Apparent balance of nitrogen and phosphorus in dairy farms in Mugello (Italy)

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ABSTRACT

The aim of the present work is to evaluate the differences in the surplus of nutrients at farm level and the risk of pollution related to farm management between the two areas of Mugello (Tuscan Apennines, Italy): Basso Mugello (LM) and Alto Mugello (HM).

Data of a survey on 36 farms of dairy cows in the area of Mugello (FI) are reported. In each farm the apparent balance of nitrogen and phosphorus was estimated in order to evaluate the equilibrium of these elements within the farms. The operative procedure, already used in Italy, is based on the estimation of fluxes of these elements entering and leaving the farm, and the difference between them represents the surplus of this element, which refers to the surface of the farm.

Two typologies of farms were identified, differing in altitude: farms in the lowlands (LM) and in the uplands (HM) of the area. Farms belonging to LM showed N surplus of 136 kg ha⁻¹, while in HM the N surplus amounted to 53 kg ha⁻¹. Surplus of P were 73 kg ha⁻¹ and 27 kg ha⁻¹ for LM and HM, respectively. Results are related to the different productive systems, with 31.7% of surface of permanent fodder crops in HM (instead of 1.5% in LM). Moreover, the LM raises maize crops in a very intensive way utilising it for animal feed together with feedstuff coming from outside the farm. Results showed that the main factors affecting the surplus of the elements are the purchase of animal supplements, fertilisation and animal stocking rate.

Key words: Nutrient balance, Nitrogen, Phosphorus, Dairy cows.

RIASSUNTO

ANALISI DI BILANCI APPARENTI DI AZOTO E FOSFORO IN AZIENDE DA LATTE DEL MUGELLO

Lo scopo del presente lavoro è quello di valutare l’entità dei surplus di nutrienti (azoto e fosforo) a livello aziendale ed i rischi di inquinamento connessi con le differenti gestioni agricole, in aziende che allevano bovini da latte. L’indagine è stata condotta in due aree del Mugello (Alto Mugello: HM, e Basso Mugello: LM), sull’Appennino Toscano, su un totale di 36 allevamenti.
Introduction

In recent years, the technical and economical conditions changed so much that the profitability of dairy farms has been greatly reduced, especially in many hilly and mountainous areas of Italy. The area of Mugello (Italy) is still an important reality in dairy milking in the mountains of Tuscany. Mugello is divided into two well-defined geographical and administrative areas: Basso Mugello (LM), with average altitude ranging from 200 m a.s.l. to 400 m a.s.l., and Alto Mugello (HM), located at an average altitude of more than 400 m a.s.l. Here, traditionally reared cows played a very important role in the conservative management of the territory and recent developments in production techniques have demonstrated remarkable results in the organisation of productive typologies: in the upper areas the traditional systems with a high presence of forage crops that are utilised through animal grazing is gradually increasing, while in the lower areas an intensive production system is more common, with high presence of forage cereals, such as maize. The former productive system is more suited to marginal areas that are widespread in Central Italy and this system can assure good management of the territory and proper preservation of the landscape.

In order to limit the surplus of nutritive elements and to reduce the waste of money and lower pollution risks, it is very useful to know the fluxes of nutrients within the farm, in order to optimise the available resources and to decrease the environmental impact connected to animal breeding (Andrighetto et al., 1996; Secchiari, 1997; Tartari and Battaglini, 1997).

The surplus of a nutrient within a farm, resulting from the difference between the input and output of that element, can originate from environmental conditions, the applied forage system and the organisation of the entire productive typology. The study of apparent balance can be done at a different level (Simon, 1995): fertilisation balance at plot level, farm balance, global diagnostic of the whole system.

One of the most used is the balance at farm level, which is very common in France (Coppenet, 1975; Simon and Le Corre, 1992; Simon, 1995) where it was also used for pig breeding (Coppenet, 1974). In Italy there are some applications to cow breeding systems (Grignani and Acutis, 1994; Segato et al., 1997), or it was used to assess and compare different rearing typologies (Argenti et al., 1996; Grignani, 1996; Bassanino et al., 2005).

