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To cite this article: Andrea Bellingeri, Victor Cabrera, Antonio Gallo, Di Liang & Francesco Masoero (2019): A survey of dairy cattle management, crop planning, and forages cost of production in Northern Italy, Italian Journal of Animal Science, DOI: [10.1080/1828051X.2019.1580153](https://doi.org/10.1080/1828051X.2019.1580153)

To link to this article: <https://doi.org/10.1080/1828051X.2019.1580153>



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Published online: 05 Apr 2019.



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A survey of dairy cattle management, crop planning, and forages cost of production in Northern Italy

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ABSTRACT

A survey regarding crop enterprise management, forages cost of production, dairy cattle management including reproductive management, housing, heat abatement, body condition scoring, nutrition, grouping strategies, and income over feed cost performance, was carried out from December 2016 to January 2018 on 50 dairy farms by the Department of Animal Science, Food and Nutrition of Università Cattolica del Sacro Cuore (Piacenza, Italy). A total of 41 herds (82%) completed the survey. Average herd size was 327 ± 162 lactating cows with the average land size of 160 ± 94 ha per farm. Herds were located in the provinces of Cremona (17), Brescia (8), Mantova (7), Piacenza (5), Cuneo (4), Bergamo (3), Lodi (3), Torino (2), and Venezia (1). These farms sold 32.8 ± 2.01 kg of milk/day per cow, had an annual culling rate of $34.0 \pm 4.00\%$, a calving interval of 14.16 ± 0.58 months, and a 21-days pregnancy rate of $17.05 \pm 2.58\%$. Implementing effective management strategies to contrast the damage caused by *Ostrinia nubilalis*, *Diabrotica spp.* and *Myocastor coypus* were identified as the main crop enterprise challenges. Main forages cultivated were alfalfa and corn silage second seeding with a total cost of production of (€/ha) 1968 ± 362 and $2,581 \pm 221$, with an average yield of 9.61 ± 1.24 and 17.22 ± 2.46 ton of DM per hectare, respectively. Results of this study can provide useful benchmark or reference for dairy management practices, crops and dairy performances, forages production costs on very well-managed North Italian dairy farms at the present time.

HIGHLIGHTS

- benchmarks for dairy farms
- management practices, economic and reproductive performance
- cost of production of forages in northern Italy

ARTICLE HISTORY

Received 16 August 2018
Revised 19 December 2018
Accepted 3 February 2019

KEYWORDS

Dairy; management; reproduction; forages; costs

Introduction

The economic objective of a farm is generally to maximise net economic returns (de Ondarza and Tricarico 2017). The complexity of the dairy farm system, the multitude of variables that can affect the efficiency and profitability of a dairy farm, raise the importance of defining benchmarks and references as a useful way to help farmers pursuing efficiency. A descriptive paper can result in a practical way to synthesise benchmarks and useful references among the main aspects that affect the profitability of a dairy farm. For instance, reproductive efficiency is an important factor affecting the economic performance of dairy farms (Meadows et al. 2005). Several studies have reported a high variability in reproductive efficiency (Olynk and

Wolf 2008). Lower reproductive efficiency is related to a lower milk yield per cow per day and lower economic efficiency (i.e. €/cow per yr.) (De Vries 2006). Furthermore, feed costs is another important factor affecting farm profitability, since it can range from 50% to 70% of the total operating costs to produce milk (Bozic et al. 2012). Consequently, farm efficiency should be evaluated by considering technical performance and economic outputs concurrently (Atzori et al. 2013). In Northern Italy, corn silage makes up to 90% of the total roughage in the lactating cow diet because of the soil fertility, favourable climate for corn silage, and its high DM yield potential per ha (Borreani et al. 2013). As a result, most dairy farms become self-sufficient for the energy requirements producing corn

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silage, but highly dependent for the protein sources from the market. This has led to a simplification of the cropping system and expose farmers to the market volatility of purchased feeds. This economic uncertainty represents one of the main economic challenges (Valvekar et al. 2010). Moreover, additional challenges with this cropping system have risen. Installation of many biogas plants has resulted on increased competition of available arable land and increased land costs (Demartini et al. 2016). Furthermore, climate change effects have influenced more persistent drought conditions in summer (Camnasio and Becciu 2011), aflatoxin issues (Battilani et al. 2016), and new and more aggressive corn pests (Boriani et al. 2006; Ciosi et al. 2008). All these new issues, have resulted in an increased uncertainty about the corn silage-based dairy farming system. As stated by Dury et al. (2013), defining cropping strategies represents a fundamental step in the decision-making process of a dairy farm, because it allows to improve the competitiveness as well as profitability of the dairies through reduction of feed costs. As a result, many dairy farms have introduced new cropping system strategies, adopted new environmental friendly soil tillage practices to reduce costs and improve soil fertility (Panagos et al. 2016) and improved the irrigation system practices. All these new elements prompt the need of understanding their impact on the cost of production of feeds and its role on farm sustainability (Wolf 2012). Different approaches have been used to compute feed costs such as fixed feed costs related to the energy content (Atzori et al. 2013) or adoption of variable feed costs associated with market prices for both purchased and home-grown feeds (Borreani et al. 2013; Buza et al. 2014). However, since dairy farms in Northern Italy combine produced and purchased feeds within a heavily integrated system, calculation of the cost of home-produced forages is often over-simplified by assigning a single universal cost to a particular feed-stuff (O'Kiely et al. 1997). Although previous studies have provided a wealth of information, details regarding specific aspects of cropping strategies, actual cost of production of different forages, irrigation and tillage system adopted, yield obtained by different forages were not considered. The objective of the present study was to examine the current forages production cost, paying particular attention to factors that could influence the final costs of production per unit of product, via an extensive survey of dairy herds that participated in the Department of Animal Science, Food and Nutrition of Università Cattolica del Sacro Cuore (Piacenza, Italy) consulting services. Current

crop and dairy management operations, nutritional and feeding strategies data has been recorded in order to give an update on the current management practices on very well managed Northern Italy dairy farms.

