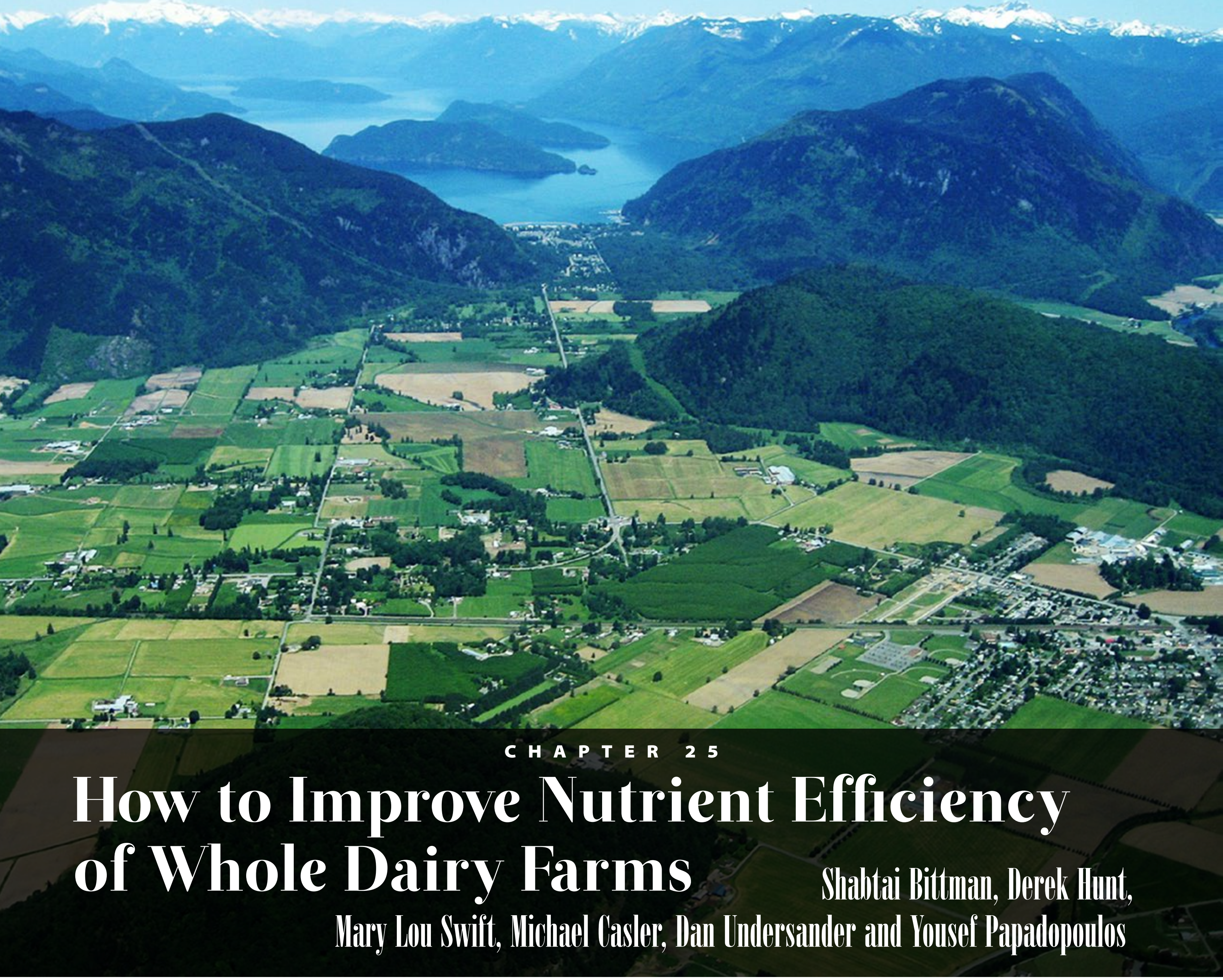

CHAPTER 25

How to Improve Nutrient Efficiency of Whole Dairy Farms

Shabtai Bittman, Derek Hunt, Mary Lou Swift, Michael Casler, Dan Undersander and Yousef Papadopoulos

Dairy farming region in southern BC, showing Harrison Lake and the town of Agassiz (lower right). PHOTO BY RON DENNIS

When manure is applied to farm soil, measures can be taken to reduce losses to the environment and enhance recovery of nutrients by the crop. But measures that enhance uptake of nutrients by plants will have no benefit if the farm has a positive nutrient balance, with a greater quantity of nutrient imports than exports. In such situations, the additional nutrients taken up by the plants will eventually be lost from the farm into the environment unless the nutrient imports to the farm are correspondingly reduced.