The aim of the present work is to analyse fluxes of nitrogen and phosphorus within dairy farms in Mugello, comparing two different productive systems of the area in order to evaluate the present entity of the surplus at farm level and the risk of pollution related to farm management.
Material and methods

The survey involved 36 dairy farms (70% of the total) in the area of Mugello (Tuscany). A preliminary survey was carried out on the whole number of farms and those with no reliable data were eliminated from the data set. The farms, as reported in the introduction, were split into two different groups (HM and LM). For each farm a questionnaire was completed to describe farm organisation, composition of the animal herd and all the productive data of the year 2004. Herd composition derived from a farm book and things purchased and stocked were collected from the farmers’ declarations. Frisona italiana in LM (89% of the total) and Bruna italiana in HM (92%) are the main breeds of animals reared in each area. Afterwards, the apparent balance of N and P was estimated according to the method proposed by Simon and Le Corre (1992) in which the registration of all fluxes of nutrients in and out the farm allows the evaluation of the surplus at farm level. Input data were represented by feedstuff, fertilisers and animals purchased along the reference year. Nitrogen fixation was estimated, according to the environmental conditions of the area, to a value of 100 kg ha$^{-1}$ for legumes cultivated in pure stand (usually lucerne) and 15 kg ha$^{-1}$ for mixtures involving legumes or natural swards, according to Argenti et al. (1996). Output data were represented by the selling of vegetal or animal products not reused in the farm. Both elements entering or leaving the farm were converted to fluxes of nitrogen and phosphorus utilising the most suitable coefficients of transformation (fertilisers title, analytical data of milk, forage and feedstuff contents) or tabular data for vegetal (Borgioli, 1981; Tamminga, 1992; Van Horn et al., 1994; Simon, 1995; Antongiovanni and Gualtieri, 2002) or animal products (Grignani, 1996).

The data obtained referred to the surface of the farm and expressed as kg ha$^{-1}$ of nitrogen and phosphorus. Efficiency of the utilisation of a nutrient was calculated as the ratio between amounts of the element entering and leaving the farm. Statistical elaboration of data was performed using the GLM procedure of SAS software (1988) following this model:

$$Y_{ij} = \mu + B_i + E_{ij}$$

where $Y = i^{th}$ observation on $j^{th}$ farm; $B =$ fixed effect of locality; $E =$ random error.

A matrix has been calculated of the most important correlations existing between farm characteristics and fluxes of nutrients.

Linear and multiple regressions were calculated for estimating the compound of nutrient surplus.

Results and discussion

Farm characteristics

In Table 1 the average characteristics of the production systems of the two farm groups are presented. Average number of animals and surface are not significantly different in the two sites. Remarkable differences concern the land use: cereals and forage crops are equally distributed in LM; in HM there is a very strong presence of forage resources (87.21%). In LM the main cereal is maize (for grain or for ensilage) with more than 31% of surface, while it is totally absent in upper areas, where only winter cereals are cultivated. Lucerne is more represented in LM than in HM, where about 45.1% of the land use is devoted to grasslands and natural pastures. Other crops are poorly represented in both typologies with no significant difference.

Main productive characteristics of the two types of farm are presented in Table 2. Stocking rate is highly different in the two sites and in HM it is less than the half of LM. These results are comparable to those reported by Argenti et al. (1996) and referring to the same area and show that in the district of Mugello an extensive management of the land is present, if compared to other areas of North Italy (Segato et al., 1997;
Reyneri et al. (1998; De Roest and Speroni, 2005). As to animal productivity, expressed as milk produced per cow (in total or for a day) there are no significant differences between the two sites, thus demonstrating equal technical results reached in both locations and this is probably due to the high care of the animals even in the mountainous lands. On the contrary, Andrighetto and Ramanzin (1987) showed a reduction in milk productivity up to 33% with animal grazing on summer pastures. Milk production per hectare is significantly higher in LM due to the more inten-