Materials and methods

Farm survey

An interdisciplinary and comprehensive survey was developed with questions regarding the most important aspects of a dairy operation. It included general management issues, reproductive management, crop management practices, forages cost of production and economic performance. Between January and February 2018, the survey was mailed to 50 selected dairy farms located in the Po Valley (Italy). The selection of farms was purposefully based on previous knowledge of these farms recording the most and the best quality data. These farms are involved in the consulting service of the Department of Animal Science, Food and Nutrition of Università Cattolica del Sacro Cuore. These herds were located in the provinces of Cremona (17), Brescia (8), Mantova (7), Piacenza (5), Cuneo (4), Bergamo (3), Lodi (3), Torino (2), Venezia (1). All cows were Holstein-Friesian housed in free-stall barns without pasture access. Once the survey completed and was received back, trained people visited each farm to conduct an oral interview to complete and/or verify answers. Furthermore, specific data on direct input crop costs, crop management, and feed consumption data were collected during such visit. If a farm operation was done by a custom operator, the custom operation service cost was considered. If input costs were not available or not provided by the farmer, present market price were used (Heinrichs et al. 2013). Small grains silage was a category of crops that included wheat, barley, triticale, and oats. Field peas was a category that included winter protein grains such as dry peas or split peas (*Pisum sativum*).

Calculations

Forages cost of production were calculated considering direct and indirect costs of production. Direct costs of production considered all the operations from tillage and plating to harvest and other input sources, as seeds, herbicides, crop protection products (insecticides, fungicides, silage bacterial inoculants, and silage inhibitors), and fertilisers. In particular, tillage and planting considered all cost of fuel, lubricants and labour workforce for all the operation related to seed

Table 1. Summary response by herd managers ($n=41$) to questions related to the dairy enterprise among labour, herd size, milk production, calving interval, culling.

Question	Mean \pm SD or (counts)	Min	Max
How many people are working in your operation?			
Full-time family (n ; h/week)	1.39 \pm 1.07; 65.7 \pm 14.5		
Part-time family (n ; h/week)	0.78 \pm 0.76; 21.4 \pm 12.4		
Full-time nonfamily (n ; h/week)	3.46 \pm 2.30; 52.8 \pm 11.2		
Part-time nonfamily (n ; h/week)	0.29 \pm 0.46; 18.7 \pm 5.28		
What is the lactating cow herd size? (n)	327 \pm 162	96	750
Dry cows	51 \pm 25	14	117
Heifers and calves	360 \pm 196	86	851
How many calves were born in your herd last year? (calves)	380.9 \pm 205.1	86	939
How much milk do you deliver per cow per day? (kg/day)	32.83 \pm 2.01	28.74	36.73
Milking 2X	32.54 \pm 2.00 (34)	28.74	36.37
Milking 3X	34.23 \pm 1.52 (7)	32.42	36.73
How much milk you delivered last year? (t/year)	3939 \pm 2055	1159	9513
Average fat content (%)	3.86 \pm 0.12	3.65	4.10
Average protein content (%)	3.39 \pm 0.06	3.25	3.51
Average SCC content (1000 cells/mL)	232 \pm 46	135	315
Age at 1st calving (month)	23.78 \pm 0.95	21.9	26
What is the average calving interval in your herd? (month)	14.16 \pm 0.58	13.3	16.3
What percentage of your cows left the herd last year? (%)	34.0 \pm 4.00	27	45

Means \pm SD or counts (binary or categorical variables).

SCC: Somatic Cells Count.

bed preparation and planting. Sprayers considered all cost of fuel, lubricants, and labour workforce for all the operation related to crop spraying. Complementary operation considered all cost of fuel, lubricants, and labour workforce for all the operation such as land rolling, rotary hoeing, between-row cultivation, irrigation canals cleaning, and fertilisers distribution. Irrigation considered all cost of fuel, lubricants, and labour workforce for all the operation related with the irrigation operations. The following irrigation systems were considered: flood irrigation, hose reel irrigation system, centre pivot irrigation, lateral pivot irrigation system, and drip irrigation. Manure considered all cost of fuel, lubricants, and labour workforce for all the operation related to handling, loading, transport, and spreading the manure from the farm pile to the fields. Harvest considered all cost of fuel, lubricants, and labour workforce for all the operation as mowing, conditioning, tedding, raking, baling, stacking, and storage when hay-based crops; chopping, transport, packing, and silo covering when silage-based crop; harvesting, transport, and drying when grain-based crops. Water for irrigation costs included surface water drainage as well as the water for irrigation. These costs are paid annually to the consortium whom manages the public canals that enables water to be used for irrigation in the summer as well as the drainage of excess rainfall in the fall and spring. Crop insurance cost was the annual insurance rate payed by the farmer by specific crop. Harvesting cost included the cost of items used for the storage of the crops, such as plastic, film, etc. Costs were calculated for each crop in €/per unit of feed DM stored and

these were converted in €/ha based on the productivity of the crops.

Indirect costs of production were calculated using different allocation indices for each cost item such as machineries and facilities insurances, repairs and maintenance costs, land cost, machineries, and facilities depreciation. Financial costs were not included due to lack of data. Machineries insurance costs reported by farmers were allocated to the different crops according to the hours used for each crop. Facilities insurance costs were allocated to the different crops according to the amount of DM stored for each crop. Repairs and maintenance cost that considered all the costs incurred in repairs and maintenance of the farm machineries involved in crop production were allocated to each crop according to the working hours spent by each machine in the different crop operations. Land cost involved land ownership and reported cost of land rental. Land ownership cost was calculated as the opportunity cost of owned land set to 500€/ha. For land that included double cropping in a year., this cost was split between the two crops. Machineries and facilities depreciation cost amount was calculated as suggested by Rotz et al. (2011) and then allocated to each crop according to the working hours spent by each machinery in the different crop operations. Lactating cow DMI (kg/cow per day) year-round was obtained based on farmer-reported total amounts of feed consumed from 1st January 2017 to 31st December 2017. Income was calculated as the revenue generated from milk sales (Hardie et al. 2014). Feed cost were calculated for lactating cows, dry cows, and young replacement from weaning until 1st

Table 2. Summary response by herd managers, question related to detection of oestrus, hormonal synchronisation, voluntary waiting period and reproduction performance.

