic
Individual	67.9% (19)	85.7% (24)	84.5% (49)
Partnership	21.4% (6)	10.7% (3)	12.1% (7)
Other	10.7% (3)	3.6% (1)	3.4% (2)

Chi-squared=4.33, p-value=0.3633

Table 4 : Hours of total labor allocated to the dairy farm for the 3 management systems.

	Conventional	Grazing	Organic	p-value
Hr/yr				
On-farm labor	8,078 (4,408)	5,303 (2,351)	6,624 (3,855)	0.02625
Paid labor	4,086 (6,960)	1,490 (3,315)	1,164 (2,352)	0.2507
Total	12,164 (9,457)	6,793 (4,073)	7,788 (4,484)	0.01843
Hr/cow per wk	2.7 (1.19)	1.6 (0.71)	2.7 (1.43)	<0.001
Hr/45.4 kg milk	0.68 (0.49)	0.50 (0.19)	1.09 (0.73)	<0.001

Table 5: Land tenure characteristics of Wisconsin surveyed dairy farms in 2010 (ha).

	Conventional	Grazing	Organic	p-value
Cropland				
Owned	86.2 (89.8)	32.3 (31.2)	48.5 (78.1)	<0.01
Rented	54.8 (68.6)	31.3 (33.8)	39.5 (58.8)	0.2521
Rented out	1.6 (8.3)	0 (0)	0.2 (1.3)	0.6073
Operated	139.4 (138.4)	63.6 (57.8)	87.8 (117.6)	<0.01
Pasture				
Owned	20.8 (23.1)	34.6 (22.7)	30.1 (24.2)	0.02215
Rented	6.8 (11.7)	16.5 (24.7)	12.8 (22.5)	0.4212
Rented out	0 (0)	0 (0)	0 (0)	NA
Operated	27.6 (24.6)	51.5 (31.6)	42.9 (32.4)	<0.01
Woodland	13.8 (18.4)	21.6 (23.5)	14.4 (19.5)	0.229
CRP*	1.3 (5.4)	5.2 (27.5)	0.8 (4.9)	0.6138

*Land in the Conservation Reserved Program

Table 6 : Herd structure on the farms using Conventional, Grazing or Organic management system in Wisconsin in 2010.

	Conventional	Grazing	Organic	p-value
Cows, #	128 (176.23)	94 (59.71)	74 (90.88)	0.03714
% 1st lactation cows	31.5 (11.3)	30.1 (12.9)	29.7 (11.9)	0.329
% 2nd, 3rd and 4th lactation cows	54.1 (12.9)	52.5 (12.9)	46.5 (13.5)	0.01166
% 5th and 6th lactation cows	11.7 (9.5)	12.4 (6.1)	17.0 (9.1)	<0.01
% 7th and higher lactation cows	2.7 (3.7)	5.0 (4.4)	6.8 (7.4)	0.01081
Heifers, #	112 (153.19)	77 (55.15)	64 (84.71)	0.09548
% Unweaned heifers	0.13 (0.09)	0.1 (0.1)	0.23 (0.19)	<0.01
% Open heifers	0.54 (0.2)	0.49 (0.12)	0.47 (0.13)	0.03929

% Bred heifers	0.35 (0.15)	0.4 (0.1)	0.31 (0.15)	0.01531
Bulls, #	1 (1.69)	3 (4.20)	1 (1.72)	0.08691

Table 7 : Dairy cow breeds used on the Conventional, Grazing, and Organic management system farms in Wisconsin in 2010 (%).

	Conventional	Grazing	Organic	p-value
Holstein	87.2 (27.0)	46.7 (42.6)	53.0 (41.9)	<0.01
Jersey	4.1 (18.9)	9.0 (25.9)	11.0 (28.4)	0.6574
Brown Swiss	0.2 (1.1)	2.5 (13.0)	1.3 (7.2)	0.698
Milking shorthorn	0 (0)	2.5 (13.2)	2.7 (9.7)	0.1517
Normande	0 (0)	0 (0)	1.8 (13.1)	0.6171
Crossbred cows	8.5 (21.2)	39.3 (39.3)	30.2 (33.4)	<0.01

Table 8 : Assessment of the difficulty of some aspects of farming on Conventional, Grazing and Organic dairy farms in Wisconsin in 2010 (scale from 1 (very easy), to 7 (very difficult))

	Conventional	Grazing	Organic	p-value
Finding grain	1.75 (1.59)	1.64 (1.11)	2.18 (1.45)	0.1279
Finding forages	1.85 (0.99)	1.84 (0.83)	2.67 (1.52)	0.0713
Finding replacement heifers	2.4 (1.58)	2.22 (1.09)	3 (1.68)	0.3744
Finding labor for the farm	3.71 (2.12)	3.92 (1.56)	3.89 (1.82)	0.9118
Keeping animals healthy	3.5 (1.45)	2.33 (1.18)	3.19 (1.19)	0.0017
Finding knowledgeable veterinarians	1.75 (1.35)	1.7 (0.82)	2.71 (1.75)	0.0040
Weed and pest management	2.75 (1.4)	3.08 (1.19)	3.98 (1.45)	<0.001
Soil fertility management	2.37 (1.08)	2.41 (0.89)	3.41 (1.35)	<0.001
Manure management	2.96 (1.73)	2.54 (0.9)	2.5 (1.27)	0.5679
Purchased fertilizers, seeds & other crop inputs	2.82 (1.66)	2.23 (1.21)	2.81 (1.67)	0.3905
Financing farm operation and investments	3.46 (2.32)	2.29 (1.37)	3.18 (1.84)	0.1384

Table 9 : Assessment of farmer's satisfaction regarding some aspects of the dairy operation on Conventional, Grazing and Organic dairy farms in Wisconsin in 2010 (scale from 1 (very dissatisfied) to 7 (very satisfied))

	Conventional	Grazing	Organic	p-value
Stress level	3.86 (1.41)	5.22 (1.31)	4.57 (1.5)	0.0030
Herd health	5 (1.36)	5.78 (1.09)	5.1 (1.22)	0.0141
Physical demands of farm work	3.93 (1.46)	5.11 (1.42)	4.34 (1.37)	0.0128

Lifestyle for the family on the farm	4.57 (1.57)	5.19 (1.55)	5.26 (1.54)	0.1275
Opportunities for children to join the farms	3.96 (1.69)	4.95 (1.2)	4.69 (1.66)	0.1382
Price received for milk	2.39 (1.29)	4.07 (1.62)	4.98 (1.76)	<0.001
Time off from farm work	3.07 (1.49)	4.15 (1.92)	3.74 (1.76)	0.0931
Net farm income	2.79 (1.75)	4.56 (1.31)	4.19 (1.67)	<0.001

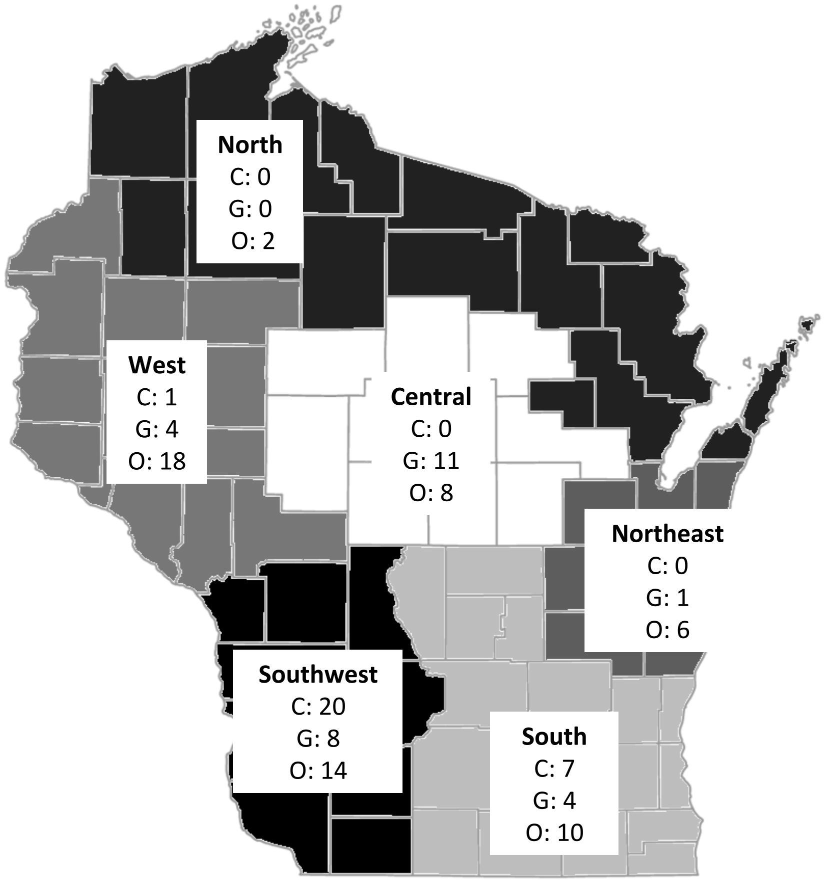

Figure 1. Distribution of the conventional (C), grazing (G), and organic (O) dairy farms surveyed in Wisconsin in 2010

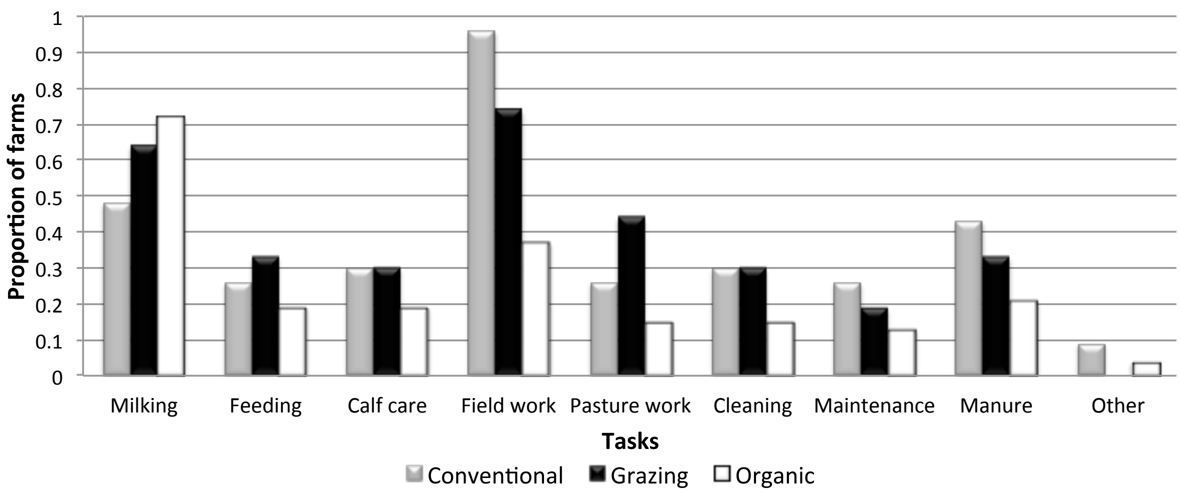

Figure 2. Main tasks for which farm managers were using hired help on selected Conventional, Grazing and Organic dairy farms in Wisconsin in 2010

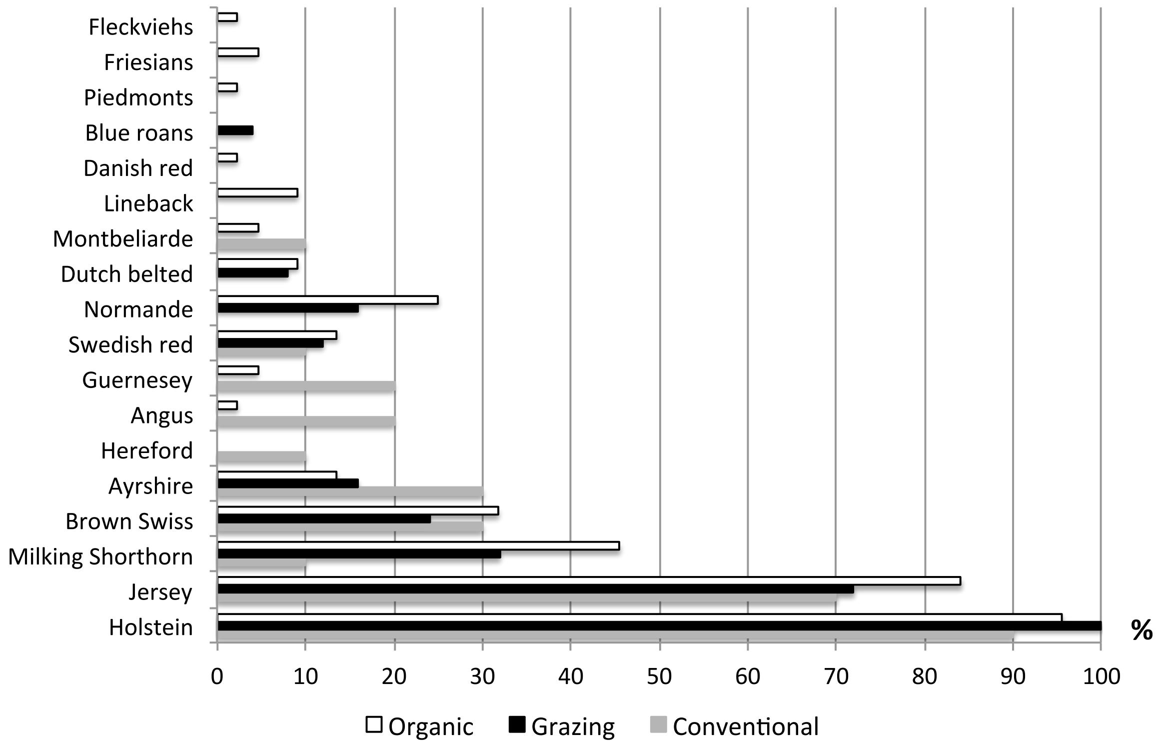

Figure 3 : Breeds included in the crossbred cows on selected farms in the Conventional, Grazing, and Organic management system in Wisconsin in 2010

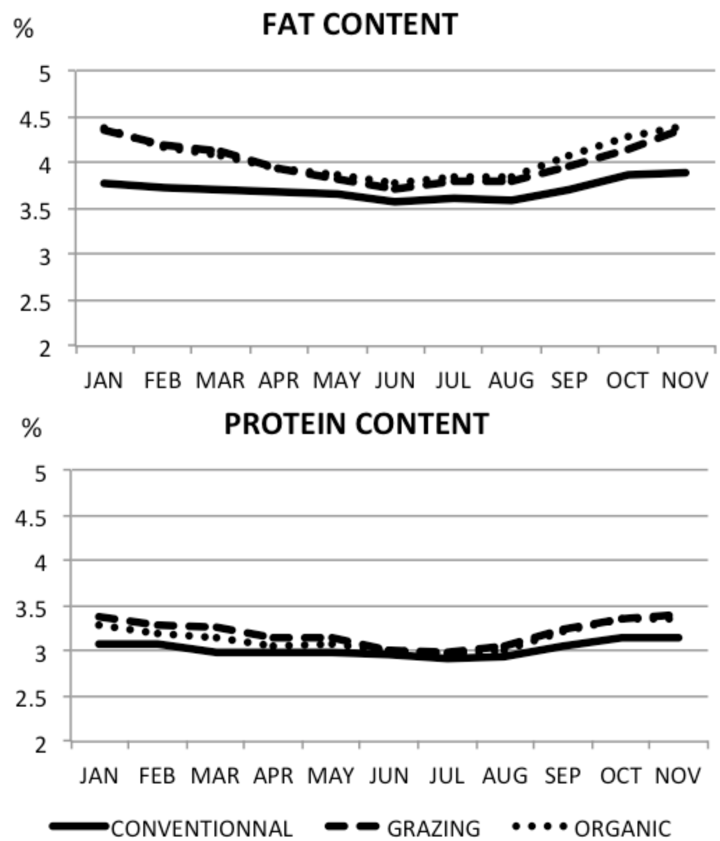

Figure 4 : Milk fat and protein content between January and November 2010 on Conventional, Grazing and Organic dairy farms in Wisconsin

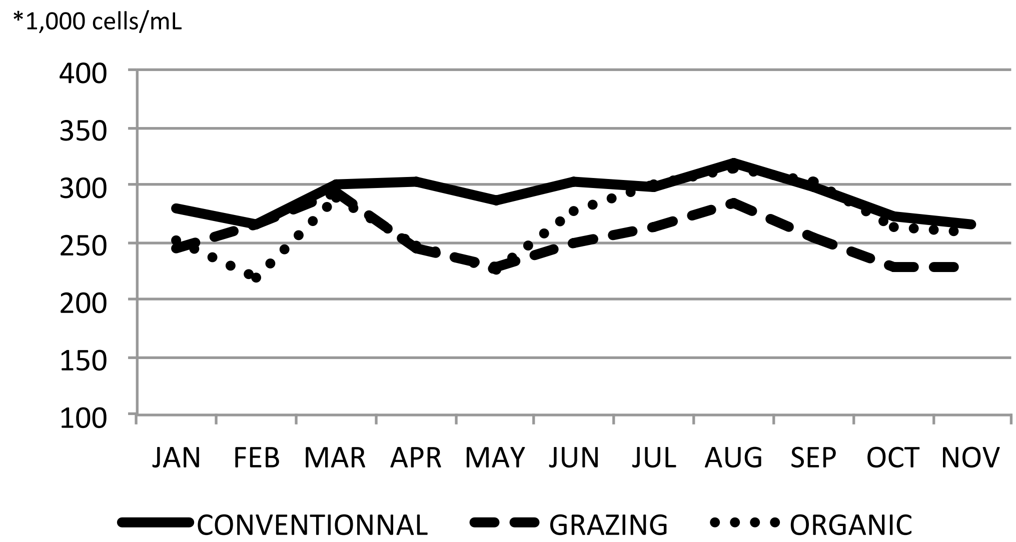

Figure 5 : Somatic cell count of milk produced between January and November 2010 on selected Conventional, Grazing and Organic dairy farms in Wisconsin