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**Table 1. Main characteristics of studied farms in the referenced year.**

| Area | RSD | P |
|------|-----|---|
| Number of farms | 14 | 22 |
| Altitude m asl | 299 | 498 |
| Average surface ha | 45.5 | 58.7 | 43.99 | ns |
| Average number of cows | 41 | 27 | 28.85 | ns |
| Milk production kg year⁻¹ | 284,129 | 136,213 | 255,285.5 | ns |
| Land use (%): |
| Winter cereals | 15.3 | 9.9 | 9.56 | ns |
| Grain maize | 12.1 | 0.0 | 6.18 | ** |
| Ensilage maize | 19.3 | 0.0 | 7.53 | ** |
| Other arable crops | 3.8 | 0.2 | 4.21 | * |
| Arable crops (tot.) | 50.48 | 10.11 | 12.13 | ** |
| Lucerne | 30.2 | 12.0 | 15.45 | ** |
| Grasslands | 1.5 | 31.7 | 22.47 | ** |
| Pastures | 2.5 | 11.6 | 12.70 | * |
| Meadows | 12.2 | 31.9 | 28.97 | ns |
| Forage crops (tot.) | 46.46 | 87.21 | 14.38 | ** |
| Other crops (tot.) | 3.06 | 2.68 | 6.29 | ns |

*ns=not significant; *=P<0.05; **=P<0.01*

**Table 2. Productive characteristics of the two farm typologies.**

| Area | RSD | P |
|------|-----|---|
| LU | 62 | 33 | 39.95 | * |
| LU ha⁻¹ | 1.36 | 0.62 | 0.41 | ** |
| Milk kg LU⁻¹ year⁻¹ | 4069 | 3831 | 1627.59 | ns |
| Milk kg ha⁻¹ | 5725 | 2665 | 3180.46 | ** |
| Milk kg cow⁻¹ year⁻¹ | 5602 | 4872 | 2454 | ns |
| Milk kg d⁻¹ | 18.37 | 15.97 | 8.05 | ns |
| Days of grazing | 26.4 | 153.6 | 54.13 | ** |
| Milk protein % | 3.26 | 3.25 | 0.121 | ns |
| Milk fat % | 3.76 | 3.74 | 0.136 | ns |

*LU=livestock unit; ns=not significant; *=P<0.05; **=P<0.01*
sive organisation of the system. This result is confirmed by data concerning the higher stocking rate and lower number of days of grazing in LM systems.

Finally it is remarkable that there are no significant differences in fat and protein content of milk despite the great differences in the management systems.

**Apparent balance of nitrogen and phosphorus**

Table 3 reports results of the balance for nitrogen. Total amount of nitrogen input is low and in both cases even lower than that imposed by EU regulations (170 kg ha\(^{-1}\) y\(^{-1}\), Reg. 1804/99) for organic farming. Anyway, in LM it is almost the double than in HM. Significant differences are present for fertilisers and feedstuffs. Nitrogen fixation is almost the same in the two locations but it is the main item in HM, while in LM it represents a marginal amount (about 20%) of the total input of N. In both cases almost no importance is due to N entering the farm as animals.

The output of nitrogen is more homogeneous. In both situations fertilisers and feedstuffs are not represented and the most remarkable difference concerns milk, with exit in LM (29.95 kg ha\(^{-1}\)) double that in HM (14.07 kg ha\(^{-1}\)). This determines a total amount of output that is almost double in LM with respect to HM.

In both cases the input of N is considerably higher than the output. Therefore, nitrogen surplus in LM is about 136 kg ha\(^{-1}\) and in HM 53 kg ha\(^{-1}\). These values are significantly lower than those calculated by Grignani (1996) for farms rearing Frisona italiana in Piedmont (308 kg ha\(^{-1}\) of N) and by Segato *et al.* (1997) for different intensive systems in Veneto (values ranging from 233 to 566 kg ha\(^{-1}\)).

