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N, P, K balances for six grazed or cut plots in an agroecological dairy cattle system

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Abstract

The low-input dairy cattle ‘OasYs’ system aims to maximise grazing through the use of diversified multi-species grasslands and annual crops. The aim of this study was to assess whether the management of organic fertilisation or grazing led to deficits or surpluses of N, P and K at plot and rotation levels. We assessed N, P and K inputs and outputs on 6 plots in a grassland-crop rotation, 3 of which were in a 7-year grazed rotation and 3 in an 8-year cut rotation. The amounts of herbage grazed were evaluated at paddock level by the Herbvalo method, and used to quantify inputs by faeces. Urinary-N excretions at grazing were assessed by the Urea model. Direct excretion by grazing animals were major inputs of N, P and K at plot level. The 3 grazed plots had a fairly balanced N (-19 to $28 \text{ kg ha}^{-1} \text{ year}^{-1}$), P (-4 to $3 \text{ kg ha}^{-1} \text{ year}^{-1}$) and K (-27 to $23 \text{ kg ha}^{-1} \text{ year}^{-1}$) balance. One cut plot was in balance and the other two in deficit, especially for K (maximum of $-100 \text{ kg ha}^{-1} \text{ year}^{-1}$).

Keywords: mixed crop-dairy system; ley pastures; OasYs

Introduction

Several authors agree that grasslands and ruminant livestock are a key to improving nutrient circularity in agroecosystems, particularly when grasslands are grazed and alternate with crops (Lemaire *et al.*, 2015). However, for these systems to be virtuous and sustainable, organic effluent and grazing management practices need to be consistent with the production and NPK absorption capacities of the grasslands (Vertès *et al.*, 2019). Exports outside the system or transfers of fertility between plots must not deplete the soil’s P and K reserves (Möller *et al.*, 2018). The low-input ‘OasYs’ system experiment (72 dairy cows, 91 ha), which aims to maximise grazing through the use of diversified multi-species grasslands and annual crops, showed good N efficiency and N balance (Novak *et al.*, 2022b). However, a balance sheet at farm level can mask disparities at plot level. The aim of this study was to assess N, P and K balances for 6 plots in the OasYs system, grazed or not, over their entire rotation, in order to provide guidelines for improving organic fertilisation practices in low-input systems with a view to ensuring long-term soil fertility.

Materials and methods

We quantified the inputs and outputs of N, P and K over the entire rotation of 6 plots of approximately 3 ha monitored in the OasYs system experiment located on an INRAE facility (Vienne, France), 3 plots of which were grazed and 3 of which were not. The all-year grazed rotation alternates 5 years of temporary grassland and 2 years of annual crops, while the cut rotation is made up of 4 years of temporary grassland and 4 years of annual crops (Novak *et al.*, 2022a). The 6 plots started their rotation with different crops. The stocking rate was 1.05 LU ha^{-1} . We assessed N, P and K balances from 2015 to 2021 for the 7-year grazed rotation, and from 2015 to 2022 for the 8-year cut rotation. Urinary N excretion by dairy cows was calculated from milk urea using the Urea model (Edouard *et al.*, 2018) and excretion in faeces was calculated as $7.2 \text{ g N (kg ingested dry matter)}^{-1}$ (Delaby *et al.*, 1997), which was itself assessed using the Herbvalo method (Delagarde *et al.*, 2018). P and K excretions were calculated using the N/P=6.6 and N/K=0.783 ratios given by Richner *et al.* (2017). Symbiotic fixation was assessed as representing 90% of the N contained in the leguminous part of the cover (A.S. Voisin, personal communication). The proportion of legumes in the covers was assessed visually in spring. Non-symbiotic N fixation by free-living soil microorganisms was set at a constant value of $5 \text{ kg N ha}^{-1} \text{ year}^{-1}$ (Smil, 1999) and atmospheric deposition

at 6 kg N ha⁻¹ year⁻¹ (M.L. Decau, personal communication) and at 2 kg K ha⁻¹ year⁻¹ (Le Gall *et al.*, 2004) and were considered in the inputs. Fertilisation and harvested crops were weighed and analysed. The amounts of herbage grazed were evaluated at paddock level by the Herbvalo method (Delagarde *et al.*, 2018) and their N, P and K contents came from analysis results.

Results and discussion

As very little mineral fertiliser was used, N inputs were mainly linked to cattle excreta on grazed plots, as well as symbiotic fixation and organic fertilisation, in liquid form for grazed plots, and in liquid or solid form for cut plots (Table 1). Cattle excreta on pasture were also the main source of P and K (Tables 2 and 3) for plots M1 and M2, but slurry inputs were greater for plot M5. For cut plots, P and K were almost exclusively supplied by organic fertilisation in liquid and solid forms. Input-output balances varied according to the plots and elements.

Table 1. Mean (min;max) N-balance (kg N ha⁻¹ year⁻¹) of 6 plots, grazed (M1, M2, M5) or cut (G22, G23, V12), over 2015-2021 and 2015-2022, respectively.