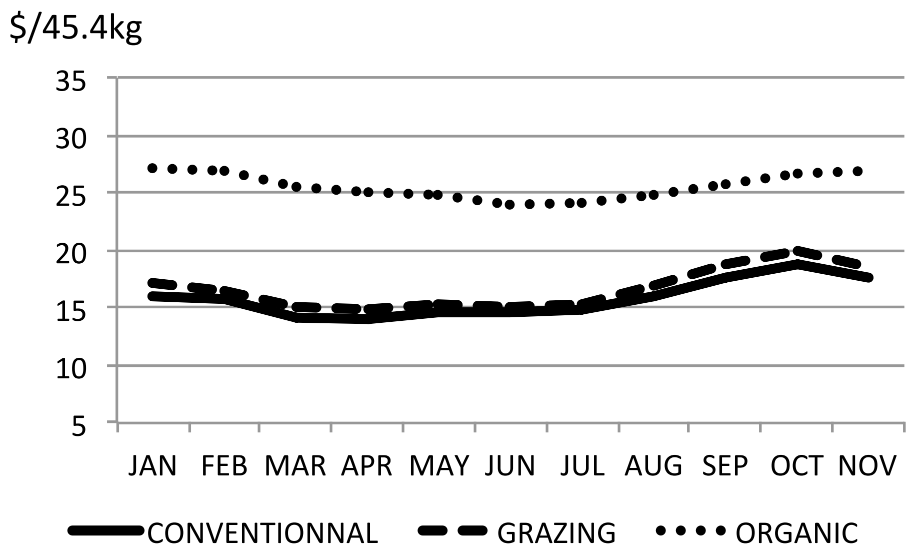

Figure 6 : Milk priced received by selected farmers in a Conventional, Grazing or Organic management system between January and November 2010 in Wisconsin

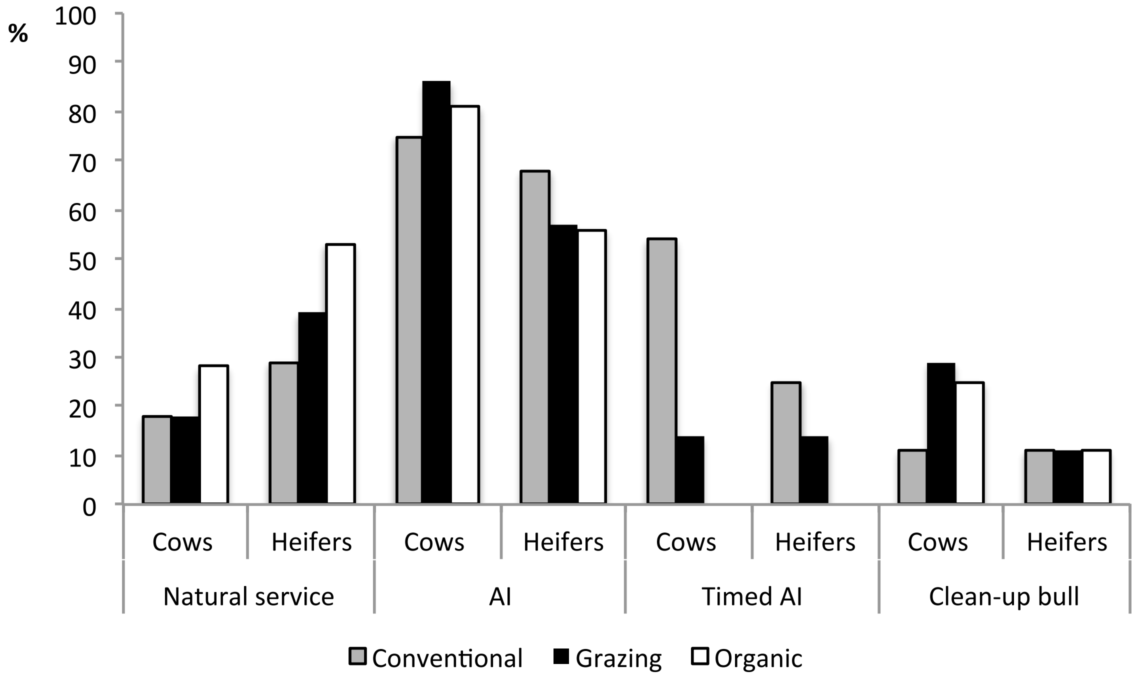

Figure 7 : Methods of reproduction used on Conventional, Grazing and Organic dairy farms in Wisconsin in 2010 reported as percentage of users (Numbers may not add-up as some of the farmers used multiple methods)

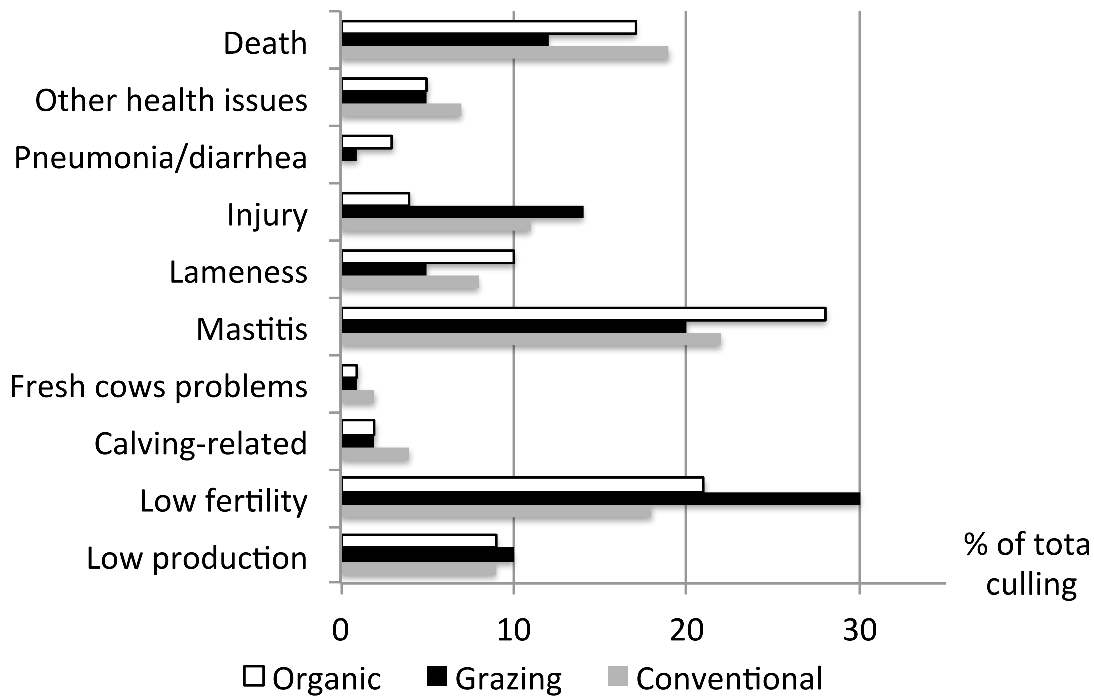

Figure 8 : Reasons for culling a cow on farms in the Conventional, Grazing and Organic management system in Wisconsin in 2010 express in % of total culling

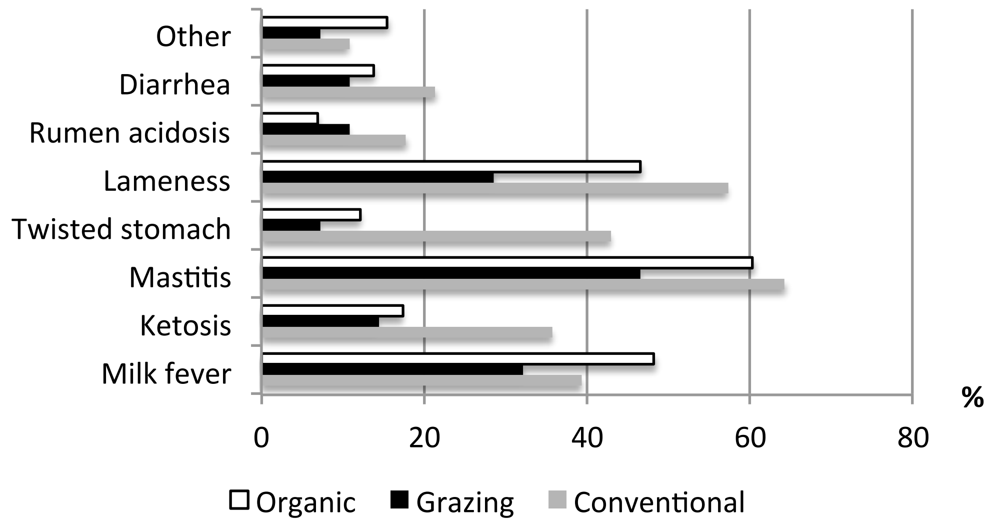

Figure 9 : Health conditions identified as an issue by the farmer on farms in the Conventional, Grazing and Organic management system in Wisconsin in 2010.

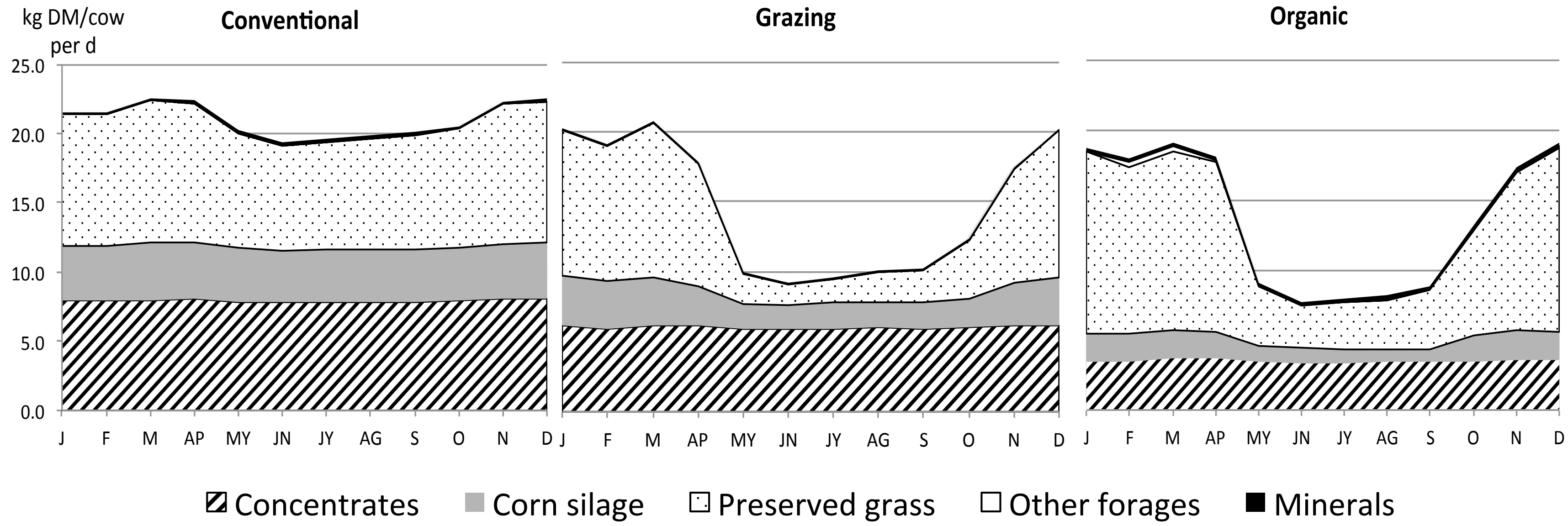

Figure 10 : Quantity of feeds offered to the lactating cows on selected Conventional, Grazing, and Organic dairy farms in Wisconsin in 2010

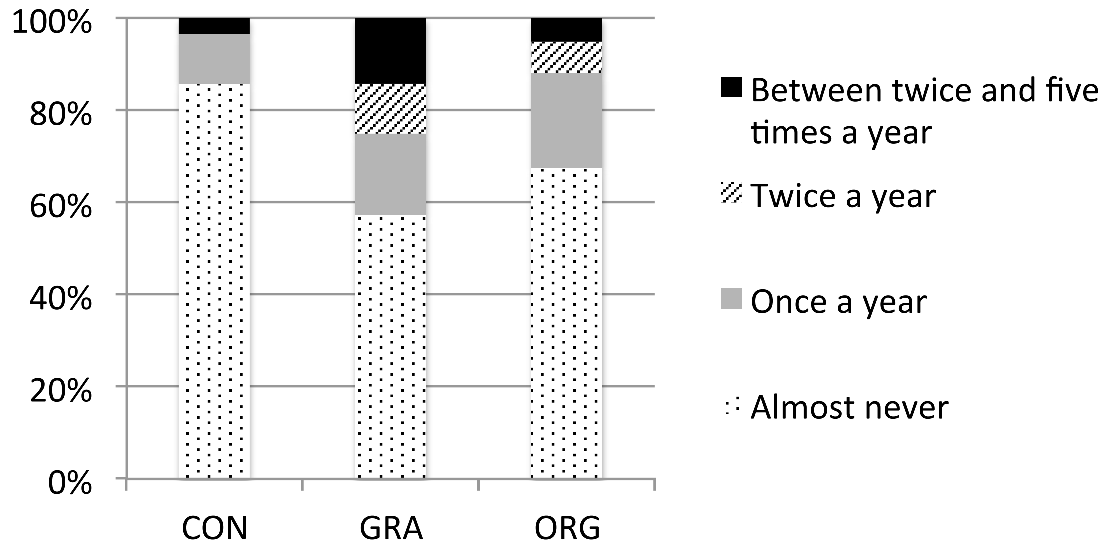

Figure 11 : Frequency of usage of alternative feeds by farmers in the Conventional, Grazin Organic management system in Wisconsin in 2010

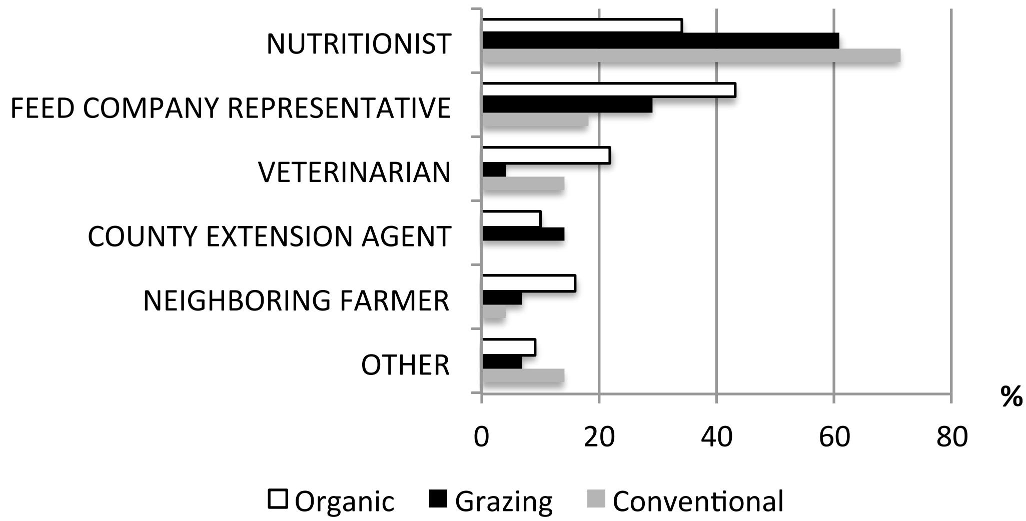

Figure 12 : Sources of animal nutrition advice used by farmers in the Conventional, Grazing, and Organic management system in Wisconsin in 2010

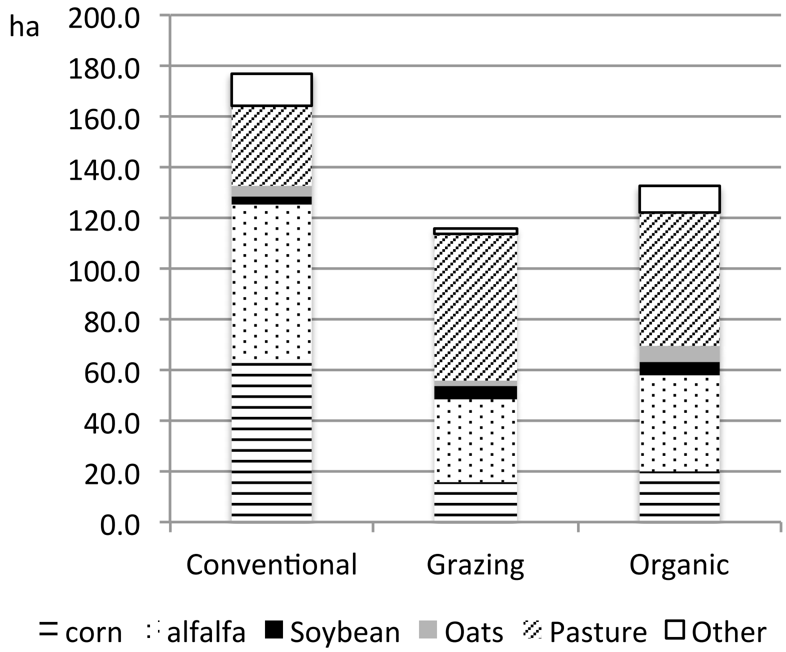

Figure 13 : Hectares of crops and pasture grown on Wisconsin dairy farms in the Conventional, Grazing and Organic management system in 2010 (Numbers may be higher than actual area available since some of the crops grown were double cropped with another one)

CHAPTER 3

KEY FACTORS ASSOCIATED TO HERD INCOME OVER FEED COST ON CONVENTIONAL, GRAZING, AND ORGANIC DAIRY FARMS IN WISCONSIN

INTERPRETIVE SUMMARY

Key factors associated to herd income over feed cost on conventional, grazing, and organic dairy farms in Wisconsin. By Dutreuil et al. A survey was conducted on conventional, grazing and organic dairy farms to identify key factors explaining farm income over feed cost. Variables related to farm size, labor, feeding management, culling, and milk were studied. For the 3 management systems, variables related to milk production were identified as key factors explaining farm income over feed cost. The rest of the variables differed substantially among the 3 systems. Those differences should be taken into account by extension specialists and policy makers to help dairy farmers improve economic sustainability.