Efficiency in the use of nitrogen is very low in both the studied situations (between 20 and 30%) although these values are higher than those estimated by Argenti *et al.* (1996) for the same area. Differing from our data, Abeni *et al.* (1997) found greater efficiency in a system involving grazing with respect to those reared in pens.

Balance of phosphorus (Table 4) shows similar trends to nitrogen. Particularly, the input of

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**Table 3. Average balance for nitrogen for the two farm typologies (kg ha\(^{-1}\)).**

| Area | LM | HM | RSD | P |
|------|----|----|-----|---|
| Inputs (+): | | | | |
| Animals | 1.60 | 0.17 | 2.446 | ns |
| Fertilisers | 49.52 | 3.94 | 22.115 | *** |
| Feedstuff | 89.01 | 45.83 | 58.987 | * |
| N-fixation | 32.61 | 23.14 | 14.58 | ns |
| Total | 172.74 | 73.07 | 66.375 | *** |
| Outputs (-): | | | | |
| Other vegetal products | 1.65 | 3.52 | 7.177 | ns |
| Animals | 4.69 | 1.73 | 2.171 | *** |
| Fertilisers | 0.00 | 0.80 | 2.065 | ns |
| Milk | 29.95 | 14.07 | 17.119 | * |
| Total | 36.30 | 20.12 | 18.209 | * |
| Surplus | 136.44 | 52.95 | 52.554 | *** |
| Efficiency | % | 21.42 | 30.83 | 17.534 | ns |

*ns=not significant; *=P<0.05; ***=P<0.001.*
P is more than the double for LM in relation to HM and the difference is mainly due to effect of fertilisers (almost absent in HM) and, secondly, to the purchase of feedstuff. Total output is limited, even concerning the milk, which is poor in terms of its content of this element.

Phosphorus surplus confirms that which has been noted for nitrogen, with a higher value in the intensive systems in the lowlands. In these cases obtained data are similar to those found in research conducted by Grignani (1996) with 76 kg ha\(^{-1}\), and by Segato et al. (1997) with values ranging from 31 to 81 kg ha\(^{-1}\). The efficiency of the use of this element is low, 14\% in LM and 40\% in HM, and it is lower than all the values from other studies. Therefore, greater attention in the use of this element is a must, particularly with respect to fertilisation.

Correlations

Tables 5 and 6 present the most important correlations existing between farm characteristics and fluxes of nutrients. Only columns with at least one significant correlation coefficient are reported. A strong and positive correlation exists between the input of N and P and percentage of arable crops while a negative and significant correlation was found for these parameters and the percentage of forage crops in the farm.

The number of days of grazing is negatively correlated to N and P input, the nitrogen as feedstuff and the phosphorus as fertilisers. A significant and negative correlation can be found between the period of grazing and surplus of the two elements. The stocking rate presents similar trends. Therefore, results show that extensive land use reduces external inputs and minimises the risk of high surplus of nutrients. On the contrary, the increase in number of animals ha\(^{-1}\) increases input of N and P, especially as feedstuff and fertilisers; productivity is high (positive correlations with total exit and surplus) and therefore efficiency was not influenced by number of animal ha\(^{-1}\).

Errors in the composition of the diet, both as excessive or poor availability of nutrients, decrease the system performance and force the increase in the proportion of excreted in relation to ingested elements. This is true, especially for nitrogen, as demonstrated by Bianchi et al. (1997) concerning the effect of the diet of dairy cows on the environmental pollution.
Table 5. Correlation coefficients among some farm characteristics and nitrogen fluxes.

