Agricultural Systems 153 (2017) 157–171

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Resource use and economic impacts in the transition from small confinement to pasture-based dairies

M. Melissa Rojas-Downing, Timothy Harrigan *, A. Pouyan Nejadhashemi

Department of Biosystems & Agricultural Engineering, Michigan State University, 524 S. Shaw Lane, Room 209, East Lansing, MI 48824, USA

ARTICLE INFO

Article history:
Received 28 July 2016
Received in revised form 22 December 2016
Accepted 20 January 2017
Available online xxxx

Keywords:
Whole-farm simulation
Dairy
Confinement
Pasture
Economic
Anaerobic digester

ABSTRACT

In recent years, many livestock farms have transitioned from total confinement housing to a pasture-based system in an effort to reduce labor and production costs and improve profitability. There is a growing interest in biogas recovery among livestock producers to reduce energy costs and manure odors but the economic benefits of anaerobic digestion (AD) on small farms is not well known. A comprehensive analysis was conducted using the Integrated Farm System Model (IFSM), to describe, evaluate and compare the farm performance and economic impacts of representative dairy farms in Michigan transitioning from conventional confinement to seasonal- and pasture-based systems, and evaluate the potential for integration of an AD in the confinement and seasonal pasture systems. The results in farm performance present higher milk production per kilogram of feed in the confinement systems, followed by the seasonal pasture and the annual pasture systems. In the economic analysis, the annual pasture-based system had the greatest net return to management and unpaid factors followed by the seasonal pasture and confinement systems. The addition of an AD on a 100-cow, total confinement dairy decreased the net return to management and unpaid factors by 20%. When anaerobic digestion was added to the seasonal pasture with an increased land base for cash crop production and an imported manure volume equivalent to a 500-cow dairy, the net return to management and unpaid factors increased 269% compared to the seasonal pasture dairy alone.

1. Introduction

The United States has 9.3 million milking cows (USDA-ERS, United States Department of Agriculture-Economic Research Service, 2016) and is the second largest milk producer in the world (FAO, Food and Agriculture Organization of the United Nations, 2016). The U.S dairy industry is concentrated in the Great Lakes region with 41% of the United States milking cows in 2015 (USDA, 2016). This region is well suited for dairying because forage is abundant and can be stored as winter feed (EPA, US Environmental Protection Agency, 2015). The Great Lakes region includes five of the top 10 milk-producing states in 2012: Wisconsin, New York, Pennsylvania, Minnesota, and Michigan (USDA-NASS, United States Department of Agriculture-National Agricultural Statistics Service, 2014). The Michigan dairy industry by itself contributes $14.7 billion to the state economy (United Dairy Industry of Michigan, 2016).

Dairy farming has different production systems including confinement, seasonal pasture, and pasture-based. A confinement dairy is a system where land use and feed management systems optimize milk production with confined cows consuming harvested forages and concentrates (Aschmann and Cropper, 2007). Almost all the herd is housed in a free stall or structure system with no access to pasture (Powell et al., 2005). In a seasonal pasture system, cattle are on pasture during the summer growing season and confined during winter. A pasture-based dairy uses land use and feed management systems that optimizes the intake of forages consumed directly by grazing cows. In this system, during the grazing season, the lactating animals will consume at least 50% of their forage intake through grazing, while dry cows consume 90% (Aschmann and Cropper, 2007). Forage is defined as edible portions of plants (commonly excluded grain) that can be grazed or harvested by animals (Wilkins, 2000). Pasture refers to the interactions between soil, plant and grazer used in a management unit devoted to produce forage for grazing animals (Rayburn, 2007).

