Environmental Impacts to Surface Water from Confined and Grass-Based Dairy Farms

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Abstract

There is little research on the effects of confined dairy farms and grass-based dairy farms on the surrounding surface water environment. This study was conducted through sampling and analysis of seven dairy farms in the Northern Hemisphere, especially between 38-degree to 45-degree north latitude. The correlation between the effect of confined dairy farms and grass-based dairy farms on the surrounding surface water (mainly Phosphorus runoff and Nitrogen precipitation) and pasture scale and waste management were obtained.

1. Introduction

Dairy products are rich in protein. When taken into the human body, proteins break down into amino acids, which are called the source of various proteins, such as serum proteins, myogens, and immunoglobulins required for human synthesis. There are a large number of calcium ions in dairy products, and its concentration ratio is suitable for the body's absorption range, is a good calcium supplement. (Kanekanian, 2014)

These benefits make a big market of the dairy product. According to the data from Food and Agriculture Organization of the United Nations (FAOSTAT), in 2013, the total worldwide milk production was 770 billion liters, valued at 328 billion dollars, ranking third in the world's agricultural products in terms of tons, and ranking first in the world in terms of value. And more than 80% of dairy products are from cow. (Food and Agriculture Organization of the United Nations, 2016) The consumption amount continuingly increased all over the world for the last 20 years and, is expected to continue to increase in the next 10 years. For the United States, from 1975 to 2016, the consumption of the milk-equivalent and milk-fat basis has increased from 539 pounds to 646 pounds per person per year. (USDAERS, 2018)

However, the dairy producing system has a significant impact on the environment, including the air, water and the soil. Atmospheric methane emissions and ammonia emissions are the main impact to the atmosphere from the dairy farm. (Garnsworthy, 2004) At the same time, wastes enter the soil and water through fertilizing and runoff. Globally, dairy systems are recognized as a grave threat to water quality around, both in groundwater and surface water. (Steinfeld, et al., 2006)

Traditional eating habits, like consuming cheese in Europe and in the United State (Kindstedt, 2012), and the diversity of taste which leads the love from people all around the world, like ice cream makes a prosperous dairy market. This prosperity causes the increasing demand of dairy products which need more cows and can produce more waste and impact to the environment.

Objectives:

The confined dairy farms make more dairy products with the same number of cows as the grass-based farms. Therefore, there is a trend that the confined farms are replacing the traditional pasture-based farms due to the differential in profits. (MacDonald, et al., 2007) Besides the profits, the environmental impact should be also considered between these two kinds of dairy farms. However, it is difficult to directly measure all of these impacts on the environment. (Rotz, 2009) This project focused on the impact to the surface water from dairy farms in different conditions. This project chose the grazing-based dairy farms and confined dairy farms in the North Central United States (Ohio and West Virginia), to represent the diversity of current normal dairy production systems in the temperate zone of the Northern Hemisphere. We compare the producing system with one typical confine dairy farm in China (Heilongjiang Province) which uses modern machining to reduce environmental impact. Finally, we conducted a comprehensive analysis of dairy farm impacts in order to develop general design parameters and suggestions for future dairy systems.

2. Literature Review

2.1 Environmental Impact Assessment of Dairies Using the Life Cycle Assessment tool

Input–output accounting, ecological footprint analysis and life cycle assessment (LCA) are three widely used methods in animal production to assess the environmental influence (Thomassen & Boer, 2005)Among these three, LCA, a tool to assess the environmental impacts for a product through the life-cycle of the product, has been used to assess the potential impacts in many environmental fields. (ISO , 2006) Due to comprehensive analysis, the LCA has been used to assess the potential impact of dairy farms for many countries and regions over a long period, like in Sweden (Flysjö, Cederberg, Henriksson, & Ledgard, 2011), Finland (Grönroos, Seppälä, Voutilainen, Seuri, & Koikkalainen, 2006), the Netherlands (Thomassen, Dolman, Calker, & Boer, 2009), Japan (OGINO, et al., 2008), New Zealand (Flysjö, Cederberg, Henriksson, & Ledgard, 2011), and Portugal (Castanheira, Dias, Arroja, & Amaro, 2010).

Input–Output Analysis (IOA) is a field of economics that shows the relationship between the producer, like the industrial sector, and the consumer, like the sector itself and others. (Miller & Blair, 2009) This analysis was considered to provide information for LCA, and this was the IO-LCA. It is important for IO-LCA to have a good IO database with up-to-date and comprehensive characters. One of the most easily accessible databases for IO-LCA is the EIO-LCA database of Carnegie Mellon University. (Ochoa, Hendrickson, & Matthews, 2002)

The LCA method consists of four interrelated components (as shown in Figure 1): 1. Goal and Scoping Definition, 2. Life-Cycle Inventory (LCI), 3. Impact Assessment, and 4. Improve Assessment (Interpretation). (Loiseau, Roux, Junqua, Maurel, & Bellon-Maurel, 2013)