| Farm characteristics | Nitrogen fluxes (kg ha\(^{-1}\)) |
|----------------------|-----------------------------------|
| Altitude LU AS Arable crops Forage crops Days of grazing LU ha\(^{-1}\) Animals Fertilisers Feedstuff N-fixation Total Inputs Outputs Surplus |
| LU                  | -0.35 1               | -0.69 0.33 -0.12 1               |
| AS                  | -0.28 0.58 1         | 0.62 -0.28 0.13 -0.97 1         |
| Arable crops        | 0.75 -0.44 0.16 -0.75 0.71 1 |
| Forage crops        | 0.66 0.52 -0.19 0.63 -0.58 -0.79 1 |
| Days of grazing     | -0.19 0.26 -0.04 0.39 -0.41 -0.24 0.48 1 |
| LU ha\(^{-1}\)      | -0.61 0.15 -0.21 0.73 -0.71 -0.60 0.58 0.49 1 |
| Animals             | -0.42 0.63 0.04 0.37 -0.34 -0.65 0.83 0.34 0.27 1 |
| Fertilisers         | -0.38 0.20 -0.03 0.18 -0.20 -0.36 0.20 -0.15 0.17 0.15 1 |
| Feedstuff           | -0.63 0.58 -0.06 0.61 -0.58 -0.79 0.90 0.45 0.63 0.90 0.36 1 |
| N-fixation          | -0.49 0.54 -0.08 0.48 -0.43 -0.68 0.80 0.46 0.37 0.87 0.14 0.84 1 |
| Total inputs        | -0.63 0.55 -0.05 0.61 -0.59 -0.78 0.87 0.42 0.67 0.85 0.40 0.99 0.74 1 |
| Total outputs       | 0.15 -0.19 -0.14 -0.16 0.22 0.21 -0.21 -0.05 -0.26 -0.16 -0.31 -0.28 0.20 -0.41 |

LU = livestock unit; AS = arable surface. In bold, significant correlation coefficients (P< 0.001)
Table 6. Correlation coefficients among some farm characteristics and phosphorus fluxes.

| Farm characteristics | Phosphorus fluxes (kg ha\(^{-1}\)) |
|----------------------|-----------------------------------|
| Altitude LU | LU | AS | Arable crops | Forage crops | Days of grazing | LU ha\(^{-1}\) | Inputs | Outputs |
| LU | -0.35 | 1 | | | | | | |
| AS | 0.28 | 0.58 | 1 | | | | | |
| Arable crops | -0.69 | 0.33 | -0.12 | 1 | | | | |
| Forage crops | 0.62 | -0.28 | 0.13 | -0.97 | 1 | | | |
| Days of grazing | 0.75 | -0.44 | 0.16 | -0.75 | 0.71 | 1 | | |
| LU ha\(^{-1}\) | -0.66 | 0.52 | -0.19 | 0.63 | -0.58 | -0.79 | 1 | | |

Inputs:

| | Animals | Fertilisers | Feedstuff | Total inputs | Total outputs | Surplus | Efficiency |
| | | | | | | | |
| Animals | -0.19 | 0.26 | -0.04 | 0.39 | -0.41 | -0.24 | 0.48 | 1 |
| Fertilisers | -0.63 | 0.10 | -0.26 | 0.79 | -0.77 | -0.66 | 0.58 | 0.52 | 1 |
| Feedstuff | -0.23 | 0.42 | -0.02 | 0.19 | -0.17 | -0.48 | 0.70 | 0.25 | 0.13 | 1 |
| Total inputs | -0.48 | 0.40 | -0.13 | 0.53 | -0.50 | -0.70 | 0.86 | 0.47 | 0.57 | 0.89 | 1 |
| Total outputs | -0.57 | 0.55 | -0.07 | 0.56 | -0.51 | -0.70 | 0.80 | 0.52 | 0.54 | 0.59 | 0.74 | 1 |
| Surplus | -0.45 | 0.38 | -0.14 | 0.51 | -0.49 | -0.68 | 0.84 | 0.46 | 0.55 | 0.89 | 0.99 | 0.70 | 1 |
| Efficiency | 0.25 | -0.21 | 0.02 | -0.21 | 0.19 | 0.27 | -0.35 | -0.11 | -0.28 | -0.28 | -0.36 | -0.05 | -0.38 | 1 |

LU = livestock unit; AS = arable surface. In bold, significant correlation coefficients (P<0.001)
Relations between surplus for N and P and stocking rate (Figure 1) show remarkable values of the coefficients of determination for both elements. This indicates that the variability of surplus in the studied farm is well described from only stocking rate. Moreover, in the graphics there is a good separation of the farms belonging to the two locations, with values of surplus in LM higher than those in HM.