This is the concept behind whole farm nutrient planning. The measures taken by farmers to reduce losses to the environment, such as better manure application techniques, must in the end contribute to improving overall farm nutrient efficiency. One of the best examples in the world of empirical assessment of abatement measures as they affect whole farm nutrient budgets and efficiencies is the De Marke demonstration farm in the Netherlands (Aarts et al. 2000; Hilhorst et al. 2001; Oenema and Verloop 2004). The flow of N into the farm, out of the farm, and within the De Marke farm is depicted in Figure 1. The values presented on the diagram reflect a suite of effective and economic measures implemented on De Marke to reduce N and P losses to air and to water. The surplus N in De Marke was reduced to less than a third that of commercial farms in the region showing the combined benefits of Best Available Technologies (BATs) employed.

Part of the efficiency of De Marke can be attributed to production of corn for whole plant silage and coblage (corn-cob silage). This is perhaps counterintuitive since corn production is well-known for its 'leakiness' due to long periods of bare ground and to poor root development compared to the grass production that was replaced. However, corn produces more digestible energy than forage grasses per unit of land and per unit of applied nutrients

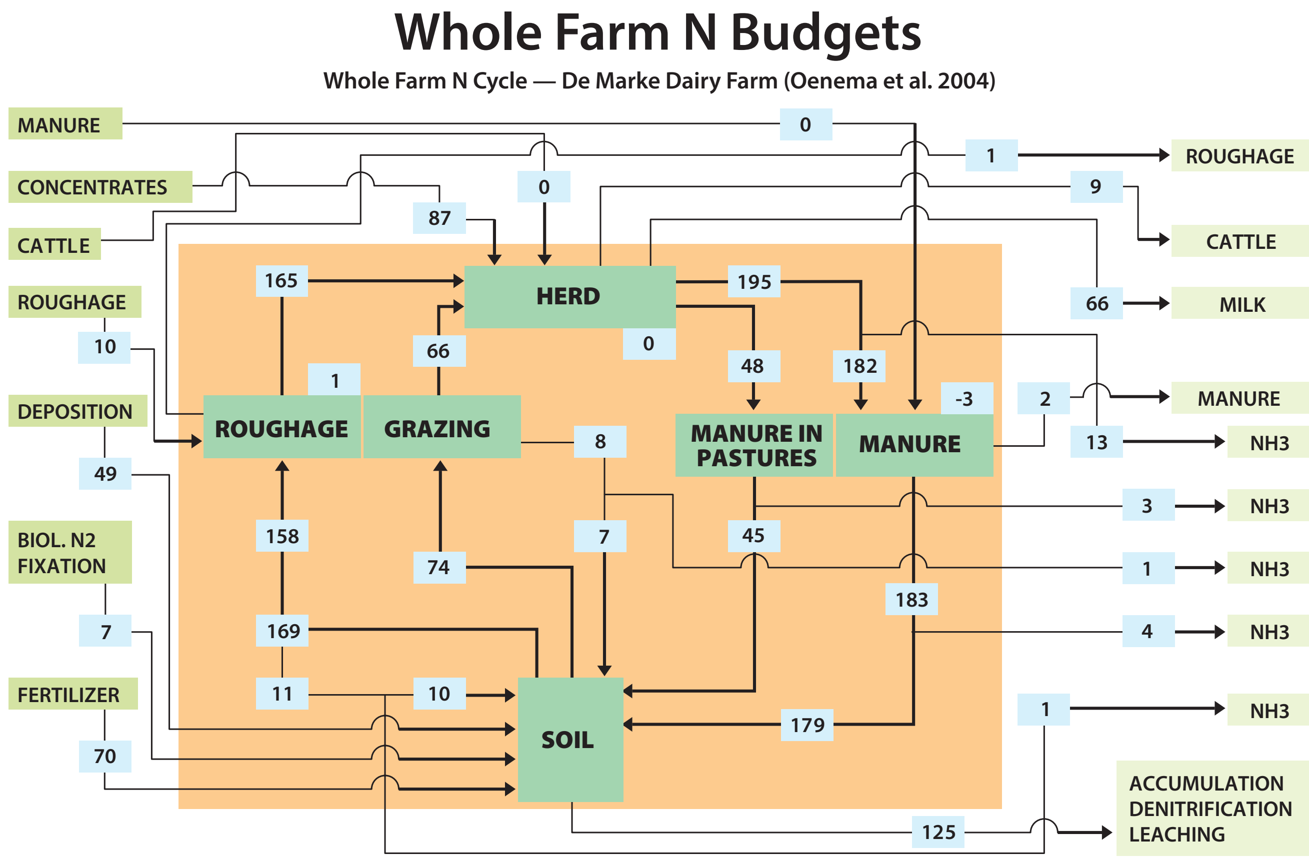

Figure 1. Nitrogen (N) cycling on the De Marke Dairy farm in the Netherlands (from Oenema 2004).