1. Goal and Scoping Definition is the first and the most critical part of the LCA. This section consists of the determination of research objectives, scope, the establishment of functional units, the establishment of a process to guarantee the quality of research, etc. It provides an early definition for the scope, premise and restrictive conditions. (Curran, 2017)2. Inventory analysis (LCI) is a technical process that quantifies the use of resources and energy throughout the life cycle of a research system, such as products, processes or activities, and discharges to the environment. (Eide & Ohlsson, 1998) 3. The impact assessment is a quantitative and/or qualitative description and evaluation of the impacts of the

environmental load identified in the inventory analysis. (ISO , 2006) This section consists of the following three steps: impact classification, characterization, and quantitative evaluation. 4. Improve assessment are mainly to identify, evaluate, and select programs that reduce the environmental impact or load of the research system. Whether improvements can be made depends on inventory analysis, impact assessment, or a combination of the two. (ISO , 2006)

Recently, life cycle assessment (LCA) has been accepted to assess the environmental impact of the dairy farm as a popular method all over the world due to the comprehensiveness. However, this may also be the critique. The comprehensive analysis means that the data should be in large numbers and exact. But uncertainties may appear in LCA. (Heijungs & Frischknecht, 2005) (Heijungs & Guinée, 2007) These uncertainties may result in an unreliable LCA because a small deviation may lead to completely opposite results in complex model calculations. Another critique of the LCA is the Goal and Scoping Definition. This is the first step of the LCA and is also the most important step. However, the scope of a dairy farm is hard to determine. (Martínez-Blanco, Inaba, & Finkbeiner, 2015)

Despite these shortcomings, LCA is a good tool to assess the various impact of a dairy farm. However, generally, many of the grass-based farms were also family farms. Because of this, data, such as the milk fat concentration and the exact amount of feed are uncertain and difficult to measure accurately. Therefore, this study will not use LCA to assess the impact of the dairy farms.

2.2 Environmental Impact Assessment of Dairies Using Water Quality Index

Water Quality Index (WQI) is defined as the statistics and summarization of the pollutants in the water body which are used to comprehensively reflect the degree of water pollution in the form of numerical values. The index is mainly used to compare water pollution at different times and places, and it can also be used as a basis for water pollution classification and grading.

Water pollution index assessment method can be roughly divided into two types, namely the Single-factor assessment method and the comprehensive pollution index method.

The single-factor assessment method uses only one parameter as an evaluation indicator. It is simple and straightforward and can directly elucidate the relationship between water quality status and evaluation criteria. Its expression is:

$$P_{i,j} = \frac{C_{i,j}}{S_i}$$

Where $P_{i,j}$ is the pollution index of water quality evaluation parameter i at point j;

$C_{i,j}$ - monitoring concentration of water quality evaluation parameter i at point j, mg/L;

S_i - Evaluation standard for water quality evaluation parameter i, mg/L. (Zhang, et al., 2017)

If the pollution index Pi of a water quality evaluation parameter is > 1, it means that the water quality evaluation parameter exceeds the specified water quality standard at point j, and it cannot meet the requirement for use. Therefore, the water pollution index assessment method can objectively reflect the degree of pollution of water bodies, can clearly identify major pollutants, major pollution periods, and major polluted areas of water bodies, and can provide complete changes in the spatiotemporal pollution of monitored water areas, reflecting pollution history. This also makes the single-factor assessment method the most commonly used detection method for bodies of water. Moreover, as one of the simplest methods, many extension methods are based on the single-factor assessment, such as the groundwater quality index (GWQI). (Saeedi, Abessi, Sharifi, & Meraji, 2010)

The comprehensive pollution index method includes many different methods, like Nemerow pollution index (NPI).

Nemerow's proposed water pollution index is in the following form:

$$PI_j = \sqrt{\frac{\left(max\frac{C_i}{S_{i,j}}\right)^2 + (\frac{1}{n}\sum_{i=1}^{n}\frac{C_i}{S_{i,j}})\text{^}2}{2}}$$

In the formula, PI_j - Water pollution index of j kinds of use water, mg/L;

$S_{i,j}$- Water quality evaluation parameter (pollution) i J type of use Water quality evaluation standard (mg/L);

C_i- Measured concentration of water quality evaluation parameter i, mg/L;

Nemerow has developed corresponding water quality evaluation standards as the basis for calculating the water pollution index according to different uses of water, and then calculated the values of water pollution indexes for various uses. The NPI considers the three factors of the average level of various pollutants, the pollution level of the pollutants with the largest concentration of pollution, and the use of water, and the design of the index form is reasonable. (Homepage, 2017)

Nemerow’s method is widely used all over the world to assess water quality. However, it is not proper for this study, as this study only needs the simple comparison between farms to analyze the different impact between the confined dairy farm and grass-based dairy farm.

3. Materials And Methods

3.1 Farm selection and description

Six farms in the United States and one farm in China were chosen to participate in this research. Firstly, 23 farms were chosen as the representative dairy farms in the northern United States, including grass-based and confinement dairy farms. To ensure that participating dairy farms were representative and comparable, three criteria were identified: (1) the farms should work well during the period of the study;

(2) the farms' range, between 25 acre and 5000 acre (grazed acres for grass-based farms or feed planting acres for confined farms); (3) a similar climate condition of the farms.

Considering the farmers' willingness to participate in the study and qualification using the above criteria, this study chose 6 of the 23 farms as subjects. All six farms are in the North Central United States with a similar surrounding environment.

The only farm in China was chosen for waste management system comparison purposes.