Figure 2 shows relations between surplus of elements and input of fertilisers. In these cases regressions show reduced values of $R^2$ with respect to before but they are still significant. It is notable that there are examples of optimal utilisation of fertilisers also in farms belonging to LM, which are able to produce in an intensive way without negative consequences for the environment and, at the same time, there are cases in which the reduced efficiency in the use of nutrients is not due to productive requirements but to incorrect management of the fertilisation itself.

The input of feedstuffs is closely related to the surplus of both elements (Figure 3) and coefficients of determination are sensibly higher than those found for fertilisers. Dispersion along the line is limited even if in this situation the partition of the cases is more limited than before, with the highest surplus values produced by a farm belonging to HM.

Finally, Table 7 presents the multiple regressions obtained to estimate the surplus of N and P from the most important parameters investigated. The input of elements is a very good predictor of surplus, with $R^2$ of 0.98 and 0.99 for N and P, respectively, and this fact emphasises that an excess of nutrient derives mainly from incorrect management within the farm, due to improper fertilisation or to imbalanced feeding.
with respect to animal requirements, according to Bianchi et al. (1997). Some important farm characteristics (land use, period of grazing, stocking rate) can estimate nutrient surplus although in a less accurate manner for both N (R²= 0.80) and P (R²= 0.61). Results confirm the conclusions of previous works (Argenti et al., 1996; Grignani, 1996) which, in any case, presented equations with a lower reliability.

Conclusions

The survey conducted on two different typologies in the area of Mugello (Tuscany) made it possible to assess the main characteristics related to the management that could affect the surplus of N and P and, as a consequence, the risk of pollution. Farms in the mountainous area are characterised by a higher presence of forage resources, both natural and sown, which consequently present a greater use of grazing and a lower stocking rate. These conditions lead to reduced milk production which, however, presents similar qualitative characteristics of more intensive farms. At the same time, this extensive management also produces a very limited surplus of nutrients.

Results also show that in Mugello the values of surplus of nitrogen and phosphorus are much lower than those estimated in other intensive areas of Italy, such as in the Po River Valley (Grignani, 1996), where excesses of N reach values ranging from 200 to 300 kg ha⁻¹. The surplus calculated for dairy farms in the Mugello area is not worrying in terms of pollution, considering also that a part of nitrogen is lost to volatilisation and consequently does not remain on the soil. In comparison to the previous survey conducted in the area (Argenti et al., 1996) the efficiency in the use of the nutrients has increased although it is still low. Therefore, it is possible to state that in recent years in Mugello there has not been intensification.

Table 7. Multiple regressions between surplus of nutrients and farm characteristics or nutrient fluxes.

| Surplus of nutrients and farm characteristics | R²  |
|-----------------------------------------------|-----|
| Surplus N= 18+ 0.184 AS – 0.193 days of grazing + 84.713 stocking rate | 0.80 |
| Surplus P= -123.19 + 0.105 altitude + 138.210 stocking rate | 0.61 |

| Surplus of nutrients and inputs fluxes |     |
|--------------------------------------|-----|
| Surplus N= -7.608 + 0.945 N fertilisers + 0.746 N feedstuff + 0.962 N-fixation | 0.98 |
| Surplus P= -4.176 + 1.169 P animals + 0.922 P fertilisers + 0.963 P feedstuff | 0.99 |
in the management of animal husbandry for milk production able to produce environmental risks, but, on the contrary, there has been a global rationalisation of the productive systems with higher efficiency in the management of nutrients.

