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Sustainable Intensification in a Dairy Farm: Effect of Dynamic Forage System on Protein and Metabolizable Energy for Milk Production

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Introduction

In the last decades, dairy farming systems in Italy have been characterized by the development of corn silage and intensively fertilized grasses, while the protein supplementation of dairy rations has been left to purchased soybean meal, which is predominantly produced overseas. Sustainable intensification is an important strategy to reduce environmental impacts, which can be obtained through improvements in the milk production per cow and feed efficiency, as well as by increasing the net primary production of the utilized agricultural area (UAA) (Gislon et al., 2020). This can be achieved by increasing on-farm cropping of legumes, double cropping, scheduling of forage cuts to early stages of growth, and the adoption of silage conservation in place of haymaking. This system, which is based on the optimization of land use and market opportunities to meet the herd requirements, introduces agronomic management and agro-ecological standards and it has been defined as 'dynamic forage system' (DYN) (Tabacco et al., 2018). The aim of this work was to analyze the effects of the transition from conventional (CONV) to DYN of an intensive dairy farm in Piedmont (Italy).

Materials and Methods

The effects of the transition of the forage system from CONV (2010-2015) to DYN (2016-2019) were evaluated over a 10-year period, in a dairy farm located in Scalenghe (TO), which rears about 100 dairy cows plus replacement animals on 60 hectares of UAA. The data relating to the crops (type of crop, yield, external input) were collected from the farmer's business notebooks, whereas the dry matter (DM) yield was measured by weighing each harvested grain and forage. The data relating to the livestock (number of milking cows and replacement animals, diets for each animal category, amount of feeds fed to animals, milk production and quality) have been daily recorded by the farmer. The nitrogen balance approach involved calculating the difference between the total imported nitrogen and that exported at the cropping system-scale. The nutrient requirements of animals for metabolizable energy (ME), crude protein (CP), and DM intake were calculated relative to their average milk production, quality, and body weight using CNCPS model (version 6.1, Cornell University, Ithaca, NY). The Carbon Calculator (Tuomisto et al., 2015) was used to compute the emissions from the whole forage system over a year. All the gathered and calculated data were referred to 4 functional units: 1 hectare (ha) of tillable land; 1 t of DM; 1 t of CP; and 1 GJ of ME.

Results

The proportion of UAA with alfalfa and with Italian ryegrass (instead of winter cereals) double-cropped with corn increased, and a higher proportion of corn was harvested as high moisture ear corn silage (Figure 1a). No whole plant corn silage was harvested in the last two years. Milking cows increased over time from 92 to 102, whereas stocking rate remained almost constant (3.1 LU/ha). Milk yield intensity increased from 17 to more than 22 t of fat protein corrected milk (FPCM)/ha (Figure 1b), whereas the amount of purchased CP and ME was constant for the whole considered period (Figure 1c). The increase in UAA cropped with alfalfa, the adoption of a regime of cutting scheduled at early stage of growth coupled with conservation through ensiling for all the harvested forages contributed to maintain the DM

and ME yield over time, while greatly increased CP yield per hectare (Table 1). Nitrogen surplus and the amount of mineral N utilized to produce 1 t of CP decreased over time. The emissions from the whole forage system (expressed as carbon footprint per kg of FPCM) decreased from 0.246 kg CO_2-eq in 2010-11 period to 0.170 kg CO_2-eq in 2018-19 period (-31.1%).

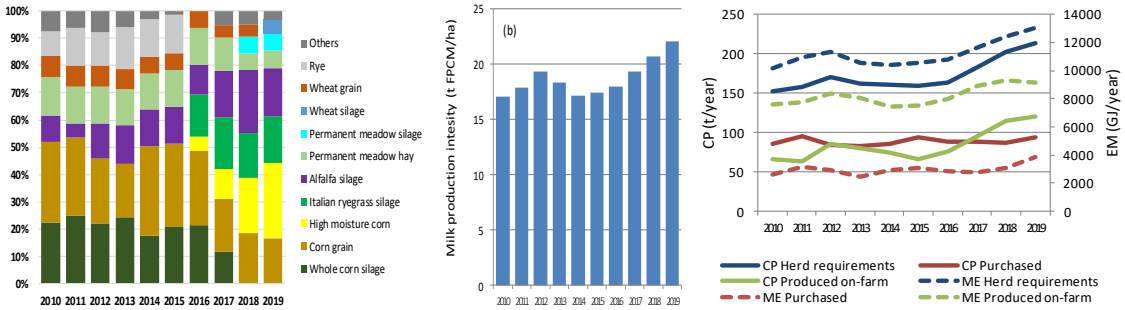

Figure 1. Proportion of crops and their utilization (a); milk production per hectare as FPCM t/ha (b); and CP and ME required, purchased and produced on farm (c) before (2010-2015) and after (2016-2019) the transition from conventional to dynamic forage system in an intensive dairy farm of the Po plain.

Table 1. Agronomic, environmental and herd performance indicators calculated over 10 years during the transition from conventional (2010-2015) to dynamic (2016-2019) forage system in an intensive dairy farm of the Po plain.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agronomic performance										
UAA (ha)	59.1	60.3	60.3	61.2	64.3	64.3	64.3	64.3	64.3	63.9
Average DM yield (t/ha)	17.2	19.0	16.8	16.7	16.3	16.5	18.4	17.2	16.3	17.3
Average CP yield (t/ha)	1.47	1.53	1.41	1.48	1.37	1.42	1.58	1.80	1.86	1.90
Average ME yield (GJ/ha)	171	181	155	155	159	161	181	164	155	169
kg N from mineral fertilizer/t CP	135	149	130	114	165	120	97	74	61	53
Environmental impacts										
Surplus (kg N/ha)	248	252	224	201	293	216	167	148	139	123
LI honeybees (TOX unit/kg CP)	20	29	227	71	34	82	36	33	13	12
Carbon footprint (kg CO_2-eq/t CP)	2780	2942	3044	2737	2829	2682	2448	2234	2013	1832
Herd performance										
Lactating cows (n)	92	95	98	95	97	99	101	102	103	102
Stocking rate (Livestock units/ha)	3.2	3.2	3.2	2.9	2.9	2.9	2.9	3.0	3.1	3.1
t FPCM/GJ of purchased ME	0.39	0.34	0.41	0.45	0.37	0.36	0.41	0.45	0.43	0.37
t FPCM/t of purchased CP	11.7	11.3	13.8	13.6	12.9	11.9	13.1	14	15.2	15.1
CF (kg CO_2-eq from farm feed/kg FPCM)	0.240	0.252	0.222	0.221	0.225	0.218	0.216	0.208	0.181	0.158

Conclusions

Dynamic forage system compared to a conventional forage system based mainly on corn production, has the potential to further increase the production efficiency and a reduction of over 30% of global warming potential even in more intensive dairy farming systems.

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