3.2 Farm Characteristics in the United States

Of the six farms selected for this study, one was a confined farm and the other five were grass-based farms. Each dairy can reasonably represent other dairies at the similar scale.

In this study, the dairy farms were promised anonymity. Because of this, the farms are described with general characteristics so that one can understand each system, but details that point out the identity of the farms are omitted.

For confined farm (called C1 in this study as Confined Farm 1), the herd size was about 6140 dairy cattle, including 40 calves, 2300 older heifers, and 3800 lactating cows. All cattle were Holstein. The average bodyweight of the herd was 1,600 pounds. Milk production was about 12,000 kg per cow per year (81 pounds per cow per day), and the milk fat concentration averaged about 3.9 percent. Energy-corrected milk (ECM) was 87.2 kg per month, accounting as the Figure 2 shows.

The calves were maintained in the stowing houses and the older heifers were in the open field lot, while the lactating cows were maintained in two free-stall barns, the two largest buildings in Figure 3.

The C1 has about 4,000-acres of cropland to grow corn and hay for the cows. The cows were fed with 4,000-ton corn silage per year containing 33% harvested silage, 30% grazed forage, and 37% purchased feed.

Water was pumped from the well and used for the cows and for flushing the floor of the barns. The wastewater went into the waste management system and separated by the solid separator. Part of the separated water was further filtrated into progressively cleaner water and used to clean the floor. The other separated water was piped into three pools to do fermentation and disinfection. The separated solid waste was set in a big pool for fermentation. After 3 months' setting in cold weather or 1 month's setting in hot weather, the waste was broken down and used as fertilizer on the cropland.

The grassed-based dairy farms were called as G1, G2, G3, G4, & G5.

Farm G1 had the herd size of about 90 dairy cattle, including 30 calves and older heifers and 60 lactating cows. The breed included Holstein and Red & White. The average bodyweight of the herd was 1,200 pounds.

The calves were maintained in 2 small barns, the old heifers were held in a separated lot in the open field, the lactating cows were held in a big barn, and the dry cows were maintained in an open field lot.

G1 had about 100-acres of pasture for the cows. The cows were fed with grazed forage and some purchased feed. Farm and field structure were shown in the Figure 4.

Water was pumped from the well and used for the cows to drink. The waste mostly was set by the farmers in one pool to decompose, or directly put on the pasture as fertilizer.

Farm G2 had a herd size of about 80 dairy cattle, including 45 calves and older heifers and 35 lactating cows. The breeds included Holstein (most), Guernsey and Brown Swiss. The average bodyweight of the herd was 1,200 pounds. Milk production was about 40 pounds per cow per day.

G2 had an about 40-acre pasture for the cows. The cows were fed with grazed forage and some purchased feed. Farm and field structure were shown in the Figure 5.

Water was pumped from the well and used for the cows to drink. In the past, when there were a large number of cows, the waste mostly was set by the farmers in one pool to decompose. During the period of this study, the waste was applied directly to the pasture as fertilizer.

Farm G3 had a herd size of about 115 dairy cattle, including 55 calves and older heifers and 60 lactating cows. The breed was all Holstein. The average bodyweight of the herd was 1,100 pounds. Milk production was about 55 pounds per cow per day.

G3 had an about 150-acre pasture for the lactating cows, and 200 acres for the calves and older heifers. The cows were fed with grazed forage and a little purchased feed. Farm and field structure were shown in the Figure 6.

Water was pumped from the well and used for the cows to drink. The waste mostly was directly put on the pasture as fertilizer (during the period of this study, focusing on the lactating cows' pasture).

Farm G4 had a herd size of about 46 dairy cattle, including 10 yearling calves, 16 older heifers and 20 lactating cows. The breed included Holstein (most), Guernsey and Brown Swiss. The average bodyweight of the herd was 1,800 pounds. Milk production was about 20000 pounds per cow per year, and the milk fat concentration averaged about 6 percent.

G4 had an about 65-acre pasture for the cows, and 25-acres of flexible land which could be turned into pasture if needed. The cows were fed with grazed forage and a little purchased feed. Farm and field structure were shown in the Figure 7.

Water was pumped from the well and used for the cows to drink. The waste was directly used to fertilize the corn field.

Farm G5 had a herd size of about 90 dairy cattle, including 30 calves and older heifers and 60 lactating cows. The breed is all Holstein. Milk production was about 2,0000 pounds per cow per year, and 60 pounds per cow per day.

G5 had an about 70-acre pasture for the cows. The cows were fed with grazed forage and a little purchased feed. Farm and field structure were shown in the Figure 8.

Water was pumped from the well and used for the cows to drink. The waste was set in the pool and eventually used to fertilizer the field.

Table 1 below shows all of the characteristics of the farms in this study. As the family dairy farms in small scale, most dairy farms did not have the details of milk production or were not willing to provide detailed data.