In recent decades, many U.S. dairy farms have increased their net income by expanding herd size (Nott, 2003; Aschmann and Cropper, 2007). This increased the demand for feed and forage and encouraged the use of confinement systems. Large confined herds required larger structures for housing and feed storage and larger handling equipment and waste management systems (Aschmann and Cropper, 2007). However, a transition from confinement dairy to pasture-based dairy has been adopted due to the profitability in the dairy industry in the Great Lakes Region (Nott, 2003). Pasture-based dairies can reduce feed, labor, equipment and fuel costs. It provides a lower-cost option for

* Corresponding author.
E-mail address: harriga1@anr.msu.edu (T. Harrigan).

http://dx.doi.org/10.1016/j.agsy.2017.01.013
0308-521X/

small farmers without expanding their dairy farm, or they can start dairying with less debt (Aschmann and Cropper, 2007). Economic studies show that grazing farms can provide satisfactory profits compared with confinement operations. Pasture-based systems generated $887 net farm income from operations (NFIFO) per cow and $4.22 per hundredweight equivalent (CWT EQ), compared to confinement operations, which generated $640 NFIFO per cow and a negative $10 per CWT EQ (Kriegl and McNair, 2005).

In the transition from a confinement to pasture-based dairy, it is important to consider all aspects of production and operation. Some changes needed to increase efficiency are to improve the milking facilities to reduce milking time; improve pasture fertilization by soil testing and applying recommended fertilizer rates; and reduce expensive farm machinery investments. In addition, during the grazing season the efficiency can increase by feeding pasture forage based on cattle dry matter intake, amount of standing forage within the paddock, and on forage nutrients (Aschmann and Cropper, 2007). During the transition from confinement to pasture system, there will be a temporary loss of milk production (Kriegl and McNair, 2005) because cows that have never grazed before expect feed that is provided in the barn. However, milk production will increase and meet or exceed their level of production when the cows have improved their grazing and maximize dry matter intake from pasture (Heckman et al., 2007).

One of the main global issues of livestock production is manure management (Teenstra et al., 2014). In 2007, there were 9158 milking cows on 71,510 operations in the U.S. (Betts and Ling, 2009). These cows produced 84.2 billion kilograms of milk along with an estimated 226.8 billion kilograms of manure (Betts and Ling, 2009). Manure processing is routinely handled by collecting, storing and spreading it over the land. However, manure management practices have generated environmental concerns such as odor, water quality, and greenhouse gas emissions.

Global livestock production contributes with 14.5% of greenhouse gas emissions, where only manure management contributes with 26% of the sector emissions (Gerber et al., 2013). Livestock manure releases methane and nitrous oxide gasses. The organic materials decomposition found in manure under anaerobic conditions releases methane (EPA, U.S. Environmental Protection Agency, 1999). Manure handled aerobically and then anaerobically releases nitrous oxide, which usually occurs during manure storage and application (Steinfeld et al., 2006). The environmental concerns, in addition to the increase in energy costs and growing interest in renewable energy has encouraged farmers to search for alternative manure handling methods (Hadrich and Wolf, 2011; Betts and Ling, 2009).

One of the alternatives that produce renewable energy in cost-effective ways is biogas recovery (USDA, EPA, DOE, 2014). The use of this technology has been increasingly attractive for manure management with around 30 million anaerobic digesters operating worldwide with manure (Chen et al., 2010). EPA estimated that there were 188 anaerobic digesters operating at commercial livestock farms for biogas recovery in the United States in 2012, and 158 were dairy digester projects (EPA, US Environmental Protection Agency, 2013). Anaerobic digestion (AD) is a process where anaerobic bacteria degrade organic materials in an oxygen free environment to create biogas (mix of methane and carbon dioxide), which can be used to produce electricity and heat (Burke, 2001). This process has been successful in developed and developing countries over many years because of the potential for global energy needs and multiple environmental benefits. For example, in 2008, about 4000 anaerobic digesters in Germany were operated in the agricultural sector to produce biogas (Weiland, 2010). In Europe, the policy states that 25% of all bioenergy can at least be derived from biogas (Holm-Nielsen et al., 2009). In China, about eight million AD are used to produce biogas for cooking and lighting in households (IEA Bioenergy, 2005). In the world, more than thousand vendor-supplied AD are operating or under construction, with the majority located in South America to treat the vinasse coproduct from sugar cane-based ethanol production (Lettinga and Van Haandel, 1992).