Key factors associated to herd income over feed cost on conventional, grazing, and organic dairy farms in Wisconsin.

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A ABSTRACT

Profitability is essential to maintain the viability of Wisconsin dairy farms. Income over feed cost can explain most of the profitability on dairy farms. Our objective was to identify the key factors explaining herd income over feed cost on conventional, grazing and organic

Wisconsin dairy farms. A comprehensive survey was administered to collect information on farm structure, labor, herd management, feeding, cropping and economics for year 2010. A complete dataset for this analysis was available for 26 conventional, 27 grazing, and 47 organic farms. Data were analyzed using multiple regression analysis. The dependent variable selected was the income over feed costs. In total, 27 independent variables related to farm size, labor, culling, feeding management and milk production were selected. Farms were found to be representative of conventional, grazing and organic farms in Wisconsin by comparing collected data to the census of agriculture of 2010. For dairy farms in the conventional system, milk production on a per cow per year basis and the use of monensin were found to have a positive impact on income over feed costs, whereas the amount of purchased feed offered daily and the total amount of feed offered daily to the lactating cows had a negative impact. For the grazing system, milk production, the length of the grazing season, the amount spent on fertilization and the length of the lactation had a positive impact on the income over feed costs, whereas the proportion of hired labor had a negative impact. For the organic system, milk price, milk production, the use of nutritional advice and the proportion of heifers had a positive impact on income over feed costs, whereas milk protein content, feed purchased and the hectares of cropland per cow had a negative impact. Our results demonstrated that factors explaining the income over feed costs on the 3 management systems were substantially different. Those differences should be taken into account when advising farmers.

Key words: management system, regression analysis, profitability.

B INTRODUCTION

Profitability is a key parameter for the viability of dairy farms. Research on factors influencing profitability is especially important for Wisconsin, a state that ranks second in the US with 14% of national milk production (USDA, 2013) and for which the dairy industry generated $26.5 billion in 2012. Several studies have looked at variables impacting profitability using different indicators and techniques (Gloy et al, 2002; Gillespie et al, 2009; Meul et al, 2012; Atzori et al, 2013). From those studies, milk price, milk quantity, milk composition, milk quality, number of cows, and education of the farmer have been identified as one key factors explaining profitability on dairy farms.

However, those studies focused mainly on conventional dairy farms and over the past few years, more and more farmers have implemented alternative ways of farming by grazing more intensively (Taylor and Foltz, 2006) or by farming organically (Greene, 2001). Conventional, grazing, and organic dairy farms differed in size and management practices (Kriegl et al, 1999; McBride and Green, 2007) and consequently, factors influencing farm profitability could differ on the 3 management systems. Even though previous studies have investigated the difference in profitability of conventional and organic farms (Rotz et al, 2008) or conventional and grazing farms (Kriegl et al, 1999; White et al, 2002; Rotz et al, 2008; Hanson et al, 2013), a comparative analysis of the 3 systems and modes of farming could not be found in the literature. Moreover, variables related to feeding management or culling have not been investigated.

Profitability of dairy farms can be assessed using different indicators such as net return on assets, debt-asset ratio or milk income over feed cost (IOFC) (Nehring et al, 2009). The IOFC, defined as the difference between income from milk and cost of feed, was highly relevant for this study for a variety of reasons. First, it includes both the main source of expenses (feed, USDA-

ERS, 2013) and the main source of revenues (milk) of the dairy farm. Secondly, the IOFC can be easily calculated and used to compare dairy farms when expressed on a per cow basis. Lastly, the IOFC represents a margin, which evaluates farm profitability even though high volatility in milk and feed prices occur, as has been observed over the past few years.

The objective of this study was therefore to determine key factors explaining the IOFC on conventional, grazing, and organic dairy farms in Wisconsin, thus, allowing a comparison across the 3 systems. Results are of importance for farmers who are seeking profitable management strategies, for advisors or consultants, and for policy makers interested in the viability of dairy farms.

C MATERIALS AND METHODS

1 Data collection

An interdisciplinary and comprehensive survey instrument was developed to collect information on Wisconsin dairy farms. Data were collected on farm structure, labor, herd management, feeding, cropping and economics for year 2010. Further details on sampling and survey protocol can be found in Hardie et al. (2014). Farms were selected from the Wisconsin's official lists of certified milk producers and organic milk producers and a list of graziers compiled from extension agents from the University of Wisconsin. Dairy farms were classified across 3 different management systems: organic, grazing and conventional. The organic system included farms that were certified organic; the grazing system included farms that used grazing as a major source of feed during the grazing season (i.e., at least 30% of the dry matter intake of the lactating cows from pasture during the grazing season) and that rotated their cows to fresh pasture at least every 3 days (qualified as managed intensive grazing) but were not certified organic; and the conventional system included farms that were the non-organic, non-grazing farms. A total of 114 farms were surveyed: 28 conventional farms, 28 grazing farms, and 58 organic farms. The location of the surveyed farms can be found in Figure 1. Complete datasets for this study were available for 26 conventional farms, 27 grazing farms and 47 organic farms. The remaining farms were not included in the analysis because data on some of the variables of interest for this study were missing.

2 Dependent variable

The IOFC was considered the dependent variable for 2 reasons: 1) feed is the primary expense on dairy farms representing 77.3% of all operating costs in 2010 in Wisconsin (USDA-ERS, 2013) and 2) the IOFC has been shown to be a good proxy for dairy farm profitability (Wolf, 2010). Average IOFC for the 3 systems can be found in Table 1. The IOFC was calculated as follows: IOFC ($/cow per d) = [Milk sold (kg/cow per d) * Milk price ($/kg)] – Feed cost ($/cow per d)

The quantity of milk sold and the milk price were collected from monthly milk checks. The milk price corresponded to the mailbox price and was expressed in $ per 1,000kg. The average milk price for the year was calculated as a weighted average using the milk price and the quantity of milk sold each month. The feed cost was calculated using data collected on feeding practices and feed prices. Costs for seeds, fertilizers, weed and pest control, irrigation, custom labor and storage and transportation were used to calculate the cost of homegrown feeds. Cost of land rental or machinery was not included in the calculation. For feed purchased, the purchased price was used as feed cost. The IOFC was calculated for the lactating cows.

3 Independent variables

A total of 27 independent variables were selected for this analysis based on a variety of published results and personal knowledge of researchers and extension specialists in the field (Table 1). They can be classified into 5 categories:

1) Farm size: It has been shown that farmers can be more economically efficient by increasing herd size, by increasing land size, or a combination of both (Wilson, 2011; Cabrera et al., 2010; Winsten et al, 2000) so the number of cows and the total number of ha operated were included in the analysis. The ratio land:cows was also of interest, so the hectares of cropland and pasture per cow (including lactating and dry) were added (Frank and Vanderlin, 1997). The cost of fertilizer per ha was used as a measure of crop management intensity.

2) Labor: Profitability can also be improved through labor efficiency (Wilson, 2011). Therefore, the total number of hours worked per cow per yr was used as a measure of labor efficiency and the proportion of paid work gave an indication of reliance on hired labor. It was hypothesized that having more decision makers on the farm could improve profitability through the exchange of ideas, so the number of decision makers was also included. Based on research showing better profitability for better-educated farmers (Gloy et al, 2002), the level of education was added by reporting farmers with at least a completed 4 yr degree.

3) Feeding management: In using the IOFC as a measure of profitability, it was hypothesized that feeding practices could substantially impact farm profitability. Seven variables

were selected: the average amount of concentrates fed to the lactating cows every day, the average amount of corn silage fed to the cows every day, the total amount of feed offered to the cows every day, the average amount of purchased feed offered to the cows every day, the use of using mixed feed, the length of the grazing season expressed in days, and the number of individuals giving nutritional advice to the farmer. The data for the first 4 variables were collected on a monthly basis and averaged for the year. For the grazing and the conventional system, the use of monensin for the lactating cows was also added to the analysis. For the grazing system, the number of days before cows were rotated to fresh pasture during the grazing season was also included in the analysis. This variable was used to quantify the intensity of grazing. This variable was deemed not relevant to the conventional and organic systems, as most of the farmers included in those 2 systems do not rotate cows frequently.

4) Culling: Involuntary culling can be a significant cost on dairy farms (Orpin and Esslemont, 2010) that can affect profitability. The proportion of first lactation animals in the herd, the length of the lactation in days (Atzori et al, 2013), the proportion of culled cows, and the proportion of heifers (non-productive young stock) in relation to cows were used to assess culling rate on the farm.

5) Milk: It has been shown that milk production and milk price are also an important factor explaining profitability on dairy farms (Wilson, 2011) and for that reason, average rolling herd average (RHA), average fat and protein content, average somatic cell count and average milk price were included in the analysis. The data for the last 4 variables were collected on a monthly basis and averaged for the year.

4 Multiple regression analysis

A separate model, one for each system (conventional, grazing, and organic), was built using the regsubsets function from the leaps package in R (version 3.0.2; http://www.R-project.org). The choice of having a separate model for each system was done due to differences in sample size and in some of the predictors selected among the 3 systems and because it made the results easier to interpret for this particular study. For each system, the best 3 models from 1 up to 15 variables based on adjusted R-square were generated using the leaps algorithm (Lumley, 2009). Thus, a total of 45 models were obtained for each system. For each system, a single model was selected as a good candidate to explain IOFC based on a combination of statistical significance, model diagnostics (assess the linearity of the function, the equal variance and independence of the error terms, the presence of outliers, and the normality of the error terms), and variables of interest. First, all models for which model diagnostic showed violation of some of the assumptions stated before were discarded. Then, in the remaining models, the 5 to 10 models with the highest adjusted R-square were kept. Out of those 5 to 10 models, the one including most of the variables that were identified as having an important impact on IOFC (see paragraph below and Table 3) was selected. For the model selected, interactions between the all-variable pairs (for variables included in the model) were also assessed.

Variables were also classified in 3 groups according to their frequency of inclusion in the models. Variables that were included in more than half of the 45 models were classified as having an impact on IOFC (code 1 in Table 3); variables that were included in less than 20% of the models were classified as not having an impact on IOFC (code 3 in Table 3); and the rest of the variables were classified as having weak evidence of impact (code 2 in Table 3). This technique allowed for the classification of predictor variables according to their impact on the response variable.

D RESULTS

1 Farm characteristics:

Farms in the conventional system had on average 134 cows producing 9,768 kg/cow per yr on 187 ha (Table 1). Milk composition was 3.72% fat and 3.03% protein with a SCC of 290,000 cells/mL. Conventional farmers received on average $384.40/1,000 kg milk during year 2010. The number of decision makers on the farm was 1.9, and 23% of the farmers surveyed had completed at least a 4-year degree. Workload on the farm represented 137 hr/cow per year, of which 21% was hired labor. Monensin and mixed feed were used by 58% of the conventional farmers. Calculated IOFC was $6.85/cow per d.

Farms in the grazing system had on average 95 cows producing 7,676 kg/ cow per yr on 137 ha (Table 1). Milk composition was 3.97% fat and 3.17% protein with a SCC of 249,000 cells/mL. Milk price was on average $364.90/1,000 kg milk during year 2010 for the grazing farms surveyed. The number of decision makers on the farm was 1.9, and 41% of the farmers surveyed had completed at least a 4-year degree. Workload on the farm represented 84 hr/cow per yr, of which 14% was hired. Mixed feed was used by 41% and monensin by 19% of the farmers. Calculated IOFC was $6.39/cow per d.

Farms in the organic system had on average 68 cows producing 6,380 kg/ cow per yr on 143 ha. Milk composition was 4.02% fat and 3.13% protein with a SCC of 270,000 cells/mL. Organic farmers received on average $561.40/1,000 kg milk during year 2010. The number of decision makers on the farm was 2.34, and 28% of the farmers surveyed had completed at least a 4-year degree. Workload on the farm represented 137 hr/cow per yr, of which 10% was hired. Total mixed rations were used by 34% of the organic farmers, and the calculated IOFC was $7.89/cow per d.

2 Model selection:

Model selection for each system was based on the amount of variation explained by the model (Table 2), the number of independent variables included in the model in regard to the number of observations, and regression diagnostic (not shown). For the 3 models selected, no assumption violations were found, no large issues with multicollinearity were detected, and no potential outliers were identified. Also, as much as possible, model selected had to include variables that were found to be of importance in explaining the IOFC (Table 3).

Based on the selected model, interactions between all pairs of variables from this model were added and a backwards elimination procedure was conducted to assess the potential significance of these interaction terms. None of these terms were found significant at $p<0.05$. As a result, no interactions were included in the final models.

3 Explaining IOFC for the conventional system

The model selected for the conventional system explained 89% (R-square=0.89) of the variance in IOFC with an adjusted R-square of 0.86 when including 5 variables (Table 2). The RHA, the use of monensin and the use of mixed feed had a positive impact on IOFC whereas the quantity of feed offered and the quantity of feed purchased had a negative impact on profitability. Results indicated that for each 1,000kg/cow per yr increase in milk production, IOFC increased by $0.40/cow per d (with all other variables held constant). The use of monensin increased IOFC by $0.89/cow per d (with all other variables held constant). In the same way, the use of mixed feed increased IOFC by $2.49/cow per d (with all other variables held constant). However, for each 1 kg DM increase in feed offered or feed purchased, the IOFC decreased by $0.16 and $0.23/cow per d, respectively (with all other variables held constant).

The best subsets analysis indicated that 2 other independent variables, although not included in the final model selected, had some importance in explaining the IOFC as indicated in Table 3. Those variables were milk fat content and length of the grazing season. On the contrary, 12 out of the 26 independent variables contained in the models were included in less than 20% of the models and were categorized as not having influence on profitability for farms included in the conventional system in Wisconsin. Those variables belonged to the pre-defined categories of farm size (total land operated and ha of cropland per cow), labor (number of decision makers, proportion of hired labor and total hours worked per cow), feeding management (amount of corn silage fed and use of nutritional advice), culling (proportion of heifers, proportion of first lactation cows, proportion of culled cows, and length of the lactation), and milk production (milk price). Based on the data and the various analyses performed, the potential impact of the other 7 independent variables (number of cows, milk protein content, SCC, amount of concentrates fed, amount spent on fertilization, level of education and ha of pasture per cow) on the IOFC for the conventional system could not be definitively ruled out although such possible impact appears weaker than the 7 variables with clear impact.

4 Explaining IOFC for the grazing system

The model selected for the grazing system explained 73% (R-square=0.73) of the variance in IOFC with an adjusted R-square of 0.67 when including 5 variables (Table 2). The RHA, the length of the grazing season, the amount spent on fertilization and the length of the lactation had a positive impact on the IOFC for the grazing farms. The reliance on hired help was the only variable included in the model with a negative impact on the IOFC. Results indicated that for each 1,000kg/cow per yr increase in milk production, IOFC increased by $0.30/cow per d (with all other variables held constant). Increasing the number of days grazed during the year by 1, the length of the lactation by 1 d, or the amount spent on fertilizer by $1/ha; increased the IOFC by $0.02, $0.01, and $0.01/cow per d, respectively (with all other variables held constant). On the other hand, increasing hired labor by 1 percentage point decreased the IOFC by $1.75/cow per d (with all other variables held constant).