Table 1: Summary of the dairy farm characteristics in United States

	C1	G1	G2	G3	G4	G5
Cattle number	6140	90	80	115	46	90
Breed	Holstein	Holstein and Red & White	Holstein (most), Guernsey & Brown Swiss	Holstein	Holstein (most), Guernsey and Brown Swiss	Holstein
Average bodyweight (pounds)	1600	1200	1200	1100	1800	N/A
Milk production						
Total (pounds/cow/year)	26,455	N/A	N/A	N/A	20,000	20,000
Total (pounds/cow/day)	81	N/A	40	55	N/A	60
Milk fat concentration	3.9	N/A	NA	N/A	6	N/A
ECM (pounds)	87.2	N/A	N/A	NA	N/A	N/A
Area of pasture or cropland (acres)	4000	100	40	150	65+25	70
Waste management system	Solid separator, separated water and solid waste pools, the waste used to fertilize the cropland	Set in the pool and used to fertilize the field	Directly fertilize the pasture	Directly fertilize the pasture	Directly used to fertilize the corn field	Set in a pool and used to fertilize the field

* NA: not available

3.3 Farm Characteristics in China

Harbin Wondersun the Cow Feeds the Reproduction Co Ltd (C2, confined dairy farm 2) is an advanced confined dairy farm whose shares are held by a famous Chinese dairy company, Heilongjiang Wondersun Dairy Co., Ltd., one of the three largest dairy companies in China owning 64 big farms with more than 200,000 fine bred cows (Australian Holstein) and 6,000,000-hectare (14 826 322.9 acre) natural grassland pasture. C2 is in the northern part of China with a similar climate to the farms chosen in the United States.

The C2 farm we used had 4600 cows and 2400-hectare (5930-acre) cropland including 1600 hectare for Chinese rye grass and 800 hectares of silage corn. These crops and the milk produced at C2 have received organic product certification from China Quality Certification Center. Annually C2 produces 30,000 tons of silage corn, 4,800 tons of Chinese rye grass and 17,000 tons of milk. As shown in the figure 9 below, six big buildings were for the lactating cows and four small buildings were for the calves and heifers.

3.4 Water samples and chemical analysis

From the six subject farms, water was sampled in the area around the farms in runoff streams or down streams, a total eight samples in all were selected. Four farms had one sample and two farms had two samples taken (one from run-off stream and one from downstream). The water of all samples was taken from at least 5 cm below the surface of the stream or run-off. All water samples were taken within one 24-hour period and kept in sealed plastic bottles under 4ºC until chemical analysis.

The Phosphate-P (PO_4), Nitrate-N (NO_3), Nitrite-N (NO_2) and Ammonia Nitrogen (NH_3) in the samples were analyzed using the colorimeter method (shown in Figure 11), while the pH of the samples were analyzed by pH tester (shown in Figure 10).

The pH value was analyzed by pH meter with the analyzing method that pH value is converted from the voltage between two electrodes of the meter.

The Phosphate is analyzed by vanadomolybdophosphoric acid method, the Nitrate-N and Nitrite-N- low range are analyzed by diazotization method, and ammonia Nitrogen is analyzed by salicylate method. The change of the color between the blank sample and reacted sample will be measured and converted to the concentration of the chemical in the sample. (LaMotte Company, 2004)

4. Results And Discussion

4.1 Chemical Analysis Results

All the samples were analyzed in the lab of Marshall University within a two-day period.

Table 2: chemical analysis results

sample		pH	PO_4 (ppm)	NO_3 (ppm)	NO_2 (ppm)	NH_3 (ppm)
1	C1-1	8.4	0.14	>3	0.097	>1.2
2	C1-2	8.2	0.1	>3	<0.001	0.348
3	G1	8.7	0.02	1.19	0.021	0.372
4	G2	7.6	15.6	0.001	0.002	>1.2
5	G3-1	7.4	0.01	0.16	0.0012	0.168
6	G3-2	7.7	0.02	1.61	0.010	0.348
7	G4	7.5	0.02	0.33	0.003	0.132
8	G5	7.8	0.03	0.12	0.001	0.12

1* Sample 1, 7 & 8 were from the downstream.

2* Sample 2, 3, 4, 5, & 6 were from the runoff stream.

3* The data of sample 1 may be higher than expected due to there being another cattle farm near the stream

4.2 The Phosphate (PO_4) in the runoff streams of the confined dairy farm and the grass-based farms

Phosphate (PO_4) is one of the main pollutants in the runoff from the dairy farms. As shown in table 2, the four columns include the PO_4 in the samples from the runoff and the downstream. The sample 2, 3, 4, 5 and 6 are from the runoff. However, the value of sample 4 is too large compared with the other values. Figure 12 is the chat with data from the sample 2,3,5 and 6. It is obvious that the PO_4 in the sample of the confined dairy farm has a higher concentration than the value in the grass-based farms. The value is five to six times higher (table 2, fourth data column).

From the data above, the PO_4 concentration in the sample of the confined farm is higher than that of the grass-based farm. The mostly likely reason is more PO_4 input. The farmer may be applying fertilizer with PO_4 to the cropland or purchasing feed which also have additional PO_4 to feed the cows. As the crops growing in the cropland are used for feeding cows and the waste of the cows is used for fertilizing the cropland, the PO_4 cannot go out of the system. The continual input of P in a virtual closed system can make the concentration of the P higher in the confined farm than in the grass-based farm. The system holds the high concentration of the P. These are possible reasons the reason that the runoff water sample had the higher value of P.