Question	Mean \pm SD or (counts)	Min	Max
Who is responsible for oestrus detection on your farm?	Hired employee (28) Family member (10)		
What oestrus-detection technologies/practices are used?	Tail chalk (10) Pedometers (36) Collars (5)		
Do you use a voluntary waiting period?	Yes (30)		
Primiparous (days)	55.24 \pm 8.73	45.7	73.2
Multiparous (days)	53.23 \pm 7.62	43.8	71.1
Do you use oestrous detection or synchronisation timed AI?	Yes (37)		
Which protocol you use to synchronise your cows for the first breeding?			
Double-Ovsynch	(5)		
Ovsynch	(16)		
Presynch	(4)		
Other	(2)		
How frequently are pregnancies diagnosed?	9.9 \pm 3.49 days		
What method is used for diagnosis?			
Palpation	(11)		
Ultrasound	(30)		
Are pregnant cows re-examined?			
Yes	(15)		
No	(16)		
What's the HDR of your herd in the last year? (%)	56.14 \pm 7.75	39.09	70.61
What's the CR of your herd in the last year? (%)	30.52 \pm 3.32	21.01	39.07
What's the PR of your herd in the last year? (%)	17.05 \pm 2.58	11.48	25.00

Means \pm SD or counts (binary or categorical variables).

HDR: Heat Detection Rate; CR: Conception Rate; PR: Pregnancy Rate.

calving including expenses related to purchased feeds a farm grown feeds. Thus, income over feed cost (IOFC) was calculated every month as follows ($\text{€}/\text{lactating cow per day}$) = [(monthly income from milk sales) – (monthly expenses for both purchased and farm grown feeds)]/(average number of lactating cows per day by month). In the present paper, IOFC has been used as indicator of farm profitability, since it can represent a proven method to evaluate dairy farm profitability when complete balance sheet data are not available (Cabrera et al. 2010). Similar to Caraviello et al. (2006) survey, data of continuous variables collected on this selected group of dairy farm, being characterised by good knowledge and high quality data availability, were descriptively (means and their standard deviations) presented and discussed. Counts were tabulated for binary (e.g. yes or no) or categorical (e.g. specific management choices) variables. In order to provide benchmark values for specific parameters, the 75° and 95° percentiles were calculated for continuous variables related to crop costs of productions.

Results and discussion

Forty-one of the 50 selected herds responded to the survey, resulting in an 82% response rate. Due to criterion (i.e. previous knowledge of these farms recording the most and the best quality data) used to select these high-performance dairy herd, all the data

presented and discussed in current survey, either for continuous, binary or categorical collected information, were descriptively reported in agreement to Caraviello et al. (2006). The response rate was relatively high because most of these herds had a good relationship with the University. Herd size of respondents was 327 ± 162 lactating cows (Table 1).

Table 1 provides a summary of information regarding labour, herd size, milk production and components, calving interval, and culling strategies. About 63% of labour was provided by nonfamily employees with most of the employees working full time. Calculation done on a basis of a 50-h work week showed an average of 79 cows and 821.6 tons of milk per year per full-time equivalent employee, an intermediate value when compared with the US reports of (Bewley et al. 2001; Caraviello et al. 2006) but lower than reported in Evink and Endres (2017). Cow/heifer ratio was 1.08 ± 0.13 (ranging from 0.77 to 1.36). Average daily milk yield, as kg milk sold per cow/day, was 32.83 ± 2.01 . Annual culling rate was $34.00 \pm 4.00\%$ and calving interval was 14.16 ± 0.58 months.

Table 2 provides a summary of responses regarding detection of oestrous, hormonal synchronisation, voluntary waiting period, and reproductive performances. Among technologies introduced in dairies to aid the oestrous detection, pedometers were the most common technologies. Most of the herds used a voluntary waiting period of 55.2 ± 8.7 days for primiparous and 53.2 ± 7.6 for multiparous, thus, extending the time

Table 3. Summary response by herd managers ($n = 41$) to question related to housing, heat stress, manure removal and bedding.

Question	Mean \pm SD or (counts)	Min	Max
How many stalls per lactating cow have your herd? (stalls/lactating cow)	0.98 \pm 0.1	0.74	1.33
How much water access space per cow have lactating cows? (cm/lactating cow)	12 \pm 4.3	6.5	19
What is the predominant bedding type in your lactating cows barn?	Straw (20) Sawdust (1) Mattress (12)		
At what frequency is fresh bedding applied? (days)	4.1 \pm 2.1		
If individual maternity pen is used, how often do you clean and disinfect them?	Every calving (0) >4 calving (6) 2-3 calving (1)	2	7
Do you use electronic sorting gates?	Yes (12) No (29)		

Means \pm SD or counts (binary or categorical variables).

Table 4. Summary response among opinion by farm managers ($n = 41$).

Question	Mean \pm SD or (counts)	Min	Max
Indicate the importance of these reproductive issues in lactating cows in your herd (1 = easy to handle to 10 = major problem)			
AI service rate	7.3 \pm 1.2	6	8.5
Conception rate	8.1 \pm 0.9	6.5	9.5
Twinning	4.1 \pm 0.3	3	5
Retained placenta and metritis	7.1 \pm 1.5	5.5	9
Estrous detection	7.5 \pm 1.4	6	9
Early embryonic loss	6.5 \pm 1.2	5	8
Ovarian cysts	8.7 \pm 0.3	7.5	9
Reproductive record keeping	6.5 \pm 0.9	5.5	9
At which level these diseases are problems in your herd? (1 = no problem to 10 = major problem)			
Mastitis	7.15 \pm 1.12	5	9
Dermatitis	5.01 \pm 1.32	5	7.5
Lameness	5.11 \pm 1.24	5	7.5
Abortions	4.61 \pm 0.72	3	6.5
Death losses	4.34 \pm 0.74	3	6
Paratuberculosis	8.57 \pm 1.05	7	9.5
Ketosis	6.91 \pm 1.22	5	8.5
Milkfever	6.69 \pm 1.39	4.5	8
Bovine viral diarrhoea	4.01 \pm 0.51	3	5
Infectious bovine rhinotracheitis (IBR)	4.21 \pm 0.47	3	5
Describe the following aspects of employee management on your operation (1 = easy to handle to 10 = major problem)			
Finding good employees	7.15 \pm 1.51	5	9
Training employees	8.51 \pm 1.21	7	9
Supervising employees	8.14 \pm 0.71	7	9
Keeping good employees	6.15 \pm 0.51	5	7

Means \pm SD or counts (binary or categorical variables).

until first insemination might enhance the first-service conception rate (Stangaferro et al. 2018). Ovsynch was the most common synchronisation protocol used for first AI service. Only a few herds have introduced the Double-Ovsynch due to a higher labour requirement of this protocol. Almost 75% of the herds used ultrasound for pregnancy check. An early and accurate detection of non-pregnant cows has been reported as

very important in order to re-breed these cows as soon as possible (Wijma et al. 2017).

