Agricultural Systems 157 (2017) 51–69

Contents lists available at ScienceDirect

Agricultural Systems

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

An economic analysis of integrated crop-livestock systems in Iowa, U.S.A.

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ARTICLE INFO

Keywords:
Integrated crop-livestock systems
Economic performance
Enterprise budget analysis
Long-term agricultural research
Crop rotation

ABSTRACT

Diversified cropping systems integrated with livestock production can provide substantial soil conservation and water quality benefits, yet farmers in the U.S. Corn Belt have shifted toward greater specialization of farming systems in recent decades. The purpose of this study was to evaluate the economic feasibility of re-integrating crops and livestock in farming systems of the U.S. Corn Belt. Using data on farming practices and yields from a long-term cropping systems experiment, we calculated annual revenue and costs of four farming systems–a simple corn-soybean rotation with and without cattle (2-yr cash and 2-yr integrated, respectively) and a diversified corn-soybean-oat/alfalfa-alfalfa rotation with and without cattle (4-yr cash and 4-yr integrated, respectively). Our analysis was conducted for a 405-ha parcel in central Iowa over the period of 2008 to 2015. To maximize the use of harvested crops, cattle enterprises differed for the 2- and 4-yr rotations: yearlings were finished using a diet of mostly concentrate feeds for the 2-yr integrated system and calves were backgrounded and finished using a diet of forages and concentrates for the 4-yr integrated system. We found that mean annual returns to land and management were similar among all four farming systems ($790 ha^{-1} averaged across the four systems). The integrated systems exhibited greater variability among years in returns to land and management than the cash systems. In addition, total costs excluding land and management were four- to nine-fold greater for the integrated crop-livestock systems than for the cash crop systems. Labor requirements increased with crop rotation diversification by 59% (4-yr cash vs. 2-yr cash) and with integration of cattle by 217% (2-yr integrated vs. 2-yr cash) or 232% (4-yr integrated vs. 2-yr cash). We concluded that diversified crop rotations with or without cattle are profitable farming systems in Iowa, but require greater capital and labor inputs than the dominant 2-yr cash grain system.

1. Introduction

A key challenge of 21st century agriculture is to meet the food, fuel, and fiber demands of a growing population while protecting environmental quality and providing adequate financial returns to farmers (Robertson and Swinton, 2005). Industrial forms of modern agriculture use plant breeding to improve the genetic basis of crop production as well as inputs of water, chemicals, and fossil energy to remove limitations to plant growth. These external inputs can decouple crop production from biological functions provided by diverse agroecosystems, such as nutrient cycling and biological pest control, and consequently can promote specialization of agricultural systems (Bowman and Zilberman, 2013). Over the last half-century, this collection of technologies has dramatically increased crop yields, allowing agriculture to meet global food demands while slowing the expansion of cropping into natural lands (Tilman et al., 2002). However, agricultural intensification has caused harm to the environment: irrigation depletes limited water resources, reactive nitrogen and phosphorus pollute surface and coastal waters and contaminate groundwater, pesticides kill non-target organisms, and altered patterns of carbon and nitrogen cycling contribute to climate change (Robertson et al., 2014). These environmental impacts raise concerns about the sustainability of current input-intensive agricultural systems (Tilman et al., 2002).

Agricultural intensification and its impacts on environmental quality are particularly apparent in the U.S. Corn Belt. Between 1945 and 2000, cattle numbers in this region (Ohio, Indiana, Illinois, Iowa, Wisconsin, and Minnesota) declined by 52% while hay and oat (*Avena sativa* L.) production decreased by 60 and 97%, respectively (Sulc and Tracy, 2007). Over this same period, corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) area increased by 29 and 80%, respectively

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http://dx.doi.org/10.1016/j.agsy.2017.07.001
Received 8 March 2017; Received in revised form 12 June 2017; Accepted 3 July 2017

(Sulc and Tracy, 2007). Concomitantly, nitrogen fertilizer rates for corn approximately tripled between the early 1960s and 1980s (Nehring, 2013). Corn and soybean now occupy 87% of the harvested area (47% in corn, 40% in soybean), while hay occupies 7% of Corn Belt cropland (USDA NASS, 2016). The U.S. Environmental Protection Agency has identified nearly 6000 impaired water bodies within the region (US EPA, 2016), and nitrate exported from corn and soybean fields in the Corn Belt has been implicated as a cause of hypoxia in the Gulf of Mexico (Goolsby et al., 1999; Alexander et al., 2008; David et al., 2010).

Diversifying crop rotations to include perennial forages such as alfalfa (*Medicago sativa* L.) may help to ameliorate the environmental impacts associated with U.S. Corn Belt agriculture. Diversified crop rotations that include both annual grain crops and perennial forages show reduced nitrate losses (Randall et al., 1997), reduced soil erosion by water (Shiftlet and Darby, 1985) and wind (Padbury and Stushnoff, 2000), increased soil organic matter (Drinkwater et al., 1998), and increased soil health (Lazicki et al., 2016; King and Hofmockel, 2017) relative to simple annual crop rotations. Diversified crop rotations can also rely on biological nutrient provisioning and pest control, requiring fewer fertilizer and pesticide inputs to achieve equivalent or greater yields than simple rotations (Davis et al., 2012; Hunt et al., 2017).