and a higher energy density than grass per unit of dry matter. Therefore, whole plant corn silage and coblage are better able to meet the energy requirement of cattle without providing a surplus of protein, which often occurs with grass harvested at an early growth stage. A better balanced diet will lower N excretion rates, reducing the risk of N impacting the environment. Also, if less feed importation is needed the farm nutrient balance is improved. Thus, growing corn reduces the need for importing both fertilizer and digestible energy as grain concentrate comprised of barley, corn or wheat. The lesson is that although corn tends to lose more nutrients to the environment than grass on the field scale, when well integrated into a whole farm system, corn may lower N losses and increase farm nutrient efficiency — showing the importance of considering the whole farm in improving sustainability (for a more complete description see Oenema et al. in *Advanced Silage Corn Management* on www.farmwest.com).

Proposed Practice

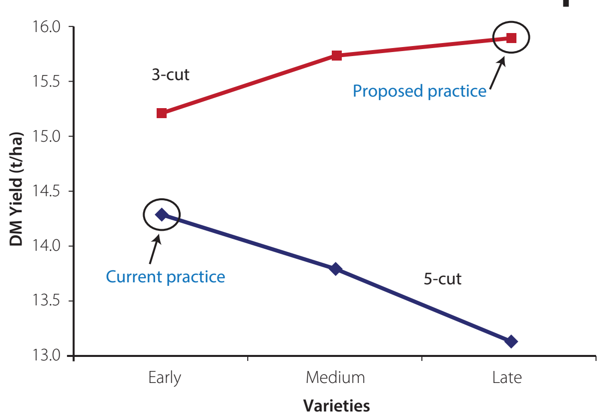

Figure 2. Yield (3-year average) of early, medium and late maturing orchardgrass varieties as affected by harvest frequency. Conventional and proposed management systems are shown (for T/ac multiply by 0.45).

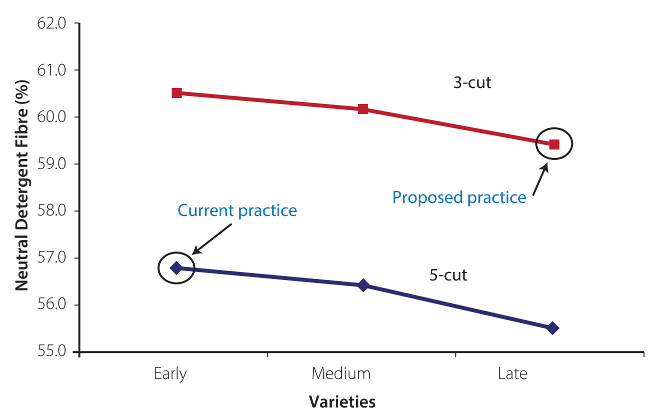

Figure 3. Concentrations of Neutral Detergent Fibre (NDF) of early, medium and late maturing orchardgrass varieties as affected by harvest frequency (3-year average).

Table 1. Forage quality parameters for the traditional Early/5-cut and proposed Late/3-cut systems. The quality parameters are defined in the text.