Table 3 summarises housing and bedding management. The surveyed farms had an average of 0.98 \pm 0.1 stalls/lactating cow (ranging from 0.74 to 1.33), which indicated that some farms were subjected to a severe overcrowding. Fewer than a quarter of dairies have a specific maternity pen, and less than a half of them cleaned the maternity pens after every calving, whereas many allowed ≥ 4 calvings between fully cleanings.

Table 4 summarises responses among opinion provided by farm managers. Ovarian cysts and conception rate has been identified as the major sources of concern among reproductive management. Among the health problems listed on a 10-point scale, paratuberculosis (8.57 \pm 1.05) and mastitis (7.15 \pm 1.12) were of greatest concern, followed by ketosis (6.91 \pm 1.22) and milk fever (6.69 \pm 1.36). Among employee management, the greatest concern is related to training employees and supervising them. Additionally, farmers spontaneously reported that major issues faced at the crop production level are related to the implementation of strategies to control the population of pests and other noxious animals like, *Ostrinia nubilalis* and *Diabrotica spp.* and *Myocastor coypus*.

Table 5 summarises nutrition, body condition scoring, and grouping strategies. The mean frequency of feed delivery was 1.27 \pm 0.47 times/day, and feed was pushed up an average of 6.8 \pm 1.2 times/day. These results are very similar to the results in the US reported by Caraviello et al. (2006). Increased feeding frequency and greater bunk space may improve DMI and promote more balanced nutrient intake and greater milk production (Sova et al. 2013). Diets were reformulated every 48 \pm 7 days, and feeds were tested every 52 \pm 2 days. Among transition cows nutritional management strategies, only three farms had introduced anionic diets, despite literature showing that

Table 5. Summary response by herd managers ($n=41$) to question related to nutrition, body condition scoring and grouping strategies.

Question	Mean \pm SD or (counts)	Min	Max
At what frequency is fresh feed delivered? (times/days)	1.27 \pm 0.47	1	2
How many times is feed pushed each day? (times/days)	6.8 \pm 1.82	4	9
How much bunk space per cow have lactating cows? (cm/lactating cow)	55.9 \pm 3.91	43	73
What is the targeted feed refusal rate? (% feed delivered)	4.2 \pm 0.4	2.5	5
How often are your feed tested? (days)	52 \pm 2	15	85
How often are the diets reformulated? (days)	48 \pm 7	30	90
Who is the main persona responsible for formulating diets?			
Feed company nutritionist	(34)		
Private consultant	(5)		
Other	(2)		
Do you use anionic diets in dry cows diets?			
Yes	(3)		
No	(38)		
How often do you BCS your cows?			
Never	(17)		
Evaluate at pen level every	45 \pm 6 d (13)	7	60
Evaluate cows individually every	65 \pm 24 d (13)	7	60
Who does the BCS?			
Veterinary	(10)		
Nutritionist	(1)		
Farm employee	(2)		
Do you use anionic diets in dry cows diets?			
Yes	(3)		
No	(38)		
Does nutritionist use these scores when balancing rations?			
Yes	(1)		
No	(13)		
What's your different nutritional groups among lactating cows?	One group (8) Post-fresh, primiparous + multiparous (25) Post-fresh, primiparous, multiparous (5) Post-fresh, primiparous, multiparous high, multiparous low (3)		
IOFC ^a (€ / lactating cow / day)	5.05 \pm 0.87	3.85	6.88
Milk Income ^b (€ per lactating cow per day)	12.38 \pm 1.11	14.61	10.43
Feed cost ^c (€ per lactating cow per day)	7.33 \pm 0.77	5.68	10.09

BCS: Body Condition Score.

Means \pm SD or counts (binary or categorical variables).^aMilk income over feed cost from January to December 2017.^bMilk Income for lactating cows from January to December 2017.^cFeed cost whole herd, except calves under 3 months of age, from January to December 2017.

managing the prepartum dietary cation-anion difference [DCAD = (Na + K) – (Cl + S)] to maintain an average urine pH between 5.5 and 6.0 would result in additional benefits in Ca status, postpartum DMI, and milk yield (Leno et al. 2017). Only a small proportion of herds evaluated cows' BCS as a routine on a consistent way, despite benefits for reproduction and health of BCS monitoring are well documented in the literature (Domecq et al. 1997).

Improved nutritional grouping strategy can be a potential way to improve IOFC and feed efficiency in these herds, since substantial improvement are obtained by switching from 1 to 2 or 3 nutritional groups (Cabrerá and Kalantari 2016; Kalantari et al. 2016). Despite undeniable advantages as higher milk productivity, better herd health, and higher IOFC due to better tailored diets and lower environmental impact because of nutritional grouping strategies (Bach 2014), many farmers concerned about the management complexity, the higher labour costs, and loss

in milk production due to more frequent intra-group movement (Contreras-Govea et al. 2015), and TMR formulations errors (Hutjens 2013). The feed cost, was calculated considering the whole feed consumption of the herd, excluding the feeds used for calves under 3 months of age, and expresses as €per lactating cow per day, using cost of production for farm grown feeds and market prices for purchased feeds. The feed cost, range from 5.68 to 10.09 €per lactating cow per day with an average and SD of 7.33 \pm 0.77. Milk income of the herd has been calculated as the sum of milk income including premiums for components and somatic cell count; the average milk income as €per lactating cow per day was 12.38 \pm 1.11. IOFC, calculated as the difference of the two precedent mentioned index, and average of the whole year of 2017, was 5.05 \pm 0.87 €/day per lactating cow with a minimum of 3.85 €/day and a maximum of 6.88 €/day.

Table 6 summarises response regarding insemination strategies, heifers and calves rearing on farms.