The best subsets analysis indicated that, in total, 6 variables out of the 27 independent variables had some importance in explaining the IOFC on the grazing system because they were included in more than half of the models tested (Table 3). Those variables were the five variable discussed above (Table 2), and ha of cropland per cow. On the contrary, 11 variables out of the 27 independent variables selected were found to have no influence on IOFC for the grazing system. Those variables belonged to the pre-defined categories farm size (total land operated and ha of pasture per cow), labor (level of education), feeding management (amount of concentrates fed, amount of corn silage fed, amount of purchased feed fed, use of mixed feed, use of monensin, use of nutritional advice), culling (proportion of heifers), and milk production (milk protein content). Results regarding the impact of milk price, number of cows, milk fat content, SCC, number of days before cows are offered fresh pasture, amount of feed offered, proportion of hired labor, total hours worked per cow, proportion of first lactation cows, and length of the lactation were inconclusive based on the data available.

5 Explaining IOFC for the organic system

The model selected for the organic system explained 78% (R-square=0.78) of the variance in IOFC with an adjusted R-square of 0.74 when including 7 variables (Table 2). The RHA, the milk price, the proportion of heifers, and the nutritional advice had a positive impact on profitability whereas the protein content in the milk, the amount of feed purchased and the number of hectares of cropland per cow had a negative impact on IOFC. Results indicated that for each increase of 1,000kg/cow per yr in milk production, IOFC increased by $1.00/cow per d (with all other variables held constant). Increasing milk price by $1/1,000 kg of milk or the proportion of heifers on the farm by 1 point, or having one more source of advice for feed management increased the IOFC by $0.03, $3.57 and $1.25/cow per d, respectively (with all other variables held constant). On the other hand, increasing protein content of milk by 1 percentage point, feed purchased by 1 kg DM/cow per d, or the cropland area by 1 ha/cow decreased IOFC by $4.61, $0.18 and $0.96/cow per d, respectively (with all other variables held constant).

The model selected included all the variables that had some importance in explaining the IOFC on the organic farms. The results of multiple regression analysis indicated that number of cows, length of the grazing season, amount of concentrates fed, amount of feed offered, amount spent on fertilization, level of education, number of decision makers, total land operated, proportion of hired labor, total hours worked per cow, proportion of first lactation cows, ha of pasture per cow, and length of the lactation had no impact on profitability on organic systems since those variables were included in less than 20% of all the models selected (Table 3). Definitive conclusions regarding the impact of the last 5 independent variables tested (milk fat content, SCC, amount of corn silage fed, use of mixed feed, and proportion of culled cows) on the IOFC of organic system could not be made based on the results of multiple regression analysis performed and the data.

E DISCUSSION

1 Representativeness of the farms

The data on size of the farm (number of cows and ha) and the milk production per cow in our sample were compared to the data from the census of agriculture in 2010 to assess their representativeness. Our sample of organic farms was found to be representative of organic farms in the state of Wisconsin in 2010 as they had about the same mean numbers of cows (74 and 61, for our sample and the census of agriculture, respectively), producing similar amount of milk (6,380 and 6,277 kg/cow per yr for our sample and the census of agriculture, respectively) on similar mean numbers of ha (145 and 142 ha, for our sample and the census of agriculture, respectively). The conventional farms in our sample had the same mean numbers of cows than the conventional farms in the 2010 census of agriculture (128 and 135 cows, respectively), producing similar mean amounts of milk (9,768 and 9,338 kg/cow per yr, respectively) but had less available land for cropland or pasture. The grazing farms in our sample were found to have more cows (+37 cows) producing more milk (1,069kg/cow per yr) on more land (+59 ha) than the grazing farms in the census of agriculture in 2010. However, the sample size for grazing farms in the census of agriculture was small (n = 14) and they defined their sample as not representative of grazing farms in Wisconsin. Consequently, we were not able to assess the representativeness of the grazing farms in our sample.

2 Explaining IOFC for the conventional system

The 7 most important factors explaining the IOFC on the conventional system were related to milk production (fat content and quantity of milk produced) and feeding practices (length of the grazing season, quantity of feed offered, quantity of feed purchased, use of mixed feed and monensin; Table 3). The link between milk production and profitability has been established in previous studies. Gloy et al (2002) reported an increase of 0.3% in return on assets for each increase of 1,000 kg/cow per yr in milk production. Atzori et al (2013) reported that milk composition, milk yield, and SCC represented the most important factors that contributed to the IOFC. The evidence was inconclusive to allow for conclusions about the relationship between the IOFC and milk protein content or SCC even though those variables may have an impact on IOFC based on previous studies. Regarding the variables related to feeding practices, our results are in line of results from previous studies. Lapple et al (2012) showed that direct costs including feeding costs decreased by \$0.16/cow per d as the length of the grazing season increased by 1 d. Ramsbottom et al (2011) reported a decrease of \$0.065/cow in net margin for each kg increase in feed purchased. Tozer et al (2003) reported a higher net farm income for farms using mixed feed compared to farms feeding pasture and concentrate separately (+\$2.76/cow per d). No studies were found on the relationship between IOFC and the quantity of feed offered or between IOFC and the use of monensin. Total feed cost is the result of 2 components: the quantity of feed and its cost. As a result, it is not surprising that increasing the total amount of feed offered would decrease the IOFC by increasing total feed cost. Experimental studies found no effect of monensin on milk production or energy corrected milk (Broderick, 2004; Odongo et al, 2007). However, in our sample, farms using monensin were producing more milk (+2,720 kg/cow per year, p-value<0.01) and had a higher IOFC (+$2.95/cow per d, p-value<0.01) than farms that were not using monensin. Since we used survey data, it could be possible that other factors besides the use of monensin were influencing the IOFC and, as a result, further research should investigate the actual relationship between monensin and IOFC.

All variables related to culling (proportion of culled cows, first lactation cows, non-producing animals, and the length of the lactation) were found to be not important in explaining the IOFC on the conventional system (Table 3). Atzori et al (2013), using principal component analysis, concluded that herd profile, including variables related to culling, had a small effect on profitability. Variables related to labor (number of decision makers, hired work, and total hours worked per cow) were also found to have no effect on profitability. Although few studies focused on the impact of labor on profitability, Cabrera et al (2010) reported a negative relationship between hired labor and technical efficiency and Meul et al (2012) showed that the number of workers positively influenced farm profitability. In our data, we were able to obtain a correlation coefficient of +0.42 between the number of decision makers on the farm and the IOFC but it seemed that the other explanatory variables included in the analysis were more important in explaining the IOFC. Likewise, milk price, which was found to have a positive impact on profitability in previous studies (Gillespie et al, 2009; Meul et al, 2012), was not significant for the conventional farms, probably due to the small variation in milk price among the conventional farms in our sample (Table 1). For the conventional system, no relationship between the use of nutritional advice and the IOFC was found, whereas Mishra and Morehart (2001) highlighted the importance of using extension services to improve farm profitability. As did Gillespie et al (2009), we found no effect of total land operated on IOFC.

As opposed to our results, previous studies (Hoshide et al, 2011; Gloy et al, 2002; Gillespie et al, 2009) showed that farm profitability was positively correlated to the number of cows on the farm. In these studies, profitability was defined as net return to management, which is more sensitive to farm size than IOFC (MacDonald et al, 2007). Atzori et al (2013), found that herd size had a small effect on IOFC. However, Atzori et al (2013) used the same feed costs for all the farms so that the economies of scale might not have been included in their analysis. More studies are needed to determine the impact of cows number on IOFC. The literature is inconsistent in regard to the impact of education on farm profitability. Our results were inconclusive regarding the impact of education on farm profitability and results from previous studies were contradictory. Gloy et al (2002) and Gillespie et al (2009) found no effect of education on profitability, whereas Wilson (2011) showed that high performance farmers were more educated and Mishra and Morehart (2001) reported a positive relationship between education and farm profitability.

3 Explaining IOFC for the grazing system

As for the conventional system, milk production and length of the grazing season were identified as key factors in explaining the IOFC on the grazing farms (Table 3). On the grazing system, fertilization expenses, the number of decision makers, the proportion of culled cows and the land size of cropland available per cow were also found to be of importance in explaining the IOFC. Delaby et al (1996) showed that increasing N fertilization increased sward productivity and milk production. According to our results, fertilization is a key variable in explaining the IOFC on the grazing system. However, because of the limitation in our data, we used an indirect measure of fertilization by examining the amount spent per ha. In future studies, a more direct measure of fertilization, such as the amount of N applied, should be used to confirm our results. The grazing system was the only management system for which the number of decision makers was significant in explaining the IOFC. This fact is in agreement with the previous work of Meul et al. (2012) who found a positive relationship between the number of workers and farm profitability on farms using grazing. The proportion of culled cows was positively correlated to IOFC. On the grazing farms, the fraction of culled cows was low, ranging from 0.09 to 0.36. Within that range, the increase in culling rate might have a positive impact on IOFC by possibly improving herd genetic index and cow performance. Finally, the larger land size of cropland available per cow was found to decrease feed costs and, as a result, increased IOFC (Frank and Vanderlin, 1997).

Some variables that have been found to be important in explaining the IOFC or profitability on grazing dairy farms in previous studies were not significant in this study. For instance, even though Tozer et al (2004) showed that increasing supplementation on pasture increased profitability, we found no effect of the amount of concentrates fed to the cows on the IOFC. Likewise, whereas Ho et al (2013) showed, using simulation, that using mixed feed for cows on pasture increased profitability, the use of TMR was not included in most of the models explaining IOFC on the grazing system. The same contradicting results held true for the milk protein content (Atzori et al, 2013), the use of a nutritionist (Mishra and Morehart, 2001), the amount of feed purchased (Ramsbottom et al, 2011), and the level of education (Wilson, 2011). However, those previous studies were conducted on conventional farms or farms using grazing extensively (rotating their cows more than every 3 days). Differences of results between our study and previous ones could be explained by the specificities of farms using intensive grazing in our sample.

Given the small sample size of grazing farms, final conclusions regarding the influence of several variables on the IOFC were not possible. This was the case for milk price, number of cows, milk fat content, SCC, occupancy period on pasture, total quantity of feed offered, hired labor, hours worked per cow, proportion of first lactation cows, and length of the lactation. Contradictory results have been reported above regarding the impact of cow number (Gillespie et al, 2009; Atzori et al, 2013) on farm profitability. The impact of cow number on farm profitability seems to depend on the type of indicator used to measure profit, the type of farms studied and the other variables included in the analysis. Unlike Foltz and Lang (2005) and Rougoor et al. (1999), who showed that farmers rotating cows more frequently were more profitable, we were not able to draw a final conclusion regarding the impact rotation frequency on IOFC. However, our grazing farms included farmers who were rotating cows every 4 days or less, whereas studies from Rougoor et al (1999) or Foltz and Lang (2005) included farms with longer rotation length (more than 1 week).

4 Explaining IOFC for the organic system

The 7 most important factors explaining the IOFC on the organic system were milk price, milk quantity, milk protein content, the amount of feed purchased, the use of nutritional advice, the proportion of heifers, and the hectares of cropland per cow. Milk production, milk protein content, and the amount of feed purchased were found significant for the same reasons they did in the models for the conventional system (Gloy et al, 2002; Ramsbottom et al, 2011; Atzori et al, 2013). Unlike for grazing and conventional systems, milk price was significant in explaining the IOFC in organic system, because as indicated by the standard deviation (Table 1), the variability in milk price was higher for the organic system compared to the 2 other management systems. This result corroborates findings from Gillespie et al (2009) who reported a significant influence of milk price in explaining net return. The organic system was the only management system for which the use of nutritional advice was included in the model explaining the IOFC. The use of extension services had previously been reported as having a positive impact on profitability (Mishra and Morehart, 2001).

As reported in previous studies, the variables related to culling (proportion of first lactation cows, length of the lactation) (Atzori et al, 2013) or labor (level of education, number of decision makers, proportion of hired labor, and hours worked per cow) (Cabrera et al, 2010; Meul et al, 2012), as well as the total land operated, and the hectares of pasture per cow were not significant in explaining the IOFC on the organic farms, a result similar to the conventional system. The organic system was the only one for which the number of cows was not important in explaining the IOFC. Previous studies have reported no effect of cow number on the IOFC (MacDonald et al, 2007; Atzori et al, 2103) and the organic farms had the smallest number of cows with the least variation (Table 1). In addition, the length of the grazing season, the amount of concentrates fed, the amount of feed offered and the amount spent on fertilization were not significant in explaining the IOFC.

Results for 5 variables were inconclusive on the organic farms. Those variables were: milk fat content, SCC, amount of corn silage offered, use of mixed feed, and proportion of culled cows.

5 Comparison of the 3 management systems

Factors explaining the IOFC on the 3 management systems were distinctly different (Table 3). Only milk production was found to be of importance consistently in explaining the IOFC among the 3 management systems (Table 3). Other variables related to milk production (milk fat content, milk protein content, SCC) were found to be either important or uncertain in explaining the IOFC. Given that milk production is the only source of income in our calculation of the IOFC, it is not surprising that variables related to milk were found to be important in explaining farm IOFC for the 3 systems.

On the other hand, total land operated was the only variable that consistently had no impact on the IOFC for the 3 management systems. Other variables which were found of no importance or uncertain importance were: number of cows, amount of concentrate fed, amount of corn silage fed, level of education, proportion of hired labor, the length of the lactation, the hectares of pasture per cow, the proportion of first lactation cows and the total hours worked per cow. Regarding those variables, previous studies found either no effect or contradictory results (Gloy et al, 2002; Wilson, 2001; Meul et al, 2012; Gillespie et al, 2009).

Some of those variables were found to have an effect on only one or 2 of the 3 management systems. This was the case for the length of the grazing season, which was found to be of importance in explaining the IOFC on the conventional and the grazing systems, but not the organic system. The use of a nutritionist and the proportion of non-productive animals were found significant on the organic system only and the number of decision makers was found to be significant on the grazing system only.

Milk price, milk protein content, amount of feed purchased, amount spent on fertilization, the use of mixed feed, and the proportion of culled cows had different influences on IOFC depending on the management system.

6 Limitations of the study

Results from this study are limited by the number of farms surveyed, especially the number of conventional and grazing farms. Moreover, the representativity of the grazing farms was difficult to assess and the sampling method using list from extension specialist might have caused the sample to be biased, including farmers that seek for management advice. Also, data were only available for the year 2010 when it would be important to study more than one year of data as profitability on dairy farms is variable across years (Shadbolt et al., 2009). Finally, even though the IOFC has been proven to be a good proxy for farm profitability (Wolf, 2010), it provides only a partial economic analysis and other factors could also affect overall profitability of a dairy farm.

F CONCLUSION

Multiple regression analysis was successful at identifying key factors explaining income over feed cost of conventional, grazing and organic dairy farm systems in Wisconsin for year 2010. Those factors were milk production, quantity of feed offered, amount of feed purchased and the use of monensin, and mixed feed for the conventional system; milk production, length of the grazing season, amount spent on fertilization, proportion of hired labor and length of lactation on the grazing system; and milk price, milk protein content, milk production, amount of feed purchased, the use of a nutritionist, the proportion of heifers, and the ha of cropland per cow on the organic system. Overall, factors influencing IOFC were distinct among the 3 systems and those differences should be taken into account by extension faculty or policy makers to help dairy farmers maintaining or improving their profitability.