	Current Early/5-cuts	Proposed Late/3-cuts
Crude Protein (% of DM)	14.9	12.7
NDF (% of DM)	58.9	62.8
Lignin (% of NDF)	6.2	6.7
IVFD (30h) (% of DM)	68.5	62.3
CH3 - Kd (% of DM/h)	4.9	4.2

We have employed the Whole Farm concept to explore improving nutrient efficiency in dairy farms in coastal BC, but without benefit of a model farm. We asked: can we improve cropping management decisions (i.e. crop choices and husbandry) by considering the whole dairy farm? Dairy farms in coastal BC allocate ~60% of their land to grass and 40% to silage corn. The prevailing grass management system is to plant early-maturing orchardgrass varieties and harvest them 5 times per year (referred to as Early/5-cut). Our concept was to try to increase production of orchardgrass by reducing harvest frequency from 5 to 3 times per growing season, and to mitigate the negative effect of fewer cuts on nutritional quality by using a late maturing variety (referred to as Late/3-cut). The varieties used in the study (Early-Cheam; Late-Haida) were developed and tested at the Agassiz Research Centre.

Our field experiment carried out over three years showed that the later maturing varieties produced less under the 5-cut system but produced more under the 3-cut system (Fig. 2). In other words, reducing harvesting frequency increased the yield of all varieties but the gain in yield was greatest for the late maturing variety. The proposed new treatment combination of late variety with three harvests (Late/3-cut) increased yield by about 15% over the conventional practice (Early/ 5-cut).

However, as expected, reducing harvest frequency also lowered the nutritional quality of the herbage, although the effect was less with the late than the early variety (Fig. 3). A comparison of forage quality parameters for the traditional Early/5-cut and proposed Late/3-cut system is shown in Table 1. The proposed system had lower crude protein (14.9 to 12.7%) and higher neutral detergent fiber concentration (62.8 vs. 58.9%). Also, in the proposed system, a greater proportion of the neutral detergent fiber (NDF) was comprised of lignin (from 6.2 to 6.7%) and this resulted in a decrease in digestibility of the neutral detergent fibre as determined using a 30 h *in vitro* digestion in rumen fluid (68.5 to 62.3%). The rate of digestion of NDF (referred to as CH3-kd) also decreased from 4.9 to 4.2% /h. Interestingly, the total production of crude protein per unit of land was similar for the two treatments (not shown).

The next step for evaluating the new system was to develop diets for high producing dairy cows based on the two grasses. This was done with a commercial ration balancing model (AMTS.Cattle.Pro, Cortland, NY). We considered two scenarios. In the first scenario, we maintained the same quantities of grass and corn as for typical forage. In the second scenario we optimized the ratio of home grown grass and corn in the diet based on their quality. We used standard values for silage corn quality and, in fact, these values

Table 2. Scenario 1 feed rations balanced for high producing dairy cows using the same quantities of conventional and alternative grass, corn and concentrate.

INGREDIENT	5-cut early variety *kg DM/cow/day*	3-cut late variety *kg DM/cow/day*
Orchardgrass Silage	3.63	3.63
Corn Silage*	9.53	9.53
Grain Mix	11.0	11.0
Ration CP (% DM)	**13.9**	**13.6**
Metabolizable Energy Allowable Milk (Kg)	**38.7**	**37.9**
peNDF	22.7	23.6

*TMR formulated using AMTS.Cattle.Pro for a one-group 38.5 kg average milk, 3.6% BF, 24 KG DMI. Corn Silage processed 25% DM, 45% NDF, 28% Starch. Grain mix is 8 kg ground barley, 1.8 kg Corn Dried Distillers Grain, 0.9 kg Canola Meal, 0.11 kg Comercial Bypass Fat and 0.2 kg Vitamin/Mineral Premix.

Table 3. Scenario 2 feed rations balanced for high producing dairy cows using different quantities of conventional and alternative grass and corn, and modified concentrate.

INGREDIENT	5-cut early variety *kg DM/cow/day*	3-cut late variety *kg DM/cow/day*
Orchardgrass Silage	3.63	2.3
Corn Silage*	9.53	10.9
Grain Mix	11.0	11.0**
Ration CP (% DM)	**13.9**	**13.9**
Metabolizable Energy Allowable Milk (Kg)	**38.7**	**38.5**
peNDF	22.7	22.8

*TMR formulated using AMTS.Cattle.Pro for a one-group 38.5 kg average milk, 3.6% BF, 24 KG DMI. Corn Silage processed 25% DM, 45% NDF, 28% Starch.
**Grain mix revised to 7.6 kg (-0.4 kg) ground barley, 2.0 kg (+0.2 kg) Corn Dried Distillers Grain, 1.1 kg (+0.2 kg) Canola Meal, 0.11 kg Comercial Bypass Fat and 0.2 kg Vitamin/Mineral Premix.