Table 6. Summary response by herd managers ($n = 41$) to question related to animal health, insemination strategies, heifers rearing.

Question	Mean \pm SD or (counts)	Min	Max
In which proportions you use sexed semen on heifers? (% of total heifers inseminations)	67.83 \pm 18.79	20	90
In which proportions you use sexed semen on cows? (% of total cows inseminations)	1.45 \pm 2	0	7
In which proportions you use beef cattle semen on heifers? (% of total heifers inseminations)	1.52 \pm 2.05	0	10
In which proportions you use beef cattle semen on cows? (% of total cows inseminations)	14.59 \pm 11.41	0	45
Did you have a waste-milk feeding programme for your calves?			
Yes	(25)		
No	(16)		

Means \pm SD or counts (binary or categorical variables).

Table 7. Summary response by crop managers ($n = 41$) to questions related to the crop enterprise among labour, farmland size, soil type, tillage practices, irrigation.

Question	Mean \pm SD or (counts)	Min	Max
How many people work in your operation? (n)			
Full-time family	0.54 \pm 0.5	0	1
Part-time family	0.07 \pm 0.26	0	1
Full-time nonfamily	1.29 \pm 0.96	0	3
Part-time nonfamily	1.12 \pm 0.51	0	3
How many ha of tillable land your farm manages? (ha)	160 \pm 94 ha	50	420
How much double cropping? (%)	33 \pm 13%	0	66
Describe the most common soil type of your farm	Sandy (4)		
	Sandy loam (13)		
	Loam (16)		
	Silty loam (5)		
	Clay (3)		
Describe the most common tillage practice adopted in you farm	Conventional tillage		
	Ploughing (17)		
	Conservation tillage		
	Chisel ploughing (18)		
	Minimum tillage (6)		
What's the most common irrigation system adopted?	Flooding irrigation direct from canals without pumps (8)		
	Flooding irrigation with pumps (17)		
	Hose reel (10)		
	Central pivot (2)		
	Rainger linear (3)		
	Drip irrigation (1)		
What kind of equipment you use the most to manage slurry?	Solid spreader (2)		
	Slurry tank spreader (21)		
	Umbilical spreader (5)		
	Umbilical injector (13)		
Do you use cover crop in order to reduce leaching and erosion?	Yes (6)		
	No (35)		
Do you systematically implement strategies to control <i>Ostrinia nubilalis</i> and <i>Diabrotica spp</i> in corn?	Yes (21)		
	No (20)		

Means \pm SD or counts (binary or categorical variables).

All farms used sexed semen, in different proportions, with an average level of utilisation on heifers of 67.83%. Beef cattle semen usage on heifers was not popular (1.45% of the total heifers inseminations); however, usage of beef semen on cows has been recorded to be more popular (14.59% of total cows inseminations).

Table 7 provides a summary of information regarding labour, land size, soil type and crop management

strategies. Average land size of respondents was 160 \pm 94 ha. Double cropping strategies, expressed as the amount of land used for growing two crops in the same year, was 33 \pm 13%. The most common type of soil was the 'loam' soil, and the most common tillage practice encountered was the chisel ploughing. In addition, not so many farms (10 out of 41) were able to provide recent soil analysis to better assess their fertilisation plans in order to reduce environmental

Table 8. Crop yield, direct, indirect and total cost of production of forages in farms, means \pm SD, 10th and 25th percentiles (€/ha).

Crops	Farms <i>n</i>		Land ^a %	Yield Ton DM / ha	DM %	tDC ^b € / ha	tIC ^c € / ha	tC ^d € / ha	tC per Unit € / ton DM				
Alfalfa hay	40	Means \pm SD	17.3 \pm 7.66	9.61 \pm 1.24	88.2 \pm 1.9	895 \pm 90	983 \pm 204	1968 \pm 362	207.1 \pm 41.9				
		25th								830.6	806.3	1719.8	179.4
		10th								806.2	784.9	1647.9	166.2
Corn silage second seeding	38	Means \pm SD	24.7 \pm 10.4	17.22 \pm 2.46	32.4 \pm 2.0	1693 \pm 153	662 \pm 132	2356 \pm 185	139.4 \pm 21.8				
		25th								1543.3	563.4	2263	122
		10th								1494.4	531.6	2185.8	112.9
Corn silage first seeding	37	Means \pm SD	25 \pm 10.2	20.38 \pm 1.78	33.4 \pm 1.4	1600 \pm 160	981 \pm 183	2581 \pm 221	127.4 \pm 14.1				
		25th								1471	814.8	2397.7	121.1
		10th								1441.1	799.5	2377.9	118.7
High moisture ear corn first seeding	36	Means \pm SD	20 \pm 8.1	11.98 \pm 0.98	59.0 \pm 3.3	1534 \pm 116	903 \pm 149	2437 \pm 168	204.8 \pm 22.7				
		25th								1442.5	768.2	2299.1	189.5
		10th								1421.8	755.4	2276.8	183.8
Ryegrass hay	35	Means \pm SD	19.5 \pm 10.1	5.85 \pm 0.35	88.8 \pm 2.0	522 \pm 78	536 \pm 125	1058 \pm 164	181.4 \pm 30.3				
		25th								460.5	428.8	917.7	163.6
		10th								447	413.2	897.9	154.3
Small grains silage	24	Means \pm SD	17.4 \pm 8.8	9.85 \pm 0.58	29.3 \pm 2.4	777 \pm 85	452 \pm 55	1230 \pm 110	125.2 \pm 12.6				
		25th								719.7	403.6	1167.3	119.9
		10th								696.6	399.2	1135.5	114
Sorghum silage second seeding	20	Means \pm SD	12.3 \pm 7.5	12.14 \pm 0.53	29.5 \pm 1.6	932 \pm 99	510 \pm 108	1442 \pm 167	119.0 \pm 15.8				
		25th								851.1	450.5	1303.4	109.9
		10th								835.4	405.8	1285.9	106.1
Mixed crops silage	17	Means \pm SD	16.9 \pm 8.9	10.15 \pm 0.75	31.5 \pm 1.9	721 \pm 78	461 \pm 84	1182 \pm 185	116.5 \pm 11.5				
		25th								689.8	409	1051.1	109.9
		10th								654	382.9	1010.5	107.6
Perennial grass hay	17	Means \pm SD	13.9 \pm 13.6	8.80 \pm 1.62	89.1 \pm 1.9	709 \pm 155	914 \pm 129	1622 \pm 253	187.1 \pm 30.2				
		25th								571.9	759.9	1410.1	168.8
		10th								559.1	787.9	1380.3	160.3
Soybeans grain first seeding	14	Means \pm SD	5.2 \pm 2.8	3.71 \pm 0.40	87.8 \pm 1.3	966 \pm 74	768 \pm 87	1734 \pm 136	474.3 \pm 71.4				
		25th								901.2	701.4	1612.1	421.2
		10th								896.2	682.5	1599.2	409.5
Soybeans grain second seeding	11	Means \pm SD	9.8 \pm 6.6	2.92 \pm 0.34	87.0 \pm 3.6	1016 \pm 79	472 \pm 53	1489 \pm 118	517.6 \pm 79.2				
		25th								970.8	441.9	1392.2	454.2
		10th								939.2	423.7	1377.9	441.1
Sorghum silage first seeding	8	Means \pm SD	6.5 \pm 3.9	13.36 \pm 0.84	29.4 \pm 1.8	982 \pm 101	795 \pm 105	1777 \pm 126	133.7 \pm 14.2				
		25th								895.5	710.8	1687.7	127.4
		10th								890.4	697.3	1654.6	121.1
Winter protein grains ^e	6	Means \pm SD	4.2 \pm 1.6	2.40 \pm 0.36	88.9 \pm 1.1	579 \pm 49	711 \pm 41	1290 \pm 62	549.5 \pm 97.7				
		25th								543.4	678.3	1256.4	469.3
		10th								531.3	671.2	1231.4	455.2
High moisture ear corn second seeding	5	Means \pm SD	6.6 \pm 3.1	9.34 \pm 0.38	56.0 \pm 1.5	1658 \pm 113	546 \pm 64	2204 \pm 112	236.2 \pm 12.1				
		25th								1561.2	496.5	2109.2	229.2
		10th								1549.9	485.1	2098.2	226.6