REFERENCES

ABENI, F., BERGOGLIO, G., REYNERI, A., 1997. Efficienza di utilizzazione dell'azoto alimentare per la produzione di latte bovino: confronto tra sistemi foraggeri e tra razze in ambiente di pianura. pp 89-96 in Proc. Nat. Congr. Parliamo di... on Animal nutrition and Environment, Fossano (CN), Italy.

ANDRIGHETTO, I., RAMANZIN, M., 1987. Sfruttamento del cotico erboso e produzioni di latte di vacche al pascolo. Zoot. Nutr. Anim. 13:119-127.

ANDRIGHETTO, I., BEREAGHI, P., COZZI, G., 1996. Dairy feeding and milk quality: the extensive systems. Zoot. Nutr. Anim. 22:241-250.

ANTONGIOVANNI, M., GUALTIERI, M. 2002. Nutrizione e alimentazione animale. Edagricole, Bologna, Italy.

ARGENTI, G., PARDINI, A., SARATINI, S., TALAMUCCI, P., 1996. Rapporti tra tipologie d'allevamento ed eccessi di azoto e fosforo stimati attraverso il metodo del bilancio apparente in aziende del Maggello. Riv. Agron. 30:547-554.

BASSANINO, M., ALLISIARDI, E., SACCO, D., GRIIGNANI, C., 2005. Bilanci azotati a diversa scala per la valutazione della sostenibilità ambientale di alcune tipologie di aziende zootecniche in Piemonte. pp 492-493 in Proc. 36th Proc. Nat. Congr. SIA, Foggia, Italy.

BIANCHI, M., FORTINA, R., MIMOSI, A., 1997. Effetti dell'alimentazione della bovina da latte sull'ambiente. pp 23-25 in Proc. Nat. Congr. Parliamo di... on Animal nutrition and Environment, Fossano (CN), Italy.

COPPENET, M., 1974. L'épandage du lisière de porcherie. Ses conséquences agronomiques. Ann. Agron. 25:403-423.

COPPENET, M., 1975. Bilan des éléments fertilisants sur les exploitations d’élevage. Fourrages 62:119-132.

DEMESTI, K., SPERONI, M., 2005. Il bilancio dell’azoto negli allevamenti da latte. Agricoltura 33:112-114.

GRIGNANI, C., 1996. Influenza della tipologia di allevamento e dell’ordinamento colturale sul bilancio di elementi nutritivi di aziende padane. Riv. Agron. 30:414-422.

GRIGNANI, C., ACUTIS, M., 1994. Assessment of mineral and organic nitrogen balance in Northwestern Italy dairy and beef cattle farms. pp 700-701 in Proc. Int. Congr. ESA, Abano (PD), Italy.

REYNERI, A., CAVALLERO, A., BERGOGLIO, G., 1998. Confronto tra un sistema foraggero stallino e uno pascolivo per l'allevamento della vacca da latte di medio-alta produttività. Riv. Agron. 32:96-104.

SAS, 1988. SAS user's guide release 6.03. SAS Institute Inc., Cary, NC, USA.

SIMON, J.C., 1995. Les exploitations herbagères de Basse-Normandie et l’environnement. Apex, France.

SIMON, J.C., LE CORRE, L., 1992. Le bilan apparent de l‘azote et l’échelle de l’exploitation; méthodologie, exemples de résultats. Fourrages. 129:79-94.

TAMMINGA, S., 1992. Nutrition management of dairy cows as a contribution to pollution control. J. Dairy Sci. 75:345-357.

TARTARI, E., BATTAGLINI, L.M., 1997. Sistemi di allevamento ed impatto ambientale. pp 5-21 in Proc. Nat. Congr. Parliamo di... on Animal nutrition and Environment, Fossano (CN), Italy.

VAN HORN, H.H., WILKIE, A.C., POWERS, W.J., NORDSTEDT, R.A., 1994. Components of dairy manure management systems. J. Dairy Sci. 77:2008-2030.