The input for an anaerobic digester is biomass, such as manure, agricultural waste, and urban waste, though they are not similarly degraded or converted to gas (Burke, 2001). The use of animal manure as biomass for AD is globally widespread because it produces a valuable fertilizer (or also known as digestate) as well as biogas (IEA Bioenergy, 2006). For example, a typical lactating dairy cow can support the production of 1.33 cubic meters of biogas per day (Betts and Ling, 2009). Assuming that the biogas contains 65% methane, this would mean 0.62 kg of methane per cow per day. The U.S. Environmental Protection Agency (EPA) in 2010 estimated 8200 U.S. dairy and swine operations produce more than 13 million MWh of electricity with biogas recovery systems; where only dairy produces about 6.8 million MWh.

Besides producing electricity, biogas recovery systems on livestock operations can also heat water and provide additional benefits to the farm (EPA, US Environmental Protection Agency, 2010). The digestate, which is the non-gaseous material remaining after digestion, can be used as a fertilizer and bedding and can be often recovered for reuse (USDOE, 1996). Revenue from electricity generated on-farm can be obtained through biogas and electricity sale, reduction in purchased electricity use, and in some cases, net metering (Roos et al., 2004). AD also has an environmental impact by reducing greenhouse gas emissions and odors (IEA Bioenergy, 2006). From each ton of carbon recycled, revenue may be obtained through carbon credits if methane is captured and prevented from escaping to the atmosphere.

Anaerobic digestion also impacts farm economics. In the case of small-scale digesters, U.S. EPA does not recommend biogas recovery systems for livestock farms with less than 500 cows (EPA, US Environmental Protection Agency, 2010). In 2010, the majority (74%) of U.S. dairy farms had less than 100 cows and in 2011, 88% had less than 200 cows, making anaerobic digestion not feasible for most of U.S. dairy farms (U.S. Census Bureau, 2012). For example, revenue from electricity sales has been profitable for large-scale operations (Nelson and Lamb, 2002), but small-scale digesters are not often profitable due to their dependence on the electricity price and the high cost of infrastructure needed to sell electricity back to the grid (Lazarus and Rudstrom, 2007; Ghafoori and Flynn, 2007). Electrical generation from biogas was not economically viable but the use of biogas to accomplish the heating requirements on-farm was found to be economically feasible in small-scale dairy farms (Bishop and Shumway, 2009). However, Millen (2008) reported on two small dairy farms (130 and 70 cows) in Ontario that were producing electricity and were profitable. The farmers credited their success to receiving three tons per day of additional waste such as grease trap waste (130 cow farm only), having a buyer for their electricity, and substantial time dedicated to the project development stage.

The Minnesota Project, a group funded by EPA-AgSTAR, is searching for solutions for small- and mid-sized dairies. In 2005, they started a feasibility study on the use of the anaerobic digestion technology by scaling it down and still providing financial incentives for farmers to use it. The Minnesota Project evaluated six anaerobic digestion systems designed for confinement dairies between 100 and 300 cows. They concluded that the digester costs, which were between $105,000 and $230,000, were still too high (Goodrich, 2005).

The Minnesota Project prepared a case study based on the Jer-Lindy confinement dairy farm in central Minnesota. This farm has 97 ha and 160 milking cows producing about 11,356 L per day of manure based on built a small-scale digester with an up-flow tank system with a 124,918 L holding capacity and five-day hydraulic retention time (HRT). The total cost of the system was $460,000 (Lazarus, 2009). The economic analysis evaluated the added value by the generator and the projected costs of owning and operating it. The analysis assumed that the system would produce 430 kWh of electricity per day in which 95 kWh was used to run the pumps, digester and fan separation equipment and 335 kWh per day to replace electricity purchases or to sell back to the grid. The manure solids from the separator replaced the sand bedding that normally costs around $1000 per month (Lazarus,