^aSome fields allow for a second crop (corn silage second seeding, sorghum silage second seeding, soybeans grain second seeding): area of these fields was considered in the numerator and denominator.

^bTotal direct costs.

^cTotal indirect costs.

^dTotal costs.

^e(*Pisum sativum* spp).

pollution and costs. Some farms ($n = 13$) have introduced the umbilical injection as a common practice for slurry management. This practice is more cost-effective than hauling or spreading raw manure (Plastina et al. 2015).

Table 8 summarises farm crop plan, yields, the crop DM at harvest, total direct costs, total indirect costs, total costs of production, and the relative cost of production per t of DM produced. Alfalfa hay resulted the most common crop with a percentage of the total crop plan of $17.3 \pm 7.66\%$ with a total cost of production of 1968 ± 362 €/ha with an average of six cuts per year, for a total duration of 3.5 ± 0.3 yerr. In the best

10 and 25% of farms considered (10th and 25th percentiles respectively), cost of production resulted lower than average with cost of production in €/per ton of DM of 166.6 and 179.4, respectively.

Mixed crop silage, which includes a mixture of small grains, vetch and pea that was sown during the fall and harvested as silage in May, has become a very popular crop cultivated in 17 surveyed farms with a yield of 10.15 ± 0.75 t DM/ha. This yield was very similar as small grains silage crop (9.85 ± 0.58 t DM/ha), however, with a slightly higher CP content. Corn silage first seeding (CSI) have higher total costs of production compared to corn silage second seeding (CSII),

Table 9. Direct cost of production of forages in farms ($n = 41$) means \pm SD, (€/ha).

Crops	Tillage ^a	Sprayers ^b	Comp ^c	Irrigation ^d	Manure ^e	Harvest ^f	Seed ^g	Herbicides ^h	Crop ⁱ	Fertilizers ^j	Water ^k	items ^l	Harvesting ^m
Alfalfa hay	64.6	28.3	17.5	64.8	44.8	418.5	71.5	88.4	29.0	10.8	28.4	0.0	27.8
	22.2	3.0	1.5	24.5	16.8	61.1	3.8	28.5	15.5	18.8	16.0	0.0	3.1
Corn silage second seeding	206.8	56.8	76.1	296.0	128.0	331.3	197.8	64.3	59.3	77.7	122.1	50.5	26.6
	55.7	34.5	18.0	139.1	32.4	58.2	7.4	1.9	21.1	25.8	60.7	8.6	1.24
Corn silage first seeding	198.9	56.6	60.1	215.6	123.9	355.2	206.4	77.9	59.2	82.9	81.4	49.6	31.4
	55.8	35.0	21.5	111.1	31.9	61.9	9.3	12.0	21.4	42.7	40.2	24.4	1.9
High moisture ear corn first seeding	197.9	62.0	43.4	202.4	121.0	321.9	202.8	64.9	65.7	99.4	94.1	48.3	10.6
	57.7	27.7	20.7	100.3	30.1	63.9	12.2	4.4	13.9	48.8	40.0	26.2	0.8
Ryegrass hay	150.1	0.0	17.9	0.0	97.6	140.4	84.9	0.0	0.0	1.3	11.2	0.0	18.3
	67.3	0.0	2.2	0.0	26.4	39.3	6.6	0.0	0.0	8.1	9.2	0.0	1.7
Small grains silage	107.9	0.0	24.5	0.0	107.8	268.0	137.4	32.0	0.0	42.2	14.6	28.3	14.2
	46.5	0.0	2.2	0.0	21.5	68.4	6.2	11.1	0.0	23.2	18.7	18.9	2.4
Sorghum silage second seeding	100.5	22.8	23.8	113.3	67.2	286.8	181.4	61.2	0.0	22.9	28.2	0.0	23.3
	46.2	6.2	1.7	37.1	17.6	73.6	6.9	2.2	0.0	30.4	12.6	0.0	0.8
Mixed crops silage	91.2	0.0	16.2	0.0	120.3	288.7	176.1	0.0	0.0	0.0	13.8	0.0	14.0
	58.7	0.0	2.1	0.0	18.1	61.97	5.4	0.0	0.0	0.0	8.4	0.0	0.4
Perennial grass hay	0.0	0.0	15.3	67.6	104.3	376.0	0.0	0.0	0.0	26.8	94.4	0.0	24.1
	0.0	0.0	1.3	65.6	25.5	66.2	0.0	0.0	0.0	64.1	58.2	0.0	2.2
Soybeans grain first seeding	169.2	25.0	40.4	89.8	32.6	292.0	165.5	65.6	0.0	0.0	34.0	51.4	0.0
	41.0	5.6	5.8	19.5	46.7	7.7	4.5	18.4	0.0	0.0	20.5	15.1	0.0
Soybeans grain second seeding	168.5	26.0	25.3	112.8	40.4	292.8	158.1	72.6	37.1	0.0	41.0	41.5	0.0
	35.4	3.3	2.4	45.3	48.7	15.8	6.5	14.2	12.3	0.0	20.4	13.9	0.0
Sorghum silage first seeding	147.9	22.2	15.7	67.0	71.0	354.1	179.6	58.2	0.0	18.1	23.3	0.0	24.3
	66.9	6.1	0.6	10.3	17.7	66.2	7.6	8.1	0.0	33.6	13.4	0.0	0.6
Winter protein grains ⁿ	106.5	1.5	38.2	0.0	60.7	191.3	165.5	0.0	0.0	0.0	15.4	0.0	0.0
	46.6	3.8	1.8	0.0	35.8	3.6	13.6	0.0	0.0	0.0	6.0	0.0	0.0
High moisture ear corn second seeding	166.9	63.7	65.9	311.4	109.6	331.2	195.9	62.0	63.9	118.4	111.0	50.0	8.1
	62.3	20.4	10.0	147.6	20.5	90.8	4.8	0.0	0.0	36.7	56.5	0.0	0.3