4.3 The N in runoff stream and downstream of the confined dairy farm and grass-based farms

In the present study, we measured the value of the NO_3, NO_2 and NH_4 to analyze the N impact on surface water from the dairy farm.

Cow's urine contains large amounts of urea, which is easily decomposed by urease and becomes urinary nitrogen. The main type of N in urinary nitrogen is NH_4 +(or NH_3). NH_4 + (or NH_3) can be oxidized to NO_2 by nitrification, then to NO_3. Therefore, the initial stage is mainly organic nitrogen and NH_3−N. As the time of exposure to air increases, the oxidation slowly takes place in the form of NO_3-N. So, NH_3-N and NO_3-−N are the main forms of inorganic nitrogen in the water. NO_2–N is rare and the concentration is usually very low.

If only considering the NO_3, NO_2, and NH_3, the Total Nitrogen (TN) can be accounted as the equation: $TN = NO_3 \times \frac{14}{62} + NO_2 \times \frac{14}{46} + NH_3 \times \frac{14}{17}$. The results of the NO_3, NO_2, and NH_3 in each sample and the Total Nitrogen (TN) calculated with the equation are shown in table 3.

Table 3: NO_3, NO_2, and NH_3 and total nitrogen (TN) for all farms

sample		NO_3 (ppm)	NO_2 (ppm)	NH_3 (ppm)	TN
1	C1-1	3	0.097	1.2	1.695
2	C1-2	3	0.001	0.348	0.964
3	G1	1.19	0.021	0.372	0.581
4	G2	0.001	0.002	1.2	0.989
5	G3-1	0.16	0.0012	0.168	0.175
6	G3-2	1.61	0.01	0.348	0.653
7	G4	0.33	0.003	0.132	0.184
8	G5	0.12	0.001	0.12	0.126

From the Figure 13 (the histogram from table 3), the value of TN in confined farm seems be same (column 2 vs. 4) or larger (column 2 vs. 3, 5, &6) than grass-based farms. However, the scale of the farm should be considered as one influencing factor. C1 had more than 6,000 cows, whose number was 60 times that of the other farms; C1 also had 4,000 acres of cropland, which was 40 times more than the others. According to this factor, nitrogen output is more easily controlled on the confined farm than on the grass-based farms. Otherwise, the C1 farm makes more milk product no matter for day per cow or for year per cow. If using the data per pound milk, the TN per pound of C1 will be lower than most grass-based farms.

4.4 The different performance of the scale and waste management in the impact of the grass-based dairy farm

According to the data of table 2, a chat was made to show the performance of the grass-based dairy farms.

From the Figure 14, the sample 4 (from G2) had the largest total nitrogen and Phosphate among the grass-based dairy farms. The high NH_3 value and small NO_2 and NO_3 shows that the runoff stream contains a large amount of fresh waste from the cows, including urine and stool. Focusing on the different data of the G2 farm, it had the smallest scale. G2 grazed 80 cows (including 35 lactating cows) in only 40acres of pasture. Considering some pasture should be used for the calves and older heifers, there is less than 1-acre pasture for every lactating cow. Moreover, the farm owner only stored one-day waste and then fertilized the crop soil with the waste. As it was raining when sampling, the runoff took a large amount of the P and the N out from the farm and into the downstream.

Dairy production is one of the main rural industries in Australia where there, in 2017, were 5,789 dairy farms and 1,512,000 dairy cows. (Dairy Australian, 2017) As one of the most advanced agriculture systems in the world, the Australian dairy system has many standard setting configuration parameters for dairying. One such parameter of interest to us now is the stocking rate of the grass-based dairy far, which is 2.7 cow/ha to 3.9 cow/ha (equal to 1.09 cow/acre to 1.58 cow/acre). In Australia, this stocking rate is considered ideal. (Phelan, Harrison, Parsons, & Kemmerer, 2015) However, for our G2 farm, the stocking rate was 2 cow/acre which is far higher than the normal standard setting Australian dairy farm. This large stocking rate may put the pasture under stress and decrease the storage and consumption capacity of the N and P in the cow waste.

4.5 The Environmental impact and waste management system

The floor of the cowshed has a mandril board with which the manure and remaining hay can be scraped along with the clear water into the underground passage. Underground pipes are connected to the underground passage and the treatment center (as Figure 15). Mixed waste is then separated by a solid separator (as Figure 16). The solid part passes through the screw extruder and becomes solids containing 80% water. The solid deposits have no odor because the uric acid, urea, and protein which can make odor by anaerobic reactions have been separated. These solids then can be used as organic fertilizer or can be sold as biofuel. (as Figure 17)

The liquid part of the mixture is then subjected to anaerobic treatment (microbiological treatment) and then separated again. The sludge containing impurities is separated (strained) and re-enters the treatment center for more anaerobic treatment; and the purified water is separated at the treatment center. After 20 days of continuous and repeated treatment, the water can reach the irrigation standard and be used to clean the cowshed again. Biogas will be generated during these repeated anaerobic treatments and is separated by an air flotation machine (Figure 18) and collected to provide heating services for the farm (Figure 19 & 20).