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Table 1 : Mean (standard deviation) of selected variables on conventional (C), grazing (G), and organic (O) dairy farms in Wisconsin in 2010

	C (n=26)	G (n=27)	O (n=47)
	Mean (SD)	Mean (SD)	Mean (SD)
Income over feed cost ($/cow per d)	6.85 (2.24)	6.39 (1.20)	7.89 (2.58)
Variables related to farm size			
Cows (#)	134 (182)	95 (61)	68 (52)
Total land operated (ha)	187 (158)	137 (74)	143 (130)
Cropland per cow (ha/cow)	1.50 (0.98)	0.99 (1.43)	1.17 (0.73)
Pasture per cow (ha/cow)	0.62 (1.45)	0.57 (0.28)	0.77 (0.55)
Amount spent for fertilization ($/ha)	81.3 (96.6)	50.0 (48.9)	38.6 (49.2)
Variables related to labor			
Number of hours worked (hrs/cow per yr)	137 (61)	84 (37)	137 (76)
Hired work (proportion)	0.21 (0.27)	0.14 (0.20)	0.10 (0.16)
Decision makers on the farm (#)	1.92 (0.80)	1.89 (0.85)	2.34 (0.84)
Farmers who completed a 4-year degree (proportion)	0.23 (0.43)	0.41 (0.50)	0.28 (0.45)
Variables related to feeding management			
Amount of concentrates fed (kg DM/cow per d)	7.8 (3.1)	6.1 (2.4)	3.6 (2.1)
Amount of corn silage fed (kg DM/cow per d)	3.9 (3.2)	2.5 (2.0)	1.4 (2.3)
Amount of feed offered (kg DM/cow per d)	20.8 (5.4)	14.1 (3.7)	13.0 (5.2)
Amount of purchased feed fed (kg DM/cow per d)	5.0 (3.7)	6.8 (4.0)	2.6 (3.4)
Use of mixed feed (proportion)	0.58 (0.50)	0.41 (0.50)	0.34 (0.48)
Length of the grazing season (d)	88 (102)	237 (33)	215 (51)
People giving nutritional advice to the farmer (#)	1.23 (0.86)	1.22 (0.75)	0.79 (0.41)
Use of monensin (proportion)	0.58 (0.50)	0.19 (0.40)	Not applicable
Time before cows are moved to fresh pasture (d)	Not applicable	0.94 (0.77)	Not applicable
Variables related to culling			
First lactation cows in the herd (proportion)	0.32 (0.12)	0.28 (0.09)	0.29 (0.09)
Length of lactation (d)	329 (47)	334 (34)	327 (44)
Culled cows (proportion)	0.31 (0.10)	0.27 (0.10)	0.22 (0.11)

Heifers in the herd (proportion)	0.86 (0.25)	0.82 (0.27)	0.83 (0.22)
Variables related to milk			
Milk production (kg/cow per yr)	9,768 (2,462)	7,676 (1,597)	6,380 (1,744)
Milk fat content (%)	3.72 (0.25)	3.97 (0.27)	4.02 (0.38)
Milk protein content (%)	3.03 (0.12)	3.17 (0.13)	3.13 (0.20)
SCC (x1,000 cells/mL)	290 (124)	249 (104)	270 (101)
Milk price ($/1,000 kg)	348.4 (20.0)	364.9 (22.6)	561.4 (54.0)

Table 2 : Results of regression analysis to explain income over feed cost on conventional, grazing, and organic farms in Wisconsin in 2010

Farm management system	Explanatory variables	Units	Coefficient estimate	SE	p-value	Regression statistics	
Conventional	Intercept		5.5177	0.9270	<0.01	Adjusted R2	0.8643
	Milk production	kg/cow per yr	0.0004	0.0001	<0.01	MSE1	0.827
	Feed offered	kg/cow per d	-0.1641	0.0384	<0.01	Prob > F	< 0.01
	Feed purchased	kg/cow per d	-0.2365	0.0511	<0.01		
	Use of monensin	proportion	0.8905	0.4528	0.06		
Grazing	Intercept		-4.6904	2.0247	0.03	Adjusted R2	0.6695
	Milk production	kg/cow per d	0.0003	0.0001	0.01	MSE1	0.688
	Grazing season	d	0.0153	1.7586	<0.01	Prob > F	< 0.01
	Fertilization	$/ha per yr	0.0085	0.0028	<0.01		
	Hired work	proportion	-1.7496	0.6767	0.02		
	Lactation	d	0.0147	0.0047	<0.01		
Organic	Intercept		-2.7066	4.5454	0.55	Adjusted R2	0.7426
	Milk price	$/1,000 kg	0.0287	0.0958	<0.01	MSE1	1.309
	Milk protein content	%	-4.6074	1.4261	<0.01	Prob > F	< 0.01
	Milk production	kg/cow per yr	0.0010	0.0002	<0.01		
	Feed purchased	kg/cow per d	-0.1788	0.0681	0.01		

Nutritional advice	# of persons	1.2517	0.5211	0.02
Proportion of non-producing animals	proportion	3.5743	0.9527	<0.01
Cropland	ha/cow	-0.9600	0.3592	0.01

1Mean Square Error.

Table 3 : Frequency of inclusion of explanatory variables in the 45 models studied to explain the income over feed cost on conventional (C), grazing (G), and organic (O) dairy farms in Wisconsin in 2010

	C1	G1	O1
Milk price	3	2	1
Number of cows	2	2	3
Milk fat content	1	2	2
Milk protein content	2	3	1
SCC	2	2	2
Milk production	1	1	1
Length of the grazing season	1	1	3
Time before cows are moved to fresh pasture	NA	2	NA
Amount of concentrates fed	2	3	3
Amount of corn silage fed	3	3	2
Amount of feed offered	1	2	3
Amount of purchased feed fed	1	3	1
Amount spent for fertilization	2	1	3
Level of education	2	3	3
Use of mixed feed	1	3	2
Use of monensin	1	3	NA
Nutritional advice	3	3	1
Number of decision makers on the farm	3	1	3

Total land operated	3	3	3
Proportion of hired work	3	2	3
Number of hours worked	3	2	3
Proportion of non-producing animals in the herd	3	3	1
Proportion of first lactation cows in the herd	3	2	3
Proportion of culled cows	3	1	2
Cropland per cow	3	1	1
Pasture per cow	2	3	3
Length of lactation	3	2	3

1: The variable was included in more than half of the models studied (>=23).
2: The variable was included in less than half of the models studied (<23), but more than 20% of them (>9).
3: The variable was included in less than 20% of the models studied (<=9). NA stands for not applicable.

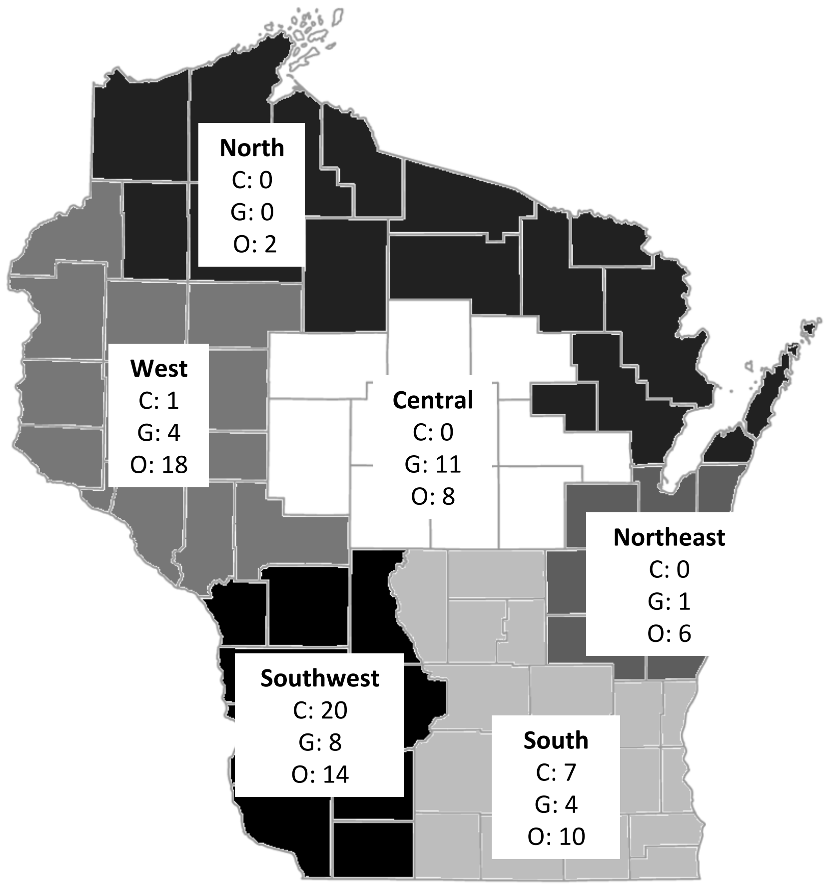

Figure 1 : Distribution of the conventional (C), grazing (G), and organic (O) dairy surveyed in Wisconsin in 2010

CHAPTER 4

FEEDING STRATEGIES AND MANURE MANAGEMENT FOR COST EFFECTIVE MITIGATION OF GREENHOUSE GAS EMISSIONS FROM DAIRY FARMS IN WISCONSIN.

INTERPRETIVE SUMMARY

Feeding strategies and manure management for cost effective mitigation of greenhouse gas emissions from dairy farms in Wisconsin. By Dutreuil et al. Dairy farmers are encouraged to decrease greenhouse gas emissions while remaining profitable. Survey data were used to characterize feeding and manure management strategies on conventional, grazing and organic dairy farms followed by simulation of mitigation strategies. The incorporation of grazing in the conventional farms and the decrease in forage to concentrate ratio in the grazing and organic farms were effective in reducing model-predicted greenhouse gas emission while maintaining profitability. However, mitigation strategies should be implemented according to farm-specific characteristics.

Feeding strategies and manure management for cost effective mitigation of greenhouse gas emissions from dairy farms in Wisconsin.

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A ABSTRACT

Greenhouse gas (GHG) emissions from dairy farms are a major concern. Our objectives were to assess the impact of mitigation strategies on GHG emissions and net return to management on 3 distinct farm production systems of Wisconsin. A survey was conducted on 27 conventional farms, 30 grazing farms and 69 organic farms. The data collected were used to characterize 3 feeding systems scaled to the average farm (85 cows and 127 ha). The Integrated Farm System Model was used to simulate the economic and environmental impacts of altering feeding and manure management in those 3 farms. Results showed that incorporation of grazing practices for lactating cows in the conventional farm led to a 27.6% decrease in total GHG emissions (-0.16 kg CO2eq/kg of energy corrected milk (ECM)) and a 29.3% increase in net return to management (+$7,005/year) when milk production was assumed constant. For the grazing and organic farms, decreasing the forage to concentrate ratio in the diet decreased GHG emissions when milk production was increased by 5% or 10%. The 5% increase in milk production was not sufficient to maintain the net return; however, the 10% increase in milk production increased net return in the organic farm but not on the grazing farm. A 13.7% decrease in GHG emissions (-0.08 kg CO2eq/kg of ECM) was observed on the conventional farm when incorporating manure the day of application and adding a 12-mo covered storage unit. However, those same changes led to a 6.1% (+ 0.04 kg CO2 eq/kg ECM) and a 6.9% (+0.06 kg CO2 eq/kg ECM) increase in GHG emissions in the grazing and the organic farms, respectively. For the 3 farms, manure management changes led to a decrease in net return to management. Simulation results suggested that the same feeding and manure management mitigation strategies led to different outcomes depending on the farm system; and furthermore, there were effective mitigation strategies to reduce GHG emissions while maintaining profitability within each farm.

Key words: IFSM, environmental stewardship, feeding system, environmental and economic sustainability

B INTRODUCTION

Greenhouse gas (GHG) emissions need to be reduced in order to limit undesirable outcomes of climate change (IPCC, 1994), such as the rise in sea's level, extensive species losses, and economic losses due to extreme weather. Livestock operations are one of the largest sources of agricultural GHG emissions (EPA, 2009), and milk production is considered to be responsible for 4% of global anthropogenic emissions of GHG (FAO, 2010). An important challenge for a state such as Wisconsin, which ranks second in the US with 14% of national milk production (USDA/NASS, 2013), is to reduce emissions of GHG while remaining economically competitive.

The 3 main GHG are carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) and their emissions are usually expressed on a CO2 equivalent basis (CO2 eq) to represent their global warming potential in the atmosphere. Methane and N2O have global warming potentials 25 and 298 times of that of CO2, respectively (IPCC, 2007). Sources of CO2 on the dairy farm include plant respiration, animal respiration, and microbial respiration in the soil and manure. Carbon dioxide can also be assimilated on the farm via carbon fixation (Rotz et al., 2011a). Methane sources include enteric fermentation, manure storage, field application of manure and feces deposited on pasture or on the barn floor (Rotz et al., 2011a). Sources of N2O on the farm include soil and manure through the processes of nitrification and denitrification (Rotz et al., 2011a). In total, enteric fermentation, feed production, and manure management typically account for 35, 32 and 26% of GHG at the farm scale, respectively. The rest of the emissions come from fuel and electricity consumption (Thoma et al., 2013).

Many reviews have looked at strategies to reduce GHG emissions from dairy farms (Rafiu et al., 2012; Cottle et al., 2011). However, these reviews did not include the economics of the mitigation strategies, did not differentiate type of dairy farm system, and limited the boundaries of the system at either the cow, housing, manure storage, or at the field level. Moreover, none of aforementioned studies included the three GHGs. Yet, the decrease in GHG emissions in one area of the farm may not necessarily lead to a reduction in GHG emissions for the whole farm or the CO2 eq per kg of milk produced on the farm. Furthermore the effects of a mitigation strategy may depend upon the farm system. Hence, it is critical to study the farm as a whole when evaluating mitigation strategies.

Simulation is a powerful tool to integrate, in a single study, the impact of management practices on both GHG emissions and economic outcomes within a whole farm system framework. In this study, two areas of management were targeted for mitigation strategies. First, feeding management was selected because of its impact on enteric CH4 emission (Aguerre et al., 2011) and it is often the single most important cost in milk production on dairy farms (Eckard et al., 2010). Furthermore, changes in this area can easily be made with readily observable impacts. The second area targeted was manure management because manure is a major source of GHG emissions on dairy farms (Sommer et al., 2000, Chadwick et al., 2011, Thoma et al., 2013). The Integrated Farm System Model (IFSM) has been used to define and study management strategies in different farm systems (Stackhouse-Lawson et al., 2012; Belflower et al., 2012; Rotz et al., 2007), and it is a useful tool to assess simultaneously the combined effect of feeding and manure management strategies on GHG emissions and profitability. The objectives of this work were: 1) to compare Wisconsin organic, grazing and conventional farms in terms of simulated GHG emissions and economics using survey data and the IFSM, and 2) to assess the potential impact of different feeding and manure management strategies on simulated GHG emissions and net return to management of those three farm systems.

C MATERIALS AND METHODS

1 Integrated Farm System Model

The IFSM is a simulation model that integrates the major biological and physical processes of a dairy farm and assesses economic performances given a set of management practices (Rotz et al., 2011a). Crop production, feed and manure management, and environmental impact were simulated on a daily time step over 25 years of daily weather conditions including minimum and maximum temperature, precipitation, and solar radiation as recorded in Madison, Wisconsin. To avoid the possible confounding effect of soil type, medium clay loam was used as a default for all simulations conducted in this study.

a Simulation of GHG emissions.

Total GHG emissions are assessed at the whole farm level including sources and sinks of CO2, CH4 and N2O. Main sources and sinks of CO2 include plant and soil respiration, plant fixation, animal respiration, manure storage, barn floor manure and fuel combustion (Rotz et al., 2011a). Carbon dioxide emitted by plant and soil respiration is assessed using functions from DAYCENT (2007), which are incorporated in the IFSM model. Carbon dioxide emitted by animal respiration is a function of total DMI (Kirchgessner et al., 1991). Emissions of CO2 from the barn floor are calculated based on ambient temperature and manure covered area using the following equation: ECO2 = max(0.0, 0.0065 + 0.0192T)*Abarn, where ECO2 = daily rate of CO2 emission from barn floor, kg CO2 day-1; T = ambient temperature in the barn, °C; and Abarn = floor area covered by manure, m2.

A coefficient of 2.637 kg CO_2/L is used to calculate emission from fuel combustion. For uncovered and covered manure storages, average emission rates of 0.04 kg CO_2/m^3 per day and 0.008 kg CO_2/m^3 per day are used, respectively. Main sources of CH_4 emission include enteric fermentation, barn floor, manure storage, field application and feces deposited on pasture. An equation developed by Mills et al. (2003) is used to assess CH_4 emission from enteric fermentation based on dietary composition, management practices, and animal type and size. The model from Sommer et al. (2004) based on volatile solids (organic compounds of animal or plant origin), temperature and storage time is used to calculate emission from manure storage. Methane emission from the barn floor is a function of ambient temperature. For bedded pack barns, an adaptation of the tier 2 approach of IPCC (2006) is used to account for higher emission rates compared to a daily cleaned barn floor. Methane emission from the field is accounted for up to 11 days after manure application and is a function of the concentration of volatile fatty acids in the soil. A factor of 0.086 g CH_4/kg of feces is used to evaluate CH_4 emission from manure deposited on pasture. Main sources of N_2O include barn floor and manure storage. The emission of N_2O occurring during the nitrification-denitrification process is modeled using functions from DAYCENT (2007), which are incorporated in the IFSM model. Nitrous oxide emitted from barn floors is calculated based on the tier-2 approach of the IPCC (2006) for bedded pack and dry lot. Emission of N_2O is set to zero for facilities where manure is removed on a daily basis. For an uncovered slurry storage tank where a natural crust forms, N_2O emission is a function of the exposed surface area. When no natural crust forms, N_2O emission is set to zero.

Whole farm GHG emissions are divided into seven categories. Emissions from housing facilities include CH_4 emitted from the barn floor, CO_2 from animal respiration, and enteric

CH_4 when animals are housed indoors. Emissions from manure storage include CO_2, CH_4 and N_2O. Emissions from feed production include CH_4 emitted from field-applied manure and cropland emission of N_2O. Emission from grazing includes enteric CH_4 of grazing cows and CO_2 from animal respiration for the time spent grazing. Net biogenic CO_2 includes emission and assimilation of CO_2 from the crops, as well as carbon sequestration (Rotz et al., 2011a). Emission from fuel combustion includes CO_2 from the engines needed for feeding, handling of manure and establishing and harvesting of crops. Finally, secondary sources include emissions of all three gases during manufacture of fuel, electricity, machinery, fertilizers, pesticides, plastic used in production of feed, and for maintenance of animals imported to the farm.

b Simulation of economic performance.

The economic analysis of the IFSM includes a whole farm budget in which the total cost of production is compared to revenues to predict annual net return (Rotz et al.,2011a). Annual fixed costs include costs for equipment, facilities and land. Annual variable costs include costs of labor (feeding, milking, animal handling and field work), resources (fuel and repairs) and products (fertilizers, seeds, chemicals, feed supplements). Total revenue includes revenue from milk sales, animal sales and feed sales. The economic parameters do not vary across years. The economic analysis does not include tax implications or other governmental subsidies.