^aTillage and planting operations costs.^bSprayers operations costs.^cComplementary operation costs.^dIrrigation costs.^eManure handling and spreading costs.^fHarvest operations costs.^gSeeds costs^hHerbicides costs.ⁱCrop protection costs (fungicides. Insecticides)^jFertilizers costs.^kDrainage and water for irrigation costs.^lCrop items costs.^mHarvest items costs (film, plastics).ⁿ(*Pisum sativum* spp).

this was due to higher land costs, since the total land cost per hectare in case of corn silage second seeding was shared with the previous crop. Anyway, is important to notice the lower direct cost for CSI compared to CSII since it has lower irrigation cost and higher yield. In the best 10% of farms, CSI cost of production was lower than average being 118.7 €/per ton of DM and 112.9 €/per ton of DM for the CSII.

High moisture ear corn first seeding (HMEC) and second seeding (HMEC-II) was used as the main starch source, in 36 and 5 farms, respectively, with a crop plan % as 20 ± 8.9 and $6.6 \pm 3.1\%$ respectively. Cost of production trend for HMEC and HMECII follow the same pattern describe for CSI and CSII. Perennial grass hay (PG) take place in crop plan for $13.9 \pm 13.6\%$ with many difference among farms, since in certain farms their presence is confined in marginal areas, whereas in other farms their presence is much more extensive. Ryegrass hay (RG) (*Lolium multiflorum*) was used in

many farms (35), with a mean proportion of $19.5 \pm 10.1\%$ of the crop plan, due to high forage quality and low cost of production (1057 ± 164.30 €/ha). Ryegrass is usually harvested as hay or silage from mid-April to mid of May as function of the weather and allow to grow a second crop after it as corn/sorghum/soybeans. Soybeans first seeding (SBI) and second seeding (SBII) was cultivated in (11) and (8) farms, respectively, with a proportion of 9.8 ± 6.6 and $6.5 \pm 3.9\%$ of the crop plan. SBI present a higher total cost pf production if compared to SBII and higher yield. In particular, SBI has lower direct cost compared to SBII and higher indirect cost due to higher land cost, since SBII share land cost with the previous cultivated crop. Sorghum popularity is raising in northern Italy in recent years, the main causes to this success is related to the lowest mycotoxin risks if compared to corn and lower irrigation requirements, sorghum in first seeding (SFI) enter in crop plan of (8) farms with

Table 10. Indirect cost of production of forages in farms ($n = 41$), means \pm SD, (€/ha).

Crops	Land ^a	Machineries depreciation	Facilities depreciation	Machineries insurance	Facilities insurance	Repairs and maintenance
Alfalfa hay	617.3	164.4	17.7	10.5	22.9	150.1
	112.6	155.3	47.5	6.7	19.8	41.7
Corn silage	304.5	149.8	53.3	9.06	11.4	133.9
second seeding	57.1	89.3	51.0	5.65	5.9	40.7
Corn silage	609.0	154.6	59.6	9.40	13.5	134.8
first seeding	114.1	97.1	58.7	5.81	6.5	39.9
High moisture ear	604.8	121.5	38.4	7.65	8.53	121.7
corn first seeding	103.8	71.7	37.8	5.31	4.74	39.8
Ryegrass hay	308.7	107.3	16.5	5.97	13.7	83.4
	58.8	80.3	43.0	4.07	10.2	23.2
Small grains silage	307.5	49.8	29.4	3.17	5.53	56.7
	40.0	40.1	26.0	2.79	2.82	20.1
Sorghum silage	318.3	71.1	48.8	4.62	8.01	58.9
second seeding	65.0	46.5	28.1	3.60	3.73	25.2
Mixed crops silage	296.6	70.3	30.2	4.16	5.42	54.2
	51.0	48.8	23.5	2.45	2.05	16.1
Perennial grass hay	613.0	103.1	44.9	7.81	15.0	129.6
	80.2	51.2	75.3	4.36	4.3	41.5
Soybeans grain	593.1	75.5	0.0	2.98	33.9	62.8
first seeding	72.5	22.5	0.0	1.54	27.1	20.3
Soybeans grain	294.6	93.1	0.0	3.29	18.7	62.4
second seeding	43.7	33.0	0.0	1.00	9.9	16.2
Sorghum silage	613.4	53.7	59.1	2.75	8.38	57.8
first seeding	73.7	31.3	29.5	1.65	4.05	15.4
Winter pro-	590.9	45.7	0.0	2.65	29.3	42.4
tein grains ^b	41.0	33.6	0.0	1.75	21.6	8.0
High moisture ear	594.2	104.1	32.4	6.57	4.29	101.7
corn second seeding	43.8	79.6	25.0	3.76	1.32	18.0