This extensive and repeated system of treatments can minimize the impact to the environment from the dairy farm. In particular, the solid separator and screw extruder which produce the solid deposit reduce the water content of the waste. This minimizes the contamination in the runoff because the liquid waste in the solid deposit, like the uric acid and urea, is the main factor causing the additional concentration of P and N. Moreover, the sealed underground liquid waste treatment center, the air flotation machine and the biogas system can effectively reduce the greenhouse gases which come from anaerobic reaction in the process of wastewater treatment. (Demirel, Yenigun, & Onay, 2005) Finally, recycling the water decreases the water needed to clean the cowshed.

5. Conclusion

In the United States, while the number of milk cows and milk per cow has increased in recent years, the farm number is decreasing. (USDA, 2018) This fact may indicate that the size of farms is increasing (Figure 21). Most large-scale dairy farms are confined dairy farms. (USDA, 2007) Many small-scale dairy farms have had to sell out or close. Moreover, “the low price of dairy products” said by one of the farm owners in this study make it hard to survive for family dairy farms.

As the number of confined dairy farms increase, the environmental impact of the both the confined dairy farm and the grass-based farm, is receiving more question for experts and researchers. Many studies have been done in this field, in particular focusing on air emissions and the carbon footprint in many countries. (Marañón, Salter, Castrillón, Heaven, & Fernández-Nava, 2011) (Gaudino, Goia, Grignani, Monaco, & Sacco, 2014) (Chobtang, Ledgard, McLaren, Zonderland-Thomassen, & Donaghy, 2016)

This study focused specifically on the impact of P and N on the surface water. In terms of environmental pollution, N and P pollution have received increasing attention, especially regarding their role in eutrophication, ecological imbalance, and health problems.

Although, from the Figure 12 and Figure 13, our investigation concludes that the grass-based dairy farm performance better in N and worse in P than the confined dairy farm, the generally larger scale and large milk product produced make the confined dairy farm performance better in the data per pound milk and the data per acre. Considering all of the characteristics evaluated in this study, especially the waste management system, the confined dairy farm may have less of an impact to the surface water than the grass-based farm, due to the convenience of being able to control the impact of the waste.

Our investigation looked only at whether the confined dairy farm is better than the family grass-based dairy farm in regard to their impact to the surface water, not whether all confined dairy farms are better than all grass-based dairy farms. Some large-scale grass-based dairy farms have more advanced waste management than those of family scale confined dairy farms, which may lead to less N and P output into the environment.

However, the confined dairy farms may perform much better in the future as the technology advances. This is because the confined dairy farm can better utilize under controlled conditions the progress of science and technology, especially in waste management system, not only in the surface water, but also in groundwater, air and soil.

This study claims that the confined dairy farm was better in the impact to the surface water than the grass-based dairy farm. In the future, more and deeper research should be developed to analyze the other fields of the environmental impacts, such as the air and the soil. All of these parameters can provide an important reference for farm owners or government officers.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

The participants who made the surveys and provided data of farms have consented to the submission of the case report to the journal.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AL collected the data and surveys from the dairy farms and the water samples from the surface water surround the farms, analyzed, and interpreted the data and was a major contributor in writing the manuscript. JZ collected the data from the farm in China and analyzed the data.

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Figures

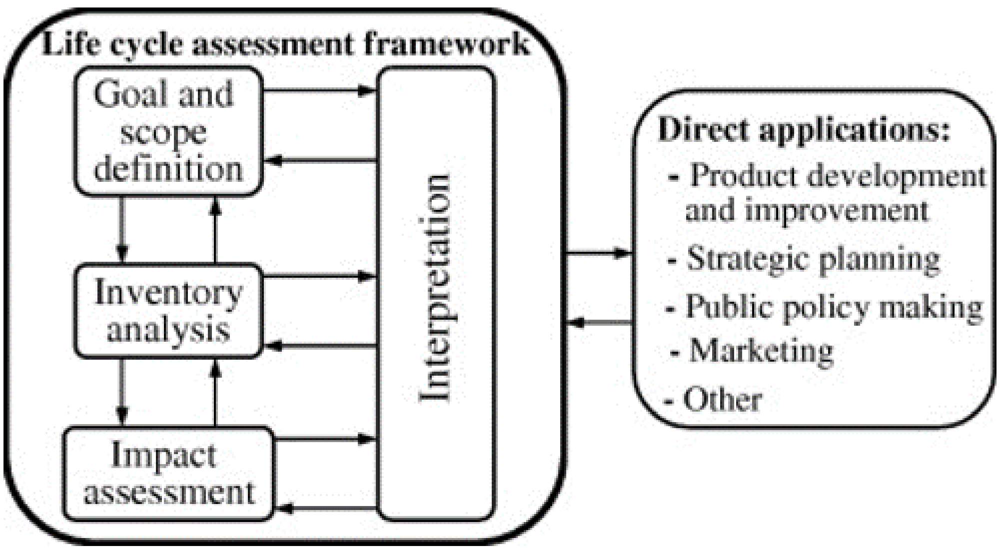

Figure 1

Stages of an LCA (ISO , 2006)

ECM = 0.327 x milk pounds + 12.95 x fat pounds + 7.2 x protein pounds

The energy-corrected milk equation

Figure 2

How to account ECM. (Spiekers & Potthast, 2004)

Figure 3

Aerial photograph of the confined farm (C1) and its cropland.