2 Wisconsin Farm Survey

An interdisciplinary and comprehensive survey instrument was developed to collect information on Wisconsin dairy farm systems. Data were collected on farm structure, labor, herd management, feeding, cropping and economics for the year 2010. Farms were selected from Wisconsin's official lists of certified milk producers and organic milk producers as well as a list of graziers compiled by extension agents of the University of Wisconsin. Further details on sampling and survey protocol can be found in Hardie et al., (2014). For this study, farms were classified in one of three feeding systems: organic, grazing and conventional. Organic farms were those that had received USDA certification. Grazing farms were those not certified organic but for which at least 30% of the estimated DMI of lactating cows during the grazing season was from grazed pasture. Conventional farms were defined as non-organic and non-grazing which included farms that typically grow crops and harvest forages for indoor feeding and housing for most of the year.

3 Farms Simulated and Management Scenarios

Survey data collected on 27 conventional farms, 30 grazing farms and 69 organic farms were used to characterize three farm management systems. To remove the possible confounding effect due to difference in farm size, data were scaled to the average surveyed farm for land area (127 ha, out of which 79 ha were owned and 48 ha were rented) and number of cows (n=85). In our sample, conventional farms were larger (125 cows on 162 ha), grazing farms were intermediate (89 cows on 121 ha) and organic farms were smaller (68 cows on 119 ha).

The main characteristics of the three production systems included in the study are found in Table 1, and values of some key economic parameters used in the simulations are presented in Table 2. Costs of seeds and chemicals come from survey results. When data were not available from surveys, estimates from previous studies were used, such as in the case of some economic parameters for feed prices (Rotz et al., 2007, Rotz et al. 2008) or veterinary and breeding costs (Kriegl, 2007).

a Conventional farm.

The standardized conventional farm (baseline: scenario 0C, Table 3) consisted of 47.4 ha of alfalfa, 42.6 ha of corn, 22.4 ha of perennial grass, 12.2 ha of oats and 2.4 ha of soybean. All crop operations, except grain harvest, were completed by on-farm labor. Alfalfa was established for 3 yr with oats as a cover crop, and was harvested 3 times a year with the first and third cuts preserved as silage and the second cut as hay. Oat was harvested as grain before the first cut of alfalfa. Grass was established for 10 yr with a seeding rate of 10% White Clover and 90% Orchardgrass. One cut of hay was harvested from these 22 ha in the spring before older heifers and dry cows were allowed to graze it for the rest of the growing season.

The herd consisted of 85 large Holstein cows producing 9,820 L of ECM/cow per yr, 36% of which were first lactation animals. The cows were milked twice daily in a double 8 parlor and housed in a naturally ventilated free stall barn. All heifers were housed in a bedded pack barn and included 35 less than 1 yr old and 40 greater than 1 yr old (Table 1).

Manure was collected using a scraper with a slurry pump and stored in a 6-mo storage pit. Eighty percent of the manure collected was applied to the cornfields. The remaining 20% of manure was applied to the alfalfa fields.

Three sets of simulations were conducted for the conventional farm (Table 3, Figure 1). In the first 2 scenarios (scenario A and B), lactating cows grazed during the grazing season. As a result, the labor needed for managing grazing animals was increased from 2 to 6 hr/wk. The impact of grazing on GHG emission was assessed using the same milk production (scenario A) or a 5% decrease in milk production (scenario B) as reported in Vibart et al, (2008). The second set of simulation scenarios focused on manure management (scenario C). The manure in this scenario was incorporated in the soil the same day it was applied. At the same time, the 6-mo storage pit was replaced with a 12-mo sealed covered storage tank to limit GHG emissions. The efficiency of the collector and flare is assumed to be 99%. The third set of simulation scenarios (scenarios AC and BC) looked at the combinations of the first two sets of simulations.

b Grazing farm.

The standardized grazing farm (baseline: scenario 0G, Table 4) consisted of 61.9 ha of grass, 37.7 ha of alfalfa, 16.3 ha of corn, 6.1 ha of soybean and 5 ha of oats. All crop operations, except grain harvest, were completed by on-farm labor. Alfalfa was established for 3 yr with oats as a cover crop, and was harvested 3 times per yr with the first and third cuts preserved as silage and the second cut as hay. Grass was established for 5 yr with 45% White Clover and 55% Orchardgrass. Two cuts of hay were harvested from these 62 ha. The first cut was done before the beginning of the grazing season and the second cut happened in the fall. All weaned animals were grazed.

The herd consisted of 85 large Holstein cows producing 7,256 L of ECM/cow per yr, 30% of which were first lactation animals. The cows were milked twice daily using a pipeline system and housed in a tie stall barn. All heifers were housed in a bedded pack barn and included 34 less than 1 yr old and 36 greater than 1 yr old (Table 1).

Manure was collected using gutter cleaners and hauled daily (i.e., no manure storage on the farm). Fifty percent of the manure collected was applied to the cornfields, 20% on grassland, 20% on alfalfa, and 10% on oats.

Three sets of simulations were conducted on the grazing farm (Table 4, Figure 1). In the first 2 scenarios (scenario D and E), the forage to concentrate ratio was set from high to low. A high forage to concentrate ratio consisted of 83, 90 and 93% forage in the diet for the early, mid and late lactation cows, respectively. A low forage to concentrate ratio consisted of 57, 68 and 80% forage in the diet for the early, mid and late lactation cows, respectively (Rotz et al., 2011a). As a result, milk production was increased by 5% (scenario D) as reported in Aguerre et al., (2011). A 10% increase was also simulated (scenario E) to follow results of Sterk et al., (2011). The second set of simulations focused on manure management (scenario F). Manure was incorporated the day of field-application and a 12-mo sealed covered storage tank to limit GHG emissions. The efficiency of the collector and flare is assumed to be 99%. The third set of simulations (scenario DF and EF) looked at the combinations of the first 2 simulations.

c Organic farm.

The standardized organic farm (baseline: scenario 0O, Table 5) consisted of 45.5 ha of alfalfa, 43.1 ha of grass, 16.8 ha of corn, 16 ha of oats, and 3.6 ha of soybean. Two ha were not available for crop production due to the organic regulation for buffer zones between organic and conventional land (USDA Agricultural Marketing Service. 2013; Rotz et al., 2007). Yields reported on the survey were used as targets for simulated yields. Farmers reported an average yield of 12.1, 13.8, 3.8, and 2.25 t DM/ha for alfalfa, corn silage, oats, and soybean, respectively, in 2010. All crop operations except grain harvest were completed by on-farm labor. Alfalfa was established for 3 yr with oats as a cover crop, and was harvested 3 times a year with the first and third cuts preserved as silage and the second cut as hay. Grass was established for 5 yr with 35% White Clover and 65% Orchardgrass. Two cuts of hay were harvested from these 43 ha. The first cut was done before the beginning of the grazing season and the second cut happened in the fall. All weaned animals were grazed.

The herd consisted of 85 large Holstein cows producing 6,159 L of ECM/cow per yr, 31% of which were first lactation animals. The cows were milked twice daily using a pipeline system and housed in a tie stall barn. All heifers were housed in a bedded pack barn and included 33 less than 1 yr old and 40 greater than 1 yr old.

Manure was collected using gutter cleaners and hauled daily (i.e., no manure storage on the farm). Fifty percent of the manure collected was applied on cornfields, 20% on grassland, 20% on oats, and 10% on alfalfa.

The same 3 sets of simulations used for the grazing farm were used for the organic farm (scenario G, H, I, GI and HI, Table 5, Figure 1).

D RESULTS

1 Comparison of feeding and manure management systems

Results of the different sets of simulations conducted on the conventional, grazing and organic farms are presented as deviation from the baseline scenario (Table 3, 4 and 5).

a Cost of Production and Net Return.

The 3 farms produced enough forage on 127 ha to feed 85 cows and their replacements (Figure 2). Due to higher forage yields, the conventional farm sold more forage than the grazing or organic farms (236, 192 and 94 tonnes/yr for the conventional, grazing and organic farm, respectively). However, higher milk production per cow in the conventional farms compared to grazing and organic farms, was associated with higher purchases of grain (187, 104 and 107 tonnes/yr for the conventional, grazing and organic farms, respectively) and higher purchases of soybean (19, 12 and 4 tonnes/yr of soybean for the conventional, grazing and organic farm, respectively).

The organic farms had an income from milk sales similar to the conventional farms ($294,179/yr and $297,834/yr, respectively) but an intermediate feed cost ($149,744/yr) compared with the conventional and grazing farms (Figure 3). Thus, the organic farm had the highest net return to management ($59,120/yr) compared with $23,895/year for the conventional farm and $14,439/yr for the grazing farm. In addition, the variation in net return across years was the smallest for the organic farms (Tables 4, 5, and 6). Thus, the conventional farms ranked second for net return because the income from the high producing cows was insufficient to compensate for the high feed cost ($182,124/yr). Even though the grazing farms had the lowest feed cost ($134,133/yr), the lower milk production led to the lowest net return to management ($14,439/yr).

b GHG Emission

On a yearly-basis, the conventional farms emitted the greatest amount of GHG (476,623 kg CO2eq/yr) and the grazing farms emitted the lowest amount of GHG (405,565 kg CO2eq/yr), whereas the organic farms had an intermediate level of emission (454,780 kg CO2eq/yr) (Tables 3, 4, and 5). However, when GHG emission was expressed by kg of ECM produced, the emission from the conventional farms was the lowest (0.58 kg CO2eq/kg ECM) followed by the grazing farms (0.66 kg CO2eq/kg ECM) and the organic farms (0.74 kg CO2eq/kg ECM). For the 3 farm systems, the major source of GHG emission was from the housing facilities (i.e., the barn floor, animal respiration and enteric fermentation when animals were housed inside the barn). Other important sources of GHG emissions on the conventional farms included secondary sources (0.17 kg CO2eq/kg ECM), manure storage (0.15 kg CO2eq/kg ECM) and feed production (0.13 kg CO2eq/kg ECM). For the grazing and organic farms, other important sources were feed production (0.21 and 0.27 kg CO2eq/kg ECM, respectively) and grazing animals (0.34 and 0.38 kg CO2eq/kg ECM, respectively) (Figure 4).

2 Assessment of strategies to reduce GHG emissions for conventional farms

a Scenarios A and B.

Scenarios A and B explored the change in feeding management strategies allowing for grazing of lactating cows with no change in milk production (scenario A) or with a drop in milk production (scenario B). Assuming milk production remained unchanged at 9,735 kg/cow per year and given the way pastures were managed in the baseline scenario, grazing lactating cows increased net return to management (+$7,005/year) and decreased GHG emission by 27.6% (-0.16kg CO2eq/kg of ECM, scenario A, Table 3). For the baseline scenario, only one cut of hay was harvested out of the pastures and only dry cows and heifers were grazing. This management did not allow the conventional system to take full advantage of the pastures. By having the lactating cows grazing, pastures were used more efficiently, so that more feed was obtained from the pastures and less preserved forage was needed during the grazing season. Consequently, sales of forage increased by 33 tonnes/yr and income from feed sales increased by $3,684/yr (not shown) in scenario A compared with the baseline scenario. Net return to management also increased because of a decrease of $3,856/yr (not shown) in total manure management cost. The time spent grazing decreased the amount of manure that needed to be stored and handled, reducing the cost of manure management. The decrease in GHG emission was possible for the same reasons. Because cows were spending time outdoors, GHG emission included in the "housing facilities" and "manure storage" categories decreased (-0.20 kg CO2eq/kg of ECM and -0.10 kg CO2eq/kg of ECM, respectively) and emission from grazing animals increased (+0.13 kg CO2eq/kg of ECM), resulting in a net reduction in GHG emission when grazing substituted for confinement feeding during part of the year. When milk production was decreased by 5% (scenario B, Table 3), GHG emissions decreased by 26% (-0.15kg CO2eq/kg of ECM). However, the increase in income from forage sales was compensated by the decrease in milk production and the net return to management remained unchanged compared to the baseline scenario ($23,093/year). Because total net return to management remained unchanged for scenario B and milk production decreased by 5%, then the net return to management per 1,000 kg of ECM was slightly better for scenario B compared to the baseline scenario ($29.1/1000kg of ECM vs. $28.9/1000kg of ECM, respectively).

b Scenario C.

Increasing manure storage capacity from 6 to 12-mo with a covered tank and incorporating manure the day of field-application led to an increase in total manure cost of $3,398/year (not shown). The net return to management decreased by $3,536 but GHG emissions decreased by 16% (-0.08kg CO2eq/kg of ECM, Table 3). The decrease in emissions from the manure storage and from the field during feed production contributed to this improvement (Table 3).

c Scenarios AC and BC.

These scenarios explored the combined effect of changes in feeding management and manure management. If milk production was maintained at the same level (9,735kg/cow per year, scenario AC, Table 3), the adoption of grazing for the lactating cows and the changes in manure management led to an increase in net return to management (+$3,180/year) compared to the baseline scenario and a decrease in GHG emission of 31% (-0.18 kg CO2eq/kg ECM). The change in net return was the result of the increase in income from feed sales, the decrease in total manure handling cost observed in the first scenario, and the increase in manure handling costs observed in the second scenario. The change in GHG emission was the result of a decrease in emission from the housing facilities and the manure storage compared to the baseline scenario. However, the overall decrease in GHG emission for scenario AC compared to the baseline scenario did not add up to the sum of the decreases observed in scenarios A and C. If milk production was reduced by 5% (9,329 kg ECM/cow per year, scenario BC, Table 3), GHG emission decreased by 0.18 kg CO2eq/kg of ECM, but net return to management was also reduced by $4,641/year compared to the baseline scenario.

3 Assessment of strategies to reduce GHG emissions for grazing farms

a Scenarios D and E.

Scenario D simulated on the grazing farm looked at the impact of changing the forage to concentrate ratio from high to low with a 5% increase in milk production. This strategy reduced GHG emission by 25.8% compared to the baseline scenario (-0.17g CO2eq/kg of ECM), but also reduced substantially the net return to management (-$12,846/yr) (Table 4). In that case, the income from the increase in milk production and the additional forage sold (+92 tonnes/yr) did not cover the expenses needed to buy the additional grain. Feed costs increased by $34,797/yr compared to the baseline scenario. In regard to GHG emission, the increase of 0.11 kg CO2eq/kg of ECM from secondary sources due to the grain purchased was offset by the reduction in emission from housing facilities (-0.11 kg CO2eq/kg of ECM), grazing (-0.10 kg CO2eq/kg of ECM) and feed production (-0.05 kg CO2eq/kg of ECM). When milk production was increased by 10% (scenario E, Table 4), the impact of changing the forage to concentrate ratio was essentially the same on GHG emission and the decrease in net return was reduced (-$4,683/yr) compared to the baseline scenario.

b Scenario F

Scenario F simulated on the grazing farm looked at the impact of changing manure management. Adding a 12-mo covered tank and incorporating the manure the same day of application increased GHG emission (+0.04 kg CO2eq/kg of ECM) and decreased net return to management (-$3,565/yr) (Table 4). The reduction in net return was due to an increase in total manure cost of $3,521/yr (not shown) over the baseline scenario. The reduction of GHG emission from feed production (-0.01 kg CO2eq/kg of ECM) possible with the incorporation of manure the same day of application did not compensate for the increase in GHG emission from the manure storage (+0.06 kg CO2eq/kg of ECM), leading to an overall increase of 0.04 kg CO2eq/kg of ECM.

c Scenarios DF and EF.

Scenarios DF and EF simulated on the grazing farm looked at the combination of scenarios D and E with scenario F. The change in net return was a cumulative combination of the results observed for the first 3 scenarios. When milk production increased by 5% (scenario DF, Table 4), net return decreased by $16,407/year compared to the baseline scenario due to an increase in feed cost from the grain purchased (+$33,498/yr, not shown) and an increase in total manure costs (+$3,521/yr, not shown). When milk production increased by 10% (scenario EF, Table 4), net return decreased by $8,247/year for the same reasons. The overall GHG emission was reduced by 0.13 kg CO2eq/kg of ECM and 0.15 kg CO2eq/kg of ECM for a 5 and 10% increase in milk production, respectively. The reduction in GHG emission compared to the baseline scenario was the result of the cumulative decrease observed in scenarios D and E and the increase observed in scenario F.

4 Assessment of strategies to reduce GHG emissions for Organic farms

a Scenarios G and H

Scenarios G and H on the organic farms (Table 5) described results for the same sets of simulations as did scenarios D and E for the grazing farms (Table 4). The results observed followed the same trend as described above for the grazing farm. With a 5% increase in milk production (scenario G, Table 5), changing the forage to concentrate ratio from high to low decreased the net return to management by $9,766/yr and decreased the GHG emission by 0.23 kg CO2eq/kg of ECM. With a 10% increase in milk production (scenario H, Table 5), GHG emissions were reduced by 0.25kg CO2eq/kg of ECM. On the organic farms, a 10% increase in milk production was sufficient to maintain net return compared to the baseline scenario (+$605/year) in spite of an increase in feed cost (+$52,369/yr, Table 5).

b Scenario I

Scenario I simulated on the organic farm focused on the impact of changing manure management. Adding a 12-mo covered tank and incorporating the manure the same day of application, decreased net return to management by \$4,855/yr because of an increase in total manure handling cost, and GHG emission were increased by 0.06 kg CO2eq/kg of ECM.