Benefits of the alternative grass harvesting regime (Scenario 2) for feed production and whole farm nutrient balance

- Higher grass yield (15%) and lower consumption (37%) means that less land will be needed for grass production and this land can be used to produce more corn silage, which is required with the ration reformulation. Since corn typically produces 25-30% higher yield than grass, more feed will be produced both on the land remaining in grass (15% more) and the land converted to corn (25-30% more).
- The freed grass land not planted to corn can be used to produce feed for sale to other farms, which would bring in revenue and help to export nutrients off the farm. Alternatively, the land can be used to grow high-energy corn coblage to replace imported concentrates or to grow high protein crops like red clover or alfalfa to replace some of the purchased protein supplements (canola meal and dry distillers grain). Alternatively, red clover or alfalfa can be planted with orchardgrass to raise the protein concentration in the feed. In all cases, purchased feed and imported N and P can be reduced.
- Corn requires about half as much N per kg of feed compared to grass, so that fertilizer consumption will likely decrease under the new cropping scenario. Since manure can be more easily injected into corn than into grass, loss of ammonia N by volatilization can be greatly reduced.
- Many farmers in the Pacific Northwest and BC are inter-seeding corn with a grass crop (Italian ryegrass) in order to provide winter cover for the soil (Fig. 4) and to scavenge residual soil nutrients (up to 75 kg N/ha or 67 lb N/ac) after corn harvest. This crop, referred to as a relay crop, produces high-quality feed (3-5 t/ha or 1.4-2.3 T/ac) in early spring and allows sufficient time for replanting corn or grass (Bittman et al. 2004). Relay crops will add additional high quality grass which can further reduce the requirement for perennial grass.
- As the perennial grass crop is harvested fewer times, less labor and tractor use is needed, although bigger crops will slow harvesting somewhat. There will also be fewer hectares to harvest.
- With a 3-cut system for grass, the first cut occurs later and this has two benefits: there is greater likelihood of good harvesting weather and there is more time in early May for planting corn and harvesting relay crops.

tend to be fairly stable. In both cases we were targeting a dairy farm feeding a one-group total mixed ration to cows milking 38.5 kg (85 lb) at 3.6% BF with 24 kg (53 lb) dry matter intake (DMI) on a daily basis. More information about the diets is provided in the Tables.

For Scenario 1 where the proportion of ingredients is not adjusted, the modelling predicts that replacing the typical Early/5-cut grass with Late/3-cut grass in the Total Mixed Ration (TMR) will decrease milk production by about 0.8 kg (1.8 lb) per cow per day (Table 2). This is not unexpected as energy content of the ration has not been balanced to account for the lower energy in the Late/3-cut grass.

In Scenario 2, the diet formulation was optimized to maintain milk production with the lower quality grass (Table 3). We lowered the amount of orchardgrass silage by 37% and increased corn silage by 14%, with the total dry matter fed from farm-grown crops remaining the same (13.2 kg or 29 lb/day). By adjusting the grass to corn ratio, the energy supplied to the cows remained the same. However, to maintain adequate protein concentration in the feed, the amount of distiller's grain and canola meal fed was each increased by 0.2 kg (0.45 lb) and the amount of ground barley was lowered by 0.4 kg. With this strategy, milk production was successfully maintained.

Figure 4. Italian ryegrass intercropped with corn (relay cropped) on a dairy farm in south coastal British Columbia, shown in late winter.

References available online at www.farmwest.com

Shabtai Bittman Agriculture and Agri-Food Canada, Agassiz, BC, Canada | shabtai.bittman@agr.gc.ca

Derek Hunt Agriculture and Agri-Food Canada, Agassiz, BC, Canada

Mary Lou Swift Current Address: Alberta Agriculture and Rural Development, Edmonton, AB, Canada

Michael Casler USDA-ARS, U.S. Dairy Forage Research Center, Madison, WI, USA

Dan Undersander University of Wisconsin, Madison, WI, USA

Yousef Papadopoulos Agriculture and Agri-Food Canada, Nova Scotia Agricultural College, Haley Institute, Truro, NS, Canada