	M1	M2	M5	G22	G23	V12
Cattle excreta	59 (16;80)	85 (33;131)	83 (23;153)	–	–	–
Slurry	19 (0;136)	9 (0;62)	52 (0;110)	45 (0;158)	8 (0;43)	12 (0;56)
Solid manure	–	–	–	40 (0;155)	42 (0;228)	29 (0;135)
Mineral N fertiliser	4 (0;30)	–	5 (0;34)	26 (0;118)	27 (0;60)	11 (0;50)
Symbiotic fixation	21 (0;70)	45 (7;122)	27 (1;47)	57 (0;194)	25 (0;85)	22 (0;65)
Total N inputs	114 (27;256)	150 (70;239)	177 (49;242)	176 (46;297)	96 (17;239)	87 (15;160)
Grazing	124 (20;190)	143 (56;223)	148 (3;273)	–	–	–
Harvested crops	10 (0;52)	7 (0;48)	1 (0;8)	182 (123;269)	125 (55;200)	140 (58;207)
Total N outputs	133 (72;190)	151 (88;223)	149 (3;273)	182 (123;269)	125 (55;200)	140 (58;207)
N balance	–19 (–116;146)	0 (–35;29)	28 (–94;170)	–4 (–82;149)	–11 (–99;184)	–55 (–131;34)

Table 2. Mean (min;max) P-balance (kg P ha⁻¹ year⁻¹) of 6 plots, grazed (M1, M2, M5) or cut (G22, G23, V12), over 2015-2021 and 2015-2022, respectively.

	M1	M2	M5	G22	G23	V12
Cattle excreta	9 (2;12)	13 (5;20)	13 (3;23)	–	–	–
Slurry	6 (0;45)	4 (0;26)	14 (0;35)	16 (0;46)	4 (0;20)	6 (0;34)
Solid manure	–	–	–	10 (0;37)	9 (0;46)	7 (0;31)
Mineral P fertiliser	–	–	–	4 (0;29)	–	–
Total P inputs	15 (2;56)	16 (8;31)	26 (3;43)	23 (0;70)	7 (0;46)	15 (0;34)
Grazing	13 (3;21)	19 (9;28)	22 (2;49)	–	–	–
Harvested crops	2 (0;7)	1 (0;6)	2 (0;17)	25 (17;33)	21 (15;30)	20 (9;25)
Total P outputs	15 (10;21)	20 (12;28)	24 (2;49)	25 (17;33)	21 (15;30)	20 (9;25)
P balance	1 (–10;35)	–4 (–12;16)	3 (–46;41)	4 (–30;53)	–9 (–26;31)	–7 (–23;15)

The 3 grazed plots were fairly well balanced: N (-19 to $28 \text{ kg ha}^{-1} \text{ year}^{-1}$), P (-4 to $3 \text{ kg ha}^{-1} \text{ year}^{-1}$) and K (-27 to $23 \text{ kg ha}^{-1} \text{ year}^{-1}$). In the cut zone, the N, P, K balances were close to equilibrium for plot G22 (-4 , 4 and $0 \text{ kg ha}^{-1} \text{ year}^{-1}$ respectively), but in deficit for the other 2 plots, especially G23 for K ($-100 \text{ kg ha}^{-1} \text{ year}^{-1}$) and V12 for N ($-55 \text{ kg ha}^{-1} \text{ year}^{-1}$). The better balance of G22 was due to greater inputs of slurry (rich in N, P and especially K) than G23 and V12, and to higher symbiotic N fixation.

Table 3. Mean (min;max) K-balance ($\text{kg K ha}^{-1} \text{ year}^{-1}$) of 6 plots, grazed (M1, M2, M5) or cut (G22, G23, V12), over 2015–2021 and 2015–2022, respectively.

	M1	M2	M5	G22	G23	V12
Cattle excreta	75 (20;102)	109 (42;168)	106 (29;196)	–	–	–
Slurry	46 (0;320)	28 (0;199)	156 (0;330)	120 (0;384)	25 (0;135)	40 (0;183)
Solid manure	–	–	–	58 (0;216)	46 (0;282)	34 (0;143)
Mineral K fertiliser	–	–	–	2 (0;17)	–	–
Total K inputs	127 (22;414)	146 (68;243)	270 (31;399)	164 (2;511)	43 (2;284)	86 (2;185)
Grazing	135 (24;224)	154 (77;232)	217 (18;549)	–	–	–
Harvested crops	15 (0;63)	9 (0;62)	24 (0;166)	182 (59;269)	173 (36;321)	141 (43;195)
Total K outputs	150 (87;268)	163 (83;232)	241 (18;549)	182 (59;269)	173 (36;321)	141 (43;195)
K balance	$-27 (-219;220)$	$-24 (-114;104)$	$23 (-518;381)$	$0 (-267;371)$	$-100 (-258;208)$	$-66 (-177;14)$

Conclusions

On the grazed plots, most of the inputs were provided by cattle excreta, and their management resulted in N, P, K balances close to equilibrium. Managing fertilisation with grazing thus seemed to be an interesting practice in low-input systems. The contrasting results obtained on the cut plots showed that slurry spreading is a strong lever for balancing the N, P, K balances.

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