Scenarios GI and HI. Scenarios GI and HI simulated on the organic farm focused on the combination of scenarios G and H with scenario I. The results for scenarios GI and HI were a cumulative combination of the results from the first 3 scenarios. With a 5% increase in milk production and a change in manure management (scenario GI, Table 5), net return to management decreased by \$14,793/yr and GHG emissions decreased by 0.18 kg CO2eq/kg of milk compared to the baseline scenario. With a 10% increase in milk production and a change in manure management (scenario HI, Table 5), net return to management decreased by \$4,403/year and GHG emission decreased by 0.20 kg CO2eq/kg of ECM.

E DISCUSSION

1 Comparison of feeding and manure management systems

a Profitability.

Previous studies have found that managed grazing can be more profitable than confinement feeding or mixed farms using extensive grazing (Dartt et al., 1999; Hanson et al., 1998; Winsten et al., 2000; Gillespie et al., 2009; Hanson et al., 2013). For instance, Hanson et al. (2013) reported a net profit of \$105.60 and \$54.44 per 1,000 kg of ECM for grazing and conventional farms, respectively. Similarly, Gillespie et al., 2009, reported a whole farm net return of \$104.88 and \$81.11 per 1,000 kg of ECM for grazing and conventional farms, respectively. However, those studies are based on survey results and involved dairy farm systems of different size, which are different to our study. Grazing herds from those studies were smaller in number of cows and land area. Winsten et al. (2000) showed the importance of herd size and milk production per cow as major factors affecting profitability. They reported a $10.03 increase in net farm income when milk production per cow per yr increased by 1 kg and a $292.14 increase in net return when herd size increase by 1 cow. This could explain the difference in results obtained with the simulation in this study, which was designed to focus on assessing the effect of management practice at the same farm size. This is supported by the finding of Foltz and Lang (2005), who showed that grazing systems are not more profitable than conventional systems when other factors are controlled. Moreover, because crop management was not the focus of this particular study, one of the assumptions was that all feeding systems had the same crop-related machinery and used the same crop-related practices (land preparation and planting). This assumption could have decreased profitability for grazing farms since they typically have less machinery compared with conventional farms. Hanson et al., 1998 reported lower machinery costs for grazing systems compared to conventional systems.

Organic premium for milk price confers an economic advantage to organic dairy farms leading to higher profitability compared to conventional herds (McBride and Green, 2009). In their study, herd size was 82 and 156 cows for Organic and Conventional farms, respectively. Rotz et al. (2007) found the same results using the IFSM model for dairy farms in Pennsylvania. They showed that with the same land base and the same number of cows, organic farms had a higher net return to management per cow in spite of lower milk production per cow, compared to grazing or confinement farms. The economic advantage was even more important when net return to management was expressed on a kg of ECM basis.

b GHG emission.

Gerber et al. (2011) reported that increasing milk production reduced the amount of GHG emission per kg of milk. The simulations conducted for our study corroborate those results. Even though the conventional farm had the highest net emission of GHG per year, it had the lowest net emission of GHG per kg of milk because of a higher milk production compared to the other two feeding and manure management systems. Kristensen et al. (2011) also showed that organic farms emitted more GHG per kg of milk produced compared to the conventional farms for the same reason as described here.

Our study revealed that the main source of GHG emissions among the three feeding and manure management systems was enteric fermentation whether the animals were fed indoors or outdoors (grazing). Even though the exact amount of GHG emission derived from enteric fermentation was not known from the simulation results, one can see that the 2 categories including enteric fermentation, housing facilities and grazing, are, together, the largest sources of emission on the farm for the 3 management systems. They represent 0.51, 0.78, and 0.90 kg CO2 eq/kg ECM on the conventional, grazing, and organic farm, respectively (Table 3, 4 and 5). Our observations agree with those from Thoma et al. (2013) who indicated that enteric fermentation, manure management and feed production are the three main sources of GHG emissions for milk production.

The importance of other sources of GHG emissions differed among feeding and manure management systems, which means that the implementation of the same mitigation strategies is likely to yield different outcomes across farms.

For the farm types studied here, emissions included in the "feed production" category were high because most of the dairy farms relied heavily on on-farm production of forages for the herd. Secondary sources of GHG emissions associated with manufacture of inputs were of less importance on the organic and grazing farms compared with the conventional farms as the former two rely more on on-farm resources.

2 Economic vs. Environmental outcomes of altering feeding and manure management practices

The simulations of mitigation strategies demonstrated that changes in management can reduce GHG emissions in all 3 farm systems studied. On the organic and conventional farms, in some cases, reduction in GHG emission may be achieved while maintaining or even improving profitability.

Changes in feeding strategies in each farm type were effective in reducing GHG emissions. Those strategies are easy to implement, their impact can be observed in the short term, and according to Vellinga et al. (2011), what farmers would be most inclined to do among all other mitigation strategies proposed. On conventional farms, based on the results from the simulations, the use of extensive grazing for the lactating cows seemed to be possible without decreasing milk production. This strategy should be possible to implement on actual farms since most of the conventional farms surveyed had some land in pasture. Future research should be done to compare pasture management when conventional farms transition to grazing of lactating cows. For the organic farm, increasing the amount of concentrates fed to the cows was also an effective way to decrease GHG emissions while maintaining profitability if milk yield was increased by 10%. One should note that those results are for 2010 prices. On the grazing farm, increasing the amount of concentrates fed to the cows was effective at reducing GHG, but at the same time reduced profitability even when a 10% increase in milk production was simulated.

Moreover, this strategy might be in contradiction with the way farmers want to operate their farms since graziers usually seek cost reduction and low input systems.

Changes in manure management led to contrasting results on GHG emissions among the types of farms. GHG emissions were reduced on the conventional farms; but, they were increased on the grazing and organic farms. In all cases, those strategies had a negative impact on net return to management due to an increase in total manure management costs. When looking at the simulation results, changes in manure management may be seen as not desirable. Although, this study focused on GHG emissions, changes in manure management could have additional beneficial impact on the environment by reducing ammonia emission, nitrate leaching and phosphorus runoff (Rotz et al., 2011b). A more complete life cycle assessment of the environmental impacts of mitigation strategies should be made before drawing final conclusions about the effect of those strategies on the environment and farm profitability.

F CONCLUSIONS

Under the simulation conditions of this study, feeding management changes can be made to reduce GHG emissions on Wisconsin conventional, grazing and organic dairy farms, and those changes can improve profitability in some cases. In contrast, changes in manure management to reduce GHG emission were possible, but these changes had a negative impact on profitability. However, the evaluation and the implementation of mitigation strategies should be based on farm characteristics and data from site-specific farm conditions are needed prior to making any recommendations.

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Table 1 : Mean (and standard deviation) of the main characteristics of the 3 farm types

	Conventional	Grazing	Organic
Farms surveyed (n)	27	30	69
Land base (ha)	127 (118.9)		
Alfalfa (ha)	47.4 (25.47)	37.7 (24.43)	45.5 (26.11)
Grass (ha)	22.4 (21.19)	61.9 (36.56)	43.1 (38.44)
Corn (ha)	42.6 (29.66)	16.3 (11.65)	16.8 (14.01)
Oats (ha)	12.2 (7.77)	5.0 (4.88)	16.0 (8.07)
Soybean (ha)	2.4 (4.49)	6.1 (10.59)	3.6 (4.93)
Young heifers (< 1 yr old)	35 (12.3)	34 (12.3)	33 (15.3)
Old heifers (> 1 yr old)	40 (11.8)	36 (12.5)	40 (14.3)
Cows (n)	85 (107.8)		
First lactation cows (%)	36 (11.4)	30 (12.9)	31 (11.0)
Milk production (L ECM/cow per year)	9,820 (2,138.5)	7,256 (1,694.9)	6,159 (1,874.9)
Milk price ($/hL)	35.99 (2.051)	37.52 (2.911)	56.20 (7.641)
Grazing strategy	Older heifers and dry cows	All weaned animals during the grazing season	All weaned animals during the grazing season
Housing facilities	Free stall barn, naturally ventilated	Tie stall barn	Tie stall barn
Manure storage	Top-loaded lined earthen basin	No storage (daily haul)	No storage (daily haul)

Table 2 : Key economic parameters used for the simulation of the conventional, grazing and organic farms

	Conventional	Grazing	Organic
Diesel fuel price ($/L)	0.68		
Electricity price ($/kWh)	0.11		
Labor wage ($/h)	11.24		
Land rental charge ($/ha per yr)	214.99		
Fertilizer prices			
Nitrogen ($/kg)	1.100	1.100	Not applicable
Phosphate ($/kg)	1.199	1.199	Not applicable
Potash ($/kg)	1.001	1.001	Not applicable
Seeds (from survey data)			
Corn ($/ha)	160	140	210
1st year Alfalfa ($/ha)	175	105	215
Oats ($/ha)	70	70	85
Soybean ($/ha)	230	250	295
Chemicals (from survey data)			
Corn ($/ha)	138	50	0
1st year Alfalfa ($/ha)	147	78	0
Oats ($/ha)	95	40	0
Soybean ($/ha)	88	27	0

Table 3 : A comparison of annual production, economic effects and greenhouse gas emissions for various management changes simulated on the conventional farm

		0C	A*	B*	C*	AC*	BC*
	Annual milk production (kg ECM†/cow)	9,735	0	-406	0	0	-406
Feed production and use	Hay and silage production (tonne DM)	332	0	0	0	0	0
	Corn and Oats production (tonne DM)	443	-3	-4	0	-5	-5
	Grazed forage consumed (tonne DM)	94	36	35	1	37	36
	Forage sold (tonne DM)	236	33	40	2	34	41
	Grain purchased (tonne DM)	187	-2	-10	0	-1	-9
	Soybean purchased (tonne DM)	19	1	0	0	2	0
	Mineral purchased (tonne DM)	6	0	0	0	0	0
Costs of production and net return	Total feed costs ($)	182,124	994	-1,795	116	1,425	-1,349
	Total income ($)	357,151	3,668	-7,979	177	3,865	-7,780
	Net return to management ($)	23,895	7,005	-802	-3,536	3,180	-4,641
	Variation (SD) in net return across years ($)	18,355	-477	1,724	-51	-803	-1,973
	Net return to management ($/1000kg ECM)	28.9	8.4	0.2	-4.3	3.8	-4.6
Greenhouse gas emission (CO2 eq)	Housing facility (kg/kg ECM)	0.46	-0.20	-0.21	0.00	-0.20	-0.21
	Manure storage (kg/kg ECM)	0.15	-0.10	-0.10	-0.08	-0.13	-0.13
	Feed production (kg/kg ECM)	0.13	-0.01	-0.01	-0.01	-0.01	-0.01
	Grazing (kg/kg ECM)	0.05	0.13	0.14	0.00	0.13	0.14
	Net biogenic CO2 (kg/kg ECM)	-0.34	0.02	0.03	0.01	0.02	0.03
	Fuel combustion (kg/kg ECM)	0.04	0.00	-0.01	0.00	0.00	-0.01
	Secondary sources (kg/kg ECM)	0.17	-0.01	-0.02	0.00	-0.01	-0.02
	Net emission (kg/cow per d)	15.36	-4.09	-4.39	-1.95	-4.79	-5.08
	Net emission (kg/kg ECM)	0.58	-0.16	-0.15	-0.08	-0.18	-0.18
	Net emission (kg/year)	476,623	-126,959	-136,289	-60,550	-148,829	-157,555

*Values are expressed as difference from the baseline scenario 0C

†ECM: Energy Corrected Milk

0C: Initial conventional farm with 85 cows, producing 9,820 L of ECM/cow per year on 127 ha, no grazing, top-loaded lined earthen basin for manure storage.

A: Grazing was offered to the lactating cows with no decrease in milk production.

B: Grazing was offered to the lactating cows with a 5% decrease in milk production;

C: Manure management changes included incorporation of manure the same day of application and a 12-month covered tank storage was used to reduce emission from manure storage;
AC: Combination of scenarios A and C;
BC: Combination of scenarios B and C.

Table 4 : A comparison of annual production, economic effects and greenhouse gas emissions for various management changes simulated on the grazing farm

		0G	D*	E*	F*	DF*	EF*
	Annual milk production (kg ECM†/cow)	7,256	362	725	0	362	725
Feed production and use	Hay and silage production (tonne DM)	314	0	0	0	0	0
	Corn and Oats production (tonne DM)	196	0	0	0	0	0
	Grazed forage consumed (tonne DM)	385	-121	-118	0	-122	-118
	Forage sold (tonne DM)	192	92	88	1	92	88
	Grain purchased (tonne DM)	104	168	176	1	168	176
	Soybean sold (tonne DM)	12	-3	-3	0	-3	-3
	Mineral purchased (tonne DM)	5	0	0	0	0	0
Costs of production and net return	Total feed costs ($)	134,133	34,797	36,670	242	34,994	36,871
	Total income ($)	288,603	21,560	32,627	95	21,614	32681
	Net return to management ($)	14,439	-12,846	-4,683	-3,565	-16,407	-8,247
	Variation (SD) in net return across years ($)	9,810	-1,768	-1,715	-48	-1,814	-1,760
	Net return to management ($/1000kg ECM)	23.4	-20.9	-9.0	-5.8	-26.4	-14.3
Greenhouse gas emission (CO2 eq)	Housing facility (kg/kg ECM)	0.44	-0.11	-0.10	0.00	-0.11	-0.10
	Manure storage (kg/kg ECM)	0.00	0.00	0.00	0.06	0.05	0.05
	Feed production (kg/kg ECM)	0.21	-0.05	-0.05	-0.01	-0.06	-0.06
	Grazing (kg/kg ECM)	0.34	-0.10	-0.10	0.00	-0.10	-0.10
	Net biogenic CO2 (kg/kg ECM)	-0.36	0.01	0.00	0.00	0.01	0.00
	Fuel combustion (kg/kg ECM)	0.04	-0.01	-0.01	0.00	-0.01	-0.01
	Secondary sources (kg/kg ECM)	0.09	0.11	0.12	0.00	0.11	0.12
	Net emission (kg/cow per d)	13.07	-2.79	-2.63	0.79	-2.11	-1.94
	Net emission (kg/kg ECM)	0.66	-0.17	-0.18	0.04	-0.13	-0.15
	Net emission (kg/year)	405,565	-86,729	-81,796	24,506	-65,447	-60,282

*Values are expressed as difference from the baseline scenario 0G

†ECM: Energy Corrected Milk

0G: Initial grazing farm with 85 cows, producing 7,256L of ECM/cow per year on 127 ha, with a high forage:concentrate ratio and no manure storage.

D: Forage:concentrate ratio was defined as 57, 68 and 80% for the early, mid and late lactation cows, respectively, with a 5% increase in milk production.

E: Forage:concentrate ratio was defined as 57, 68 and 80% for the early, mid and late lactation cows, respectively, with a 10% increase in milk production.
F: Manure management changes included incorporation of manure the same day of application and the addition of a 12-month covered tank storage;
DF: Combination of scenarios A and C;
EF: Combination of scenarios B and C.

Table 5 : A comparison of annual production, economic effects and greenhouse gas emissions for various management changes simulated on the organic farm

		0O	G*	H*	I*	GI*	HI*
	Annual milk production (kg ECM†/cow)	6,159	308	615	0	308	615
Feed production and use	Hay and silage production (tonne DM)	347	0	0	0	0	0
	Corn and Oats production (tonne DM)	160	0	0	0	0	0
	Grazed forage consumed (tonne DM)	268	-61	-59	-1	-61	-60
	Forage sold (tonne DM)	94	150	145	1	150	146
	Grain purchased (tonne DM)	107	157	164	1	158	165
	Soybean sold (tonne DM)	4	-2	-2	0	-1	0
	Mineral purchased (tonne DM)	5	0	0	0	0	0
Costs of production and net return	Total feed costs ($)	149,744	49,788	52,369	403	49,861	52,465
	Total income ($)	350,185	39,429	53,253	130	39,526	53,322
	Net return to management ($)	59,120	-9,766	605	-4,855	-14,793	-4,403
	Variation (SD) in net return across years ($)	14,498	-2,991	-2,941	98	140	161
	Net return to management ($/1000kg ECM)	112.9	-23.1	-9.2	-9.2	-32.3	-17.9
Greenhouse gas emission (CO_2 eq)	Housing facility (kg/kg ECM)	0.52	-0.13	-0.12	0.00	-0.13	-0.12
	Manure storage (kg/kg ECM)	0.00	0.00	0.00	0.07	0.06	0.05
	Feed production (kg/kg ECM)	0.27	-0.08	-0.08	-0.01	-0.09	-0.08
	Grazing (kg/kg ECM)	0.38	-0.11	-0.10	0.00	-0.11	-0.10
	Net biogenic CO_2 (kg/kg ECM)	-0.38	0.01	0.00	0.00	0.01	0.00
	Fuel combustion (kg/kg ECM)	0.06	-0.02	-0.02	0.00	-0.02	-0.01
	Secondary sources (kg/kg ECM)	0.12	0.12	0.12	0.00	0.12	0.12
	Net emission (kg/cow per d)	14.66	-3.30	-3.15	0.99	-2.47	-2.31
	Net emission (kg/kg ECM)	0.87	-0.23	-0.25	0.06	-0.18	-0.20
	Net emission (kg/year)	454,780	-102,405	-97,632	30,728	-76,632	-71,615

*Values are expressed as difference from the baseline scenario 0O

†ECM: Energy Corrected Milk

0O: Initial organic farm with 85 cows, producing 6,159L of milk/cow per year on 127 ha, with a high forage:concentrate ratio and no manure storage.