Figure 4

Aerial photograph of G1

Figure 5

Aerial photograph of G2

Figure 6

Aerial photograph of G3

Figure 7

Aerial photograph of G4

Figure 8

Aerial photograph of G5

Figure 9

Aerial photograph of C2

Figure 10

Oakton Ecotestr pH 2

Figure 11

LaMotte SMART 2 Colorimeter and the chemical used during measuring.

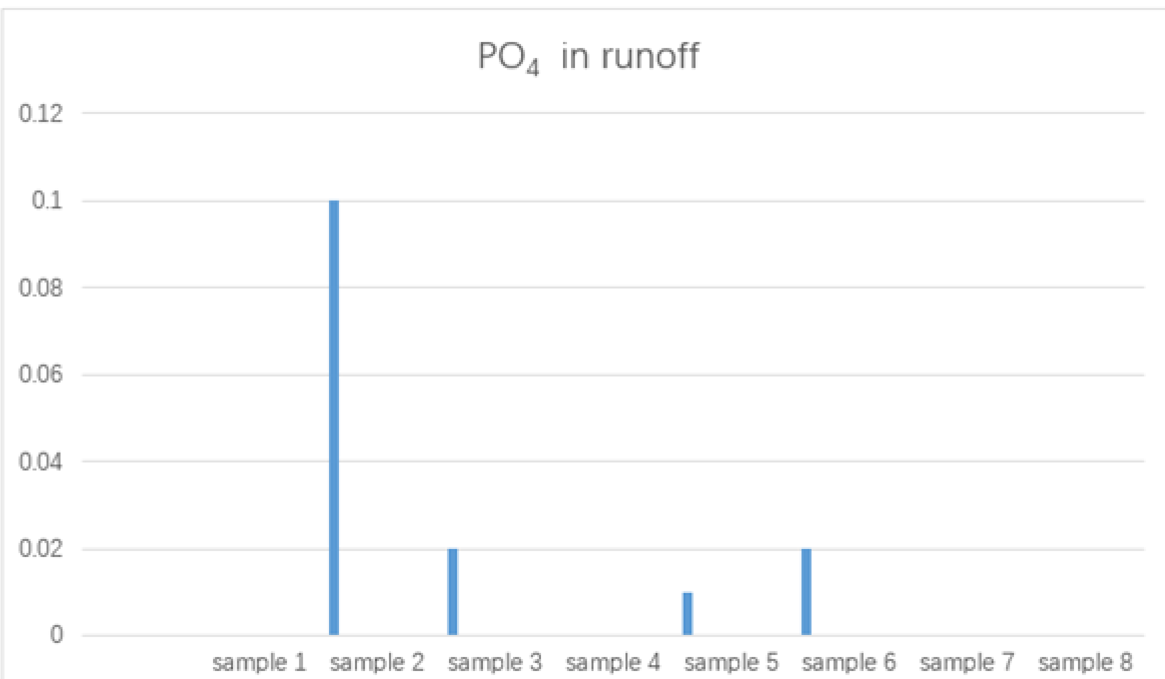

Figure 12

Phosphate (PO4)in samples from the runoff stream

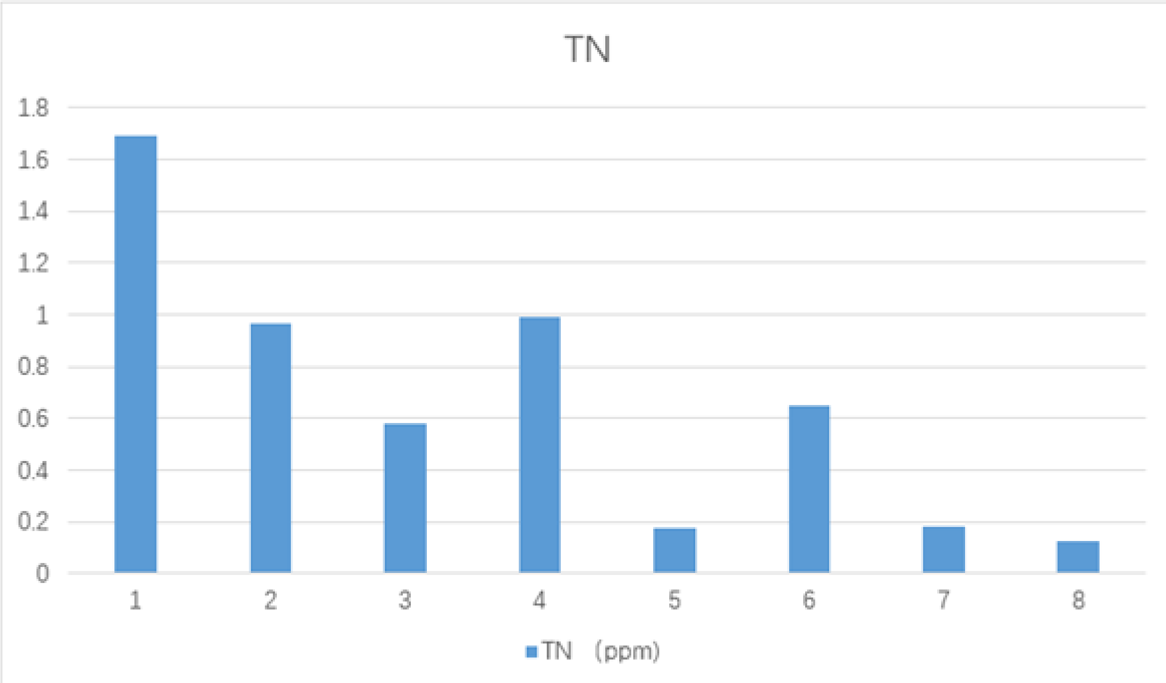