^aland ownership and rental costs.^b(*Pisum sativum* spp).

an average $6.5 \pm 3.9\%$ of the crop plan, whereas sorghum silage second seeding (SFII) was used by (20) farms with an average $12.3 \pm 7.5\%$ of the crop plan. About SFI, since all the farms have access to irrigation in almost all the fields, SFI lost much of its convenience in favour to CS, a crop that provide higher yields and more energy per hectare at lower cost in €/ton DM produced. Among SFII, these results show how SFII was much more appreciate than SFI, this because SFII shows a small difference in yield production if compared to SFI, SFII result competitive also with CSII especially in light soil farms with high irrigation cost and become more interesting if compared to CSII in case of late planting (i.e. second seeding after a late small grain silage harvest). As small grains silage, we assume a category that include, in the farm surveyed, wheat, barley, triticale and oats. This crop category was cultivated in (24) farms with an average proportion of $17.4 \pm 8.8\%$ of the crop plan. Winter protein grains (WPG), is a category referred to field peas (*Pisum sativum*).

Among cost of production of forages, at the best of our knowledge, very limited sources of data have been published in order to compare cost of production of forages for the area considered (Northern Italy). To obtain some kind of comparable data, (Borton et al. 1997) showed great difference in cost of

production of forages among different farm dimensions considering a 100 and 500 lactating cows farms as sample. (Cesaro and Marongiu 2013) provided a very detailed cost of production analysis for crop commodities as maize, wheat, durum wheat. Only a small part of these data can be compared with our database. Anyway, the comparable data as seeds, fertilisers, crop protection, depreciation costs, show high similarity among corn and small grains cost of production. Table 9 provides a detailed summary of direct cost of production of forages. Large difference among irrigation costs among farms is noticed. Farms that rely on flooding and pivots had lower irrigation costs than farms that used hose reel equipment or drip irrigation. It is important to notice that not all farms were suitable for flooding irrigation system or pivots due to fields and soil intrinsic characteristics. Farms with minimum tillage or chisel ploughing had significant lower tillage and planting costs. Costs of spraying operations were relatively high because almost all farms have recently introduced an insecticide treatment for the control of European corn borer (*Ostrinia nubilalis*) and Western corn rootworm (*Diabrotica* spp.), in addition to pre-emergence and sometimes post-emergence herbicides treatments. The use of transgenic corn hybrids is currently restricted in Italy and the use of chemical insecticides is still the main

method for European corn borer control in field conditions (Labatte et al. 1996), since the associated grain yield losses vary between 5% to 45% (Lynch et al. 1980). The treatment also reduces aflatoxin contamination problem (Masoero et al. 2010). In addition, potential opportunities can be derived by the introduction of fungicides application on corn, in order to improve corn silage yield (Paul et al. 2011) and overall quality (Venancio et al. 2009). These effects are beneficial also at the cows' level in order to improve feed efficiency, as reported by (Haerr et al. 2015). Among fall seeding crops, the most expensive items were the harvest operations and tillage and planting operations.

Table 10 provides a detailed summary of indirect cost of production of forages. Land cost results lower in crops involved in double cropping strategies, since the land cost (€/ha) were splitted between the two crops involved. Machineries depreciation (Md) costs were higher in crops that required expensive equipment and longer working hours such as the case of corn silage and alfalfa hay with costs of 154.67 ± 97.12 and 164 ± 155.33 €/ha, respectively. Facilities depreciation (Fd) costs were higher for high producing crops and for crops that require expensive storage facilities (e.g. horizontal silo is more expensive than a hay shed). For those reasons, corn silage and sorghum silage first seeding had the higher facilities depreciations costs of 59.66 ± 58.68 and 59.09 ± 29.56 €/ha, respectively. Machineries insurance cost (Mi) and facilities insurance costs (Fi) follow the same pattern as Md and Fd, respectively. Among repairs and maintenance costs (R), results showed higher costs for AA and CS, since these are the crops with the higher requirement in machinery work hours per hectare, with a cost of (150.11 ± 41.76) and (134.88 ± 39.95) €/ha, respectively, followed by CSII, HMC and PG. The cost of production of forages showed a great variability among farms, even if the sample of farms considered include farms with similar characteristics, similar land management, dimensions and machineries used. This means that cost of production of forages is farm specific and general market value to estimate costs for farm grown forages can be described as an oversimplification.

Conclusions

The present study provides a comprehensive summary about dairy herd management and farm performances with emphasis on cost of production of the main forage crops on medium to large very well managed commercial dairy farms located throughout Northern Italy. As such, it can serve as a useful reference

regarding crop general management issues, employee management, crop management practices, and forages cost of production. Several key challenges and opportunities were identified. Crop managers identified training good employees and finding good employees as their greatest labour management challenge. Contrast pests as *Ostrinia nubilalis*, *Diabrotica spp.* and noxious animals as *Myocastor coipus* has been identified as another important challenges farmers faced from an agronomical standpoint. With regard to the high variability among cost of production of forages showed in this paper, additional opportunities may exist. First, cost of production references can be useful to find points of weakness in the crop management practices and highlight inefficiencies. Second, forage cost of production analysis carried out at the farm level, can be the first step, for a new kind of decision making process, in order to provide to dairy farmers better suggestions among cropping plan design based on their herd nutritional requirements. An integration of this aspect through least cost ration formulation using mathematical optimizations can be an interesting argument to focus future research. Forages cost of production analysis require a high input effort in order to collect all the data necessary for a correct cost calculation and a bigger analysis that include more farms can be beneficial in order to obtain more variability, new insight and different farm situations. In summary, this study can provide useful references with regard to commonly used crop management practices and relative costs on well managed commercial dairy farm located in Northern Italy at present time.

Geolocation information: Italy

Disclosure statement

The authors declare they have no conflicts of interest.

Funding

This work was supported by the MAP (Meccatronica per l'Agricoltura di Precisione) project from Emilia Romagna under Grant 886 13/06/2016 and by the Fondazione Romeo ed Enrica Invernizzi (Milan, Italy).

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