G: Forage:concentrate ratio was defined as 57, 68 and 80% for the early, mid and late lactation cows, respectively, with a 5% increase in milk production.

H: Forage:concentrate ratio was defined as 57, 68 and 80% for the early, mid and late lactation cows, respectively, with a 10% increase in milk production.
I: Manure management changes included incorporation of manure the same day of application and the addition of a 12-month covered tank storage;
GI: Combination of scenarios A and C;
HI: Combination of scenarios B and C.

Figure 2. Feed production and use on simulated conventional (C), grazing (G) and organ

feeding systems of Wisconsin dairy farms

Figure 3. Feed costs and income on simulated conventional, grazing and organic feeding sy

of Wisconsin dairy farms

Figure 4. Greenhouse gas emissions from simulated conventional, grazing and organic fe

and manure management systems on Wisconsin dairy farms

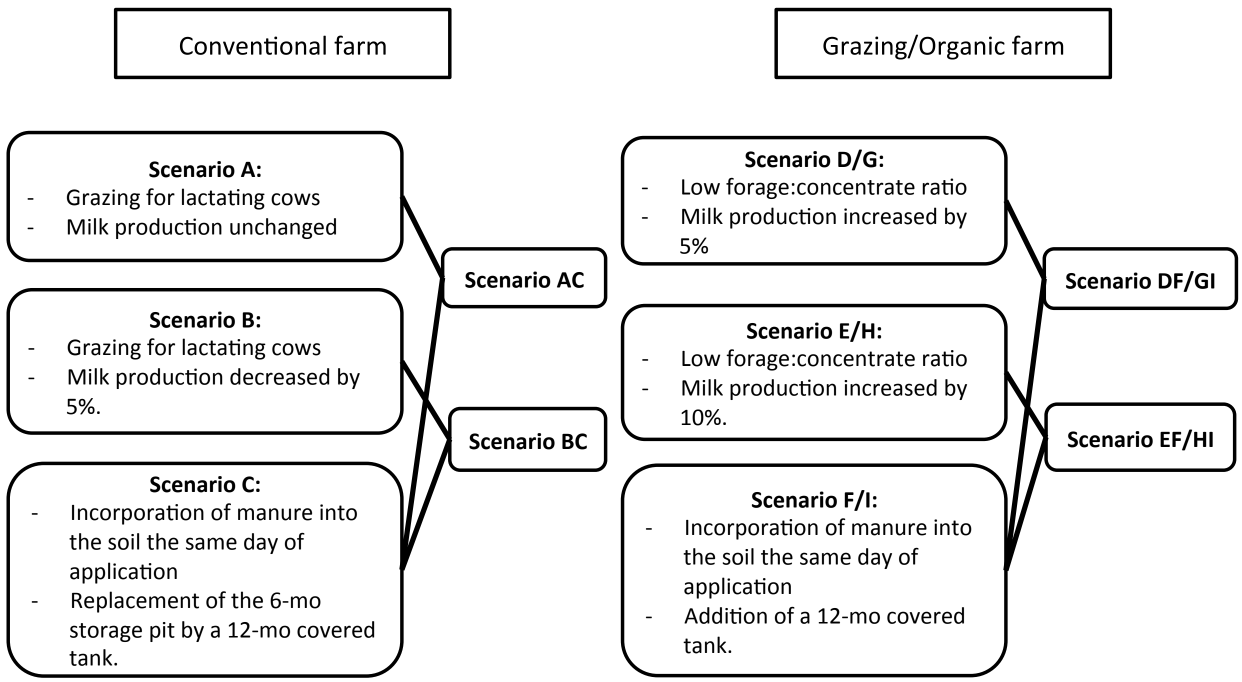

Figure 1 : Scenarios simulated on the conventional, grazing and organic farms.

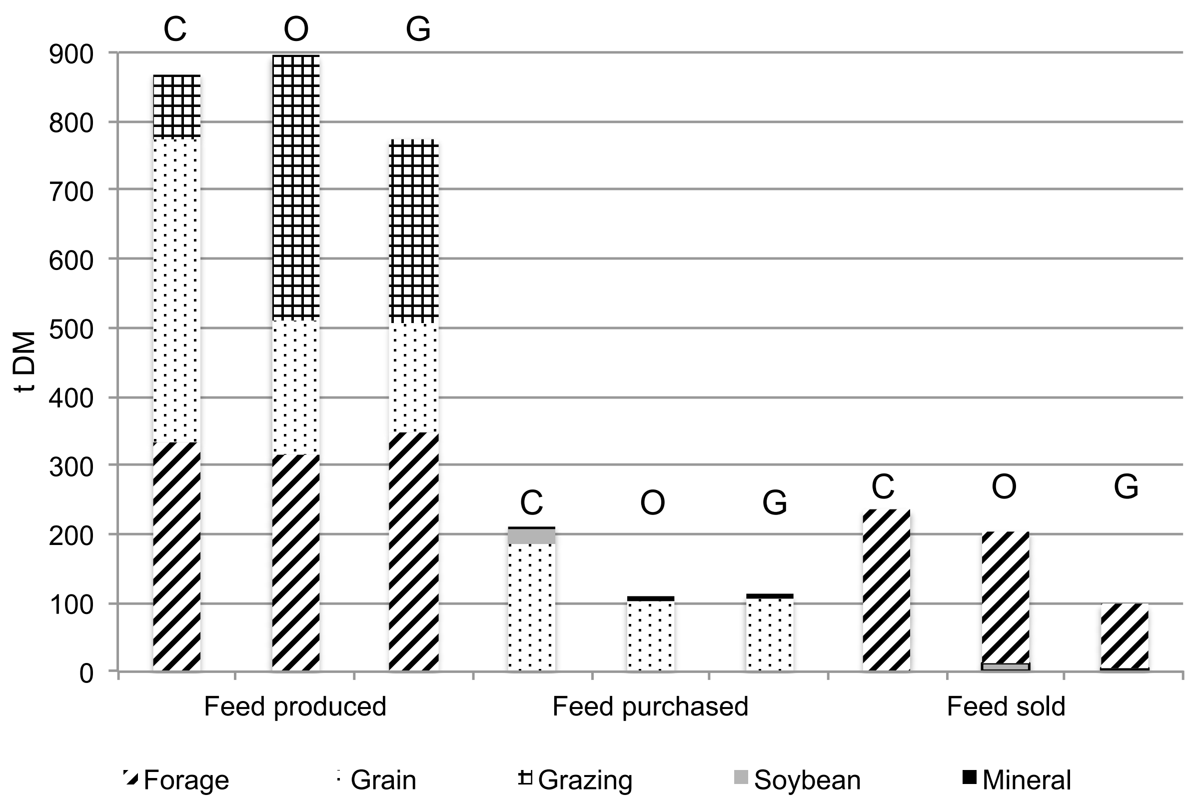

Figure 2 : Feed production and use on simulated conventional (C), grazing (G) and organic (O) feeding systems of Wisconsin dairy farms

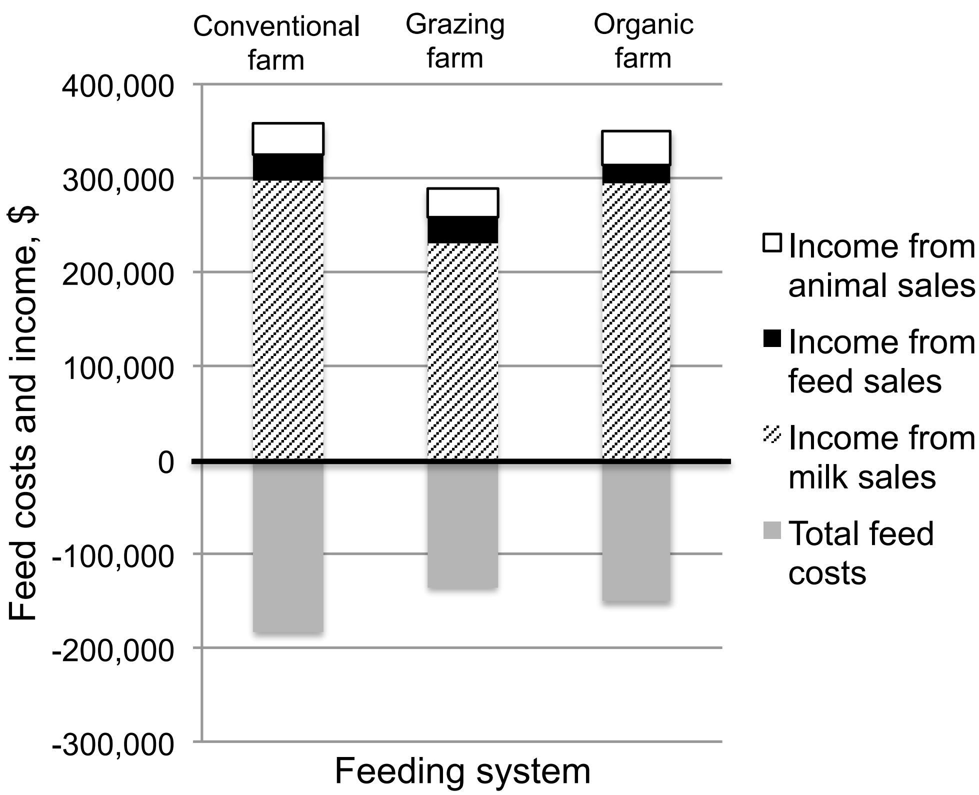

Figure 3 : Feed costs and income on simulated conventional, grazing and organic feeding systems of Wisconsin dairy farms

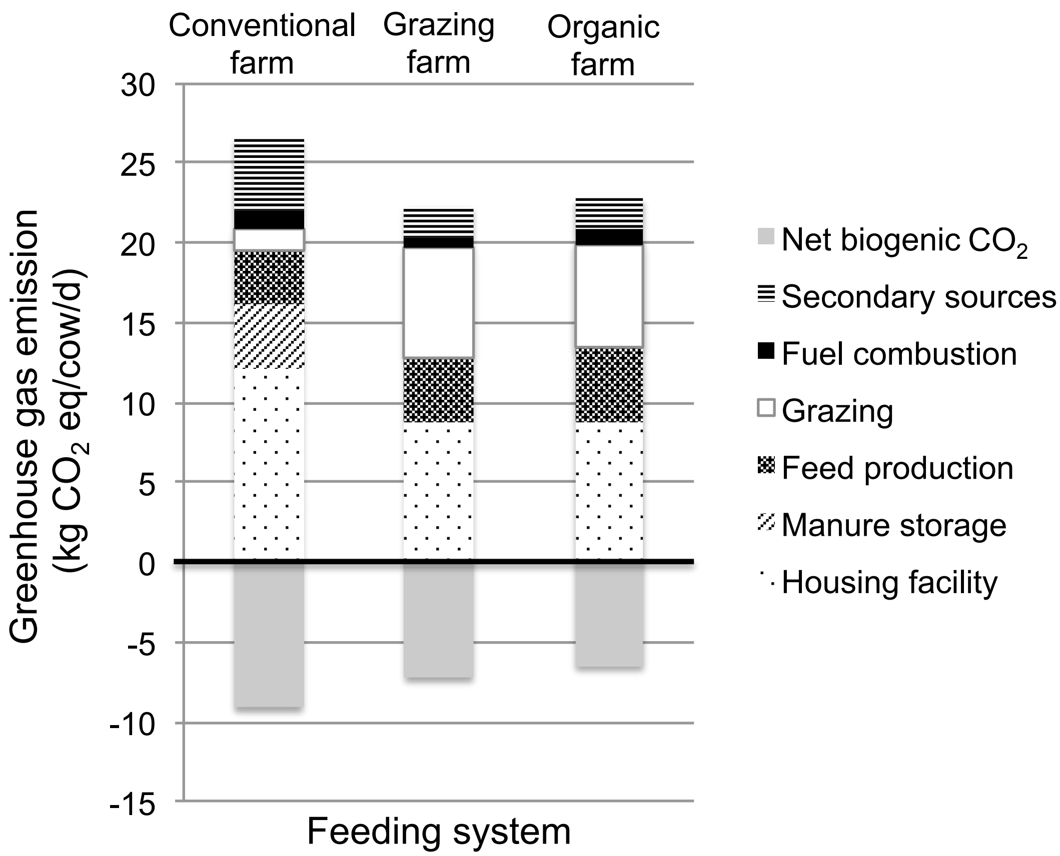

Figure 4 : Greenhouse gas emissions from simulated conventional, grazing and organic feeding and manure management systems on Wisconsin dairy farms

OVERALL CONCLUSIONS

The objectives of this thesis were:

1.) To describe and compare farm characteristics and management practices on conventional, grazing and organic dairy farms in Wisconsin.

2.) To determine key factors associated to farm profitability on conventional, grazing and organic dairy farms in Wisconsin.

3.) To compare conventional, grazing and organic dairy farms in terms of simulated greenhouse gas emission in Wisconsin using survey data and the Integrated Farm System Model.

Results from the survey indicated that farm characteristics and farm management practices were different among the 3 management systems studied. More specifically, farms in the conventional management system were larger, had more cows, producing more milk than farms in the 2 other systems. Main differences in management practices were observed in regard to feeding. Conventional farms were more likely to use feed additives such as rBST or Monensin, were feeding a larger amount of feed and relied more on a nutritionist. Despite all those differences between the 3 management systems, a large variation was also observed inside each group, indicating that other factors than just the management system could be used to classify farms in a more homogeneous way. The only variables for which no differences between the 3 groups were observed were variables in relation to farmer's characteristics such as age, education or years of experience.

Variables associated to farm profitability were different among the 3 management systems studied. IOFC, on the conventional farms, was positively associated with milk production per cow and the use of monensin and negatively associated with the amount of feed purchased and the total amount of feed offered. For farms in the grazing management system, profitability was higher when milk production was increased, when grazing season was longer and when amount spent on fertilization was higher. A lower profitability was observed when the proportion of hired work increased. On the organic farms, milk price, milk production, the use of nutritional advice and the proportions of heifers had was positively associated to IOFC, whereas milk protein content, feed purchased and the hectares of cropland per cow was negatively associated to IOFC. Those results demonstrated the importance of taking into account the specificity of the farm when trying to understand profitability.

Overall simulated GHG emissions were lower on the organic and grazing farms compared to the conventional farm when expressed in CO_2eq per unit of milk produced. Simulation realized with the IFSM showed that for each system, mitigations strategies were possible in order to reduce GHG emissions. Those strategies include the incorporation of grazing for the lactating cows on the conventional farms and decreasing the forage to concentrate ratio on the organic and grazing farms. For the 3 systems, the addition of a 12-mo covered manure storage and the incorporation of manure the same day of application was also an effective way to reduce GHG emission.

The main limitations of this study lied in the way farms were sampled, as well as in the choice of indicators used to assess some aspects of farming. The complete sample contained 114 dairy farms with 28 conventional farms, 28 grazing farms and 58 organic farms. This repartition did not reflect accurately the repartition of Wisconsin dairy farms, where most of the farms are conventional. Consequently, this sample should not be used to estimate overall farms management practices in Wisconsin. However, the representativity of the sample was assessed for each management system and the organic sample was found to be representative of Wisconsin organic dairy farms and the conventional sample was found to be representative of "medium-sized, family labor farms" in Wisconsin. The assessment of representativity was not possible for the grazing farms due to the lack of information on this group. Because grazing farms were sampled using lists from extension specialists, the sample might not be fully representative of the average grazing farm in Wisconsin and results of productivity and economics might be higher for the sampled farms compared to the population of Wisconsin grazing farms. Regarding the choice of indicators, even though the IOFC has been shown to be a good proxy for farm profitability, it does not take into account expenses such as facilities, labor or interests, which might be different between systems. Further research should look at the net farm income to compare profitability of different management systems. Finally, the lack of information collected did not allow the calculation of on-farm nitrogen and phosphorus balance, which are a good indicator of the environmental impact of dairy farms.

Results from this study allowed the comparison of farm characteristics and farms management practices between conventional, grazing and organic dairy farms. The impact of the system on farm profitability and GHG emissions was also assessed. Moreover, this project resulted in the gathering of a lot of valuable information from Wisconsin dairy farms. Most of this information was synthetized in a database and is made available to the public in a tool, online: http://dairymgt.info/tools/feeding_strategies/. This information can be used by researchers working with models or by dairy specialists or by farmers themselves. Further analysis of the rest of the data collected on farm should yield even more information, especially on manure management.

APPENDIX: Survey questionnaire