Figure 13

Total Nitrogen

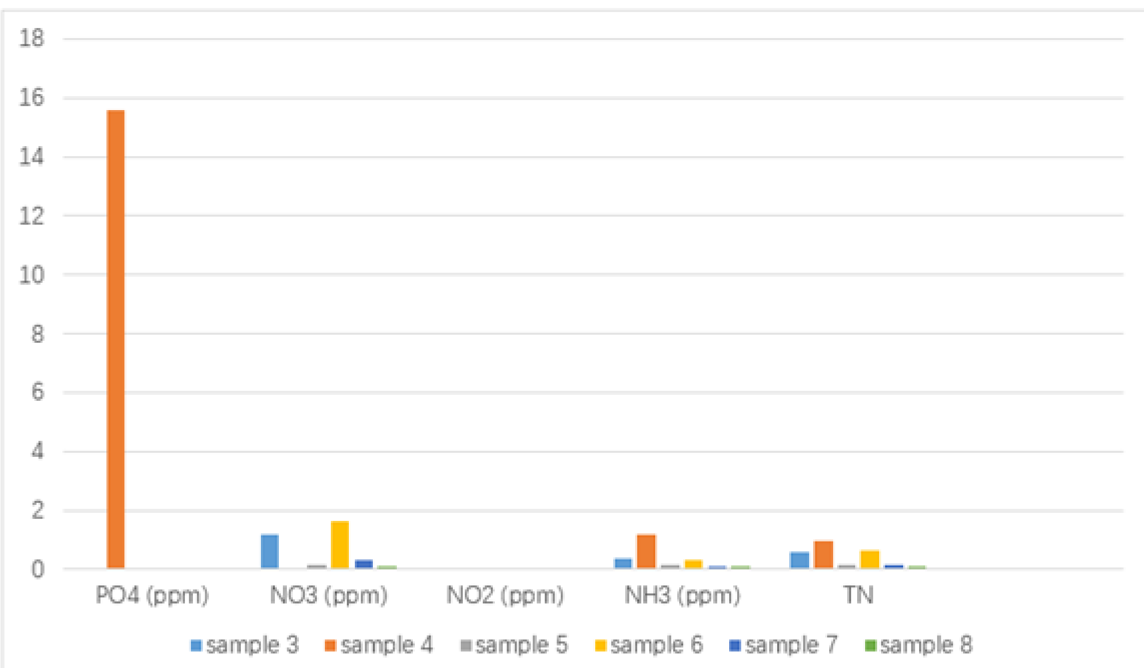

Figure 14

the impact of the grass-based dairy farm

Figure 15

Treatment center

Figure 16

Solid separator

Figure 17

Solid deposits

Figure 18

Air flotation machine

Figure 19

Biogas purification and collection system

Figure 20

Biogas storage system

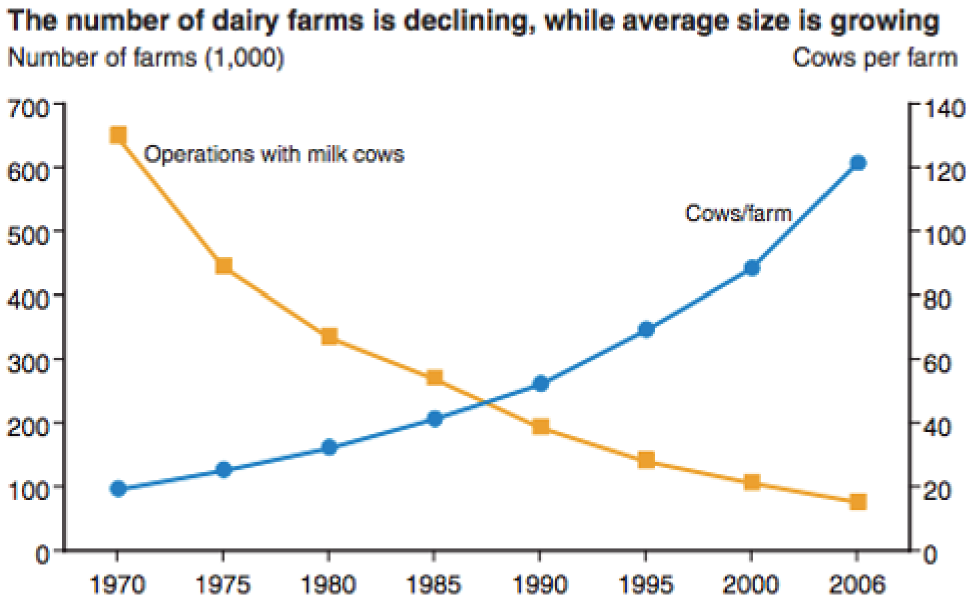

Figure 21

The number of cows per farm and dairy farms (USDA, 2007)