Ruminant livestock provide the economic incentive to diversify crop rotations with perennial forages. Perennial forages are not suitable as food for humans, but ruminant livestock such as cattle and sheep are capable of converting them into useable food and fiber products. Because ruminants generate demand for hay, farms that raise perennial forages often raise livestock as well (Russelle et al., 2007). The integration of crop and livestock enterprises eliminates the need to import feed stuffs or export harvested crops. Moreover, livestock manure can serve as a source of nutrients for crop production, recycling nutrients removed from cropland and replacing synthetic fertilizer inputs. Using soil erosion and nitrogen budget models applied to western Iowa watersheds, Burkart et al. (2005) showed that the adoption of integrated crop-livestock systems that include grain- and forage-based crop rotations and cattle would lead to significant reductions in leachable nitrogen, lower soil losses, and greater soil organic nitrogen compared to current agricultural systems.

Decisions regarding land use in the U.S. Corn Belt can influence the supply of major agricultural commodities as well as the status of the regional and global environment. These decisions, while far-reaching in their impact, are made at a local scale: on the farm by individuals and families with careful consideration of expected profitability weighed alongside their own personal values, skills, interests, and financial and physical resources. Past research has shown that diversified crop rotations with manure amendments can be as profitable as simple crop rotations in Iowa (Karlen et al., 1995; Olmstead and Brummer, 2008; Davis et al., 2012, Hunt et al., 2017), but previous economic evaluations have not provided in-depth considerations of integrated livestock enterprises.

Table 1
Products harvested from the four farming systems evaluated in this study and their intended use.

Product	2-yr cash	2-yr integrated	4-yr cash	4-yr integrated
Corn grain	Sold	Fed	Sold	Fed
Corn stover	–	Bedding[a]	–	Bedding[a]
Corn silage	–	Fed[a]	–	–
Soybean grain	Sold	Sold	Sold	Sold
Oat grain	–	–	Sold	Sold
Oat straw	–	–	Sold	Sold
Oat silage	–	–	–	Fed[a]
Alfalfa hay	–	–	Sold	Fed/sold[b]
Fed cattle	–	Sold[a]	–	Sold[a]

[a] Products that were not harvested in the Marsden Farm experiment.
[b] A portion of the hay not used for feeding cattle was sold to the market.

In this study, we wanted to evaluate the economic feasibility of integrated crop-livestock systems for the U.S. Corn Belt. We calculated annual revenue and costs of four farming systems – a simple corn-soybean rotation with and without cattle (2-yr cash and 2-yr integrated, respectively) and a diversified corn-soybean-oat/alfalfa-alfalfa rotation with and without cattle (4-yr cash and 4-yr integrated, respectively) for 405 ha in Iowa over the period of 2008 to 2015. We assumed that the four farming systems were already in place and therefore did not include start-up costs in our budgets. Profitability was calculated as return to land and management (gross revenue – total costs except for land and management).

2. Materials and methods

2.1. Crop enterprise budgets

Crop enterprise budgets were based on actual yields and herbicide inputs for the Marsden Farm cropping systems experiment (Liebman et al., 2008; Hunt et al., 2017). The Marsden Farm experiment was established in 2002 in Boone, IA (42° 01′ N, 93° 47′ W). The trial includes a corn-soybean rotation (2-yr rotation) and a corn-soybean-oat/alfalfa-alfalfa rotation (4-yr rotation) arranged in a replicated, randomized complete block design. The corn-soybean rotation is managed as a typical cash grain farm in the region, with conventional fertilizer and herbicide inputs. The 4-yr rotation is representative of a diversified farming system in the region, which often includes swine or cattle. As such, composted manure is applied in the fall prior to the corn phase of the 4-yr rotation. Beginning in 2008, each plot was split in half to compare conventional and low-input weed management practices (Gómez et al., 2012). We used herbicide input costs and yield data from the portion of the plots with conventional weed management for the crop enterprise budgets (Hunt et al., 2017).

For this study, the harvested crop products differed slightly between the cash crop and integrated systems for the same crop rotation based on cattle feed and bedding requirements for livestock (Table 1). As a result, some crop products included in this study were not harvested in the Marsden Farm rotations (i.e., corn stover and corn silage in the 2-yr integrated system and corn stover and oat silage in the 4-yr integrated system). Also, two of the systems evaluated in this study differed from Marsden Farm rotations in manure use: for this study we assumed that the 2-yr integrated system would receive manure but the 2-yr Marsden Farm rotation did not, and we assumed that the 4-yr cash system would not receive manure but the 4-yr Marsden Farm rotation did receive manure. Manure applied prior to corn is expected to increase corn yield by 2% (Singer et al., 2004) and soybean yield by 6% (McAndrews et al., 2006) relative to synthetic nitrogen fertilization of corn for Iowa soils. Therefore, we increased corn and soybean yields by 2% and 6%, respectively, in the 2-yr integrated system relative to the 2-yr cash system and decreased corn and soybean yields by these percentages in the 4-yr cash system relative to the 4-yr integrated system. Replacing manure application prior to corn with synthetic fertilization was not expected to affect oat and alfalfa yields in the 4-yr cash system (Porter et al., 2003).

Per-hectare gross revenue for each crop product was calculated as the crop yield from the corresponding Marsden Farm rotation (averaged across replicates; Appendix 1) multiplied by the marketing year price (from USDA NASS, 2016; Appendix 2). When calculating per-hectare gross revenue for each system, the per-hectare gross revenue for each crop was weighted by the proportion of farm area annually allocated to that crop in each system. Corn silage and oat silage yields were estimated using allometric relationships applied to measured grain yields (Edwards, 2008). Corn stover yields were calculated assuming that 50% of total aboveground dry matter was harvested as grain and that 30% (2-yr integrated) or 35% (4-yr integrated system) of the stover was baled. The percentage of stover baled was adjusted so that total stover harvested matched bedding requirements of the livestock enterprise. The proportional area in production was calculated as one divided by