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The environmental impact of buffalo manure in areas specialized in mozzarella production, southern Italy

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Abstract. Buffalo livestock plays a central role in the regional economy in some areas of southern Italy, through the production of mozzarella cheese. With about 250,000 heads per utilizable agricultural area (equal to 107,400 ha), livestock husbandry is intensive. An important issue with regard to high animal density is manure management, an activity determined by cost optimization and the laws governing environmental sustainability. According to community, national and international rules (European Directive 91/676, Italian rules 152/99 and 258/00), nitrate leakage is considered a pollution indicator related to breeding activities and must be kept within limits. Simulation studies were carried out in the Italian province of Caserta to evaluate the impact of leakage on groundwater. Manure was also collected from 35 livestock farms and the nitrogen content measured in the laboratory. The results showed an average content of 2 kg/m^3 of nitrogen, corresponding to 50 kg per animal and year, while the nitrate concentrations in the groundwater were found to be lower than those predicted by simulation. The nitrogen content found in buffalo manure <60% of the standard content produced by the bovine species (on average 83 kg nitrogen per adult animal per year). The fact that the bovine species is used as the standard reference for legislation on nitrogen production explains the inconsistency observed between the impact of buffalo livestock on the environment predicted by simulation and the nitrate concentration measured in the groundwater. Although it would be out of line with current regulations, it would theoretically be possible to increase the buffalo load on the territory without environmentally negative effects. Therefore, in this context, the common referral points, i.e. the American Midwest Point Service and others usually consulted for the assessment of livestock impact in terms of nutritional excretion and the risk of pollution for the environment, should be revisited.

Keywords: buffalo manure, nutritional content, manure analysis, spatial assessment, Italy.

Introduction

Buffalo breeding for milk production is an economically important activity in the Campania region in southern Italy. The total number of buffalo heads amounts to 250,000 and the annual turnover expressed in € exceeds 1 billion. Thus, breeding is characterised by extreme density with regard to the number of animals per ha, and the economic and social importance of livestock husbandry is crucial for life in the region. One consequence of the high animal density is the complex manure management required. While aiming at cost optimization, the strong rules aimed at safeguarding the environment must be respected as inadequate manure management can lead to pathogen diffusion and contamination of potable water with risk for the human and animal health.

According to a recent Italian agricultural census

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(ISTAT), the Caserta province has a livestock population of 180,000 water buffaloes and 50,000 dairy cattle (ISTAT, 2000) distributed over an utilizable agricultural area (UAA) of 107,400 ha. This equals an average ratio of 2 heads per ha, which is causing a substantial manure management problem with nitrate leaching becoming a sizeable risk in the local context and agronomic practices. Considering that about a half of the total UAA is associated with farming of fodder and cereals, the load can be estimated at more than 4 heads per ha of the UAA. As the animals can be fed fodder of external origin, a further increase of heads per ha is possible and indeed foreseen.

The buffalo species has always been linked to the bovine species in terms of manure production and nutritional content. The American Midwest Point Service (MWPS) Committee (1993), considering both the liquid and the solid fractions, estimates manure production at 85 kg/m^3 per day 1,000 kg animal weight for both the species, while Burton and Turner (2003) report that the average total nitrogen content is 4 kg/m^3 for slurry, and 5.5 kg/m^3 for solid manure, from both species.

In the 1999-2000 period, Boccia et al. (2003) monitored the shallow part of the groundwater in an area in the Campania region, which is strongly influenced by the buffalo breeding in the Volturno basin's Caserta province. Their results showed presence of nitrate pollution in groundwater, but the values were not comparable to the nitrate concentrations characteristic of other strongly agricultural systems in Europe such as, for example, the Flanders and some areas of Brittany, France. They went on to apply a management model (GLEAMS) to predict the amount of nitrate leaching into groundwater based on data on daily rainfall from the Italian National Hydrographic Service covering 1959-1996 (Boccia et al., 2003). A simulation, based on the idea that the buffalo manure nitrogen content is similar to that of the bovine species, was carried out with consideration to climatic features, soil characteristics and agronomic management in general. It was demonstrated that the risk for nitrate leaching was not extremely high considering the annual rotation cycle based on ryegrass (*Lolium multiflorum*) and corn silage (Boccia et al., 2003).

New sampling campaigns and more detailed territorial studies conducted with geostatistical tools provided further information about the spatial distribution of groundwater nitrate content in the Volturno basin (Infascelli et al., 2007). However, the analysis did not match the buffalo distribution in the same area, a result which sowed doubts on the validity of the assumption of equal contents of nitrogen in buffalo and bovine manure. In order to better understand the situation, a method to assess the effective nitrogen distribution in pure buffalo territories was advanced by analysing orthophotographs, i.e. geometrically scale-corrected, aerial photographs of the terrain (Infascelli et al., 2009a; Boccia et al., 2010). One might suppose that the more animals on the farm, the more nitrate should find its way into groundwater. Thus, based on the animal load in the study area, we should have found a greater nitrate content in groundwater than what we actually did using sampling and prediction. A negative correlation coefficient "ρ" arose as our results fell short of what was expected.

New studies have increasingly questioned the assumed similarity between the buffalo and the bovine species (Campanile et al., 2010). If demonstrated, a reduced nutritional content would allow new perspectives on sustainable livestock breeding, in which local features in terms of environment, landscape, society and economy can be considered. In addition, low nutritional concentration would have an impact on management leading to higher costs for manure spreading, an effect which influences the competitiveness between manure and synthetic fertilizers negatively.

With these considerations in mind, the characterization of the composition of buffalo manure appeared to be the next logical step. An integrated approach has been adopted in various parts of Europe, e.g. in Brittany (Gascuel-Odoux et al., 2009). This approach, leads directly to territorial studies, simulation models and characterization of contents of manure would make it possible to evaluate real nitrogen surplus and to hypothesize different management strategies. A local research project based on these ideas was developed to assess the impact the animal load could have on the environment, especially considering the nitrogen content in manure.

Material and methods

Assessment of nitrate leaching

Nitrate leakage is considered a pollution indicator related to breeding activities, according to community, national and international rules (European Directive 91/676, Italian rules 152/99 and 258/00).

The study area is characterised by a soil permeability varying from high to medium-low without continuous impermeable layers. Hence it has been thought that the nitrate content in wells not deeper than 40 m is closely correlated to land management (Allocca et al., 2003). To assess this assumption, two sampling campaigns were conducted in 1999 and 2005 to measure nitrate concentration in wells in the study area. These investigations revealed that nitrate content in groundwater did not correspond to the animal load on the same area. This could be explained by incorrect manure management, for example spilling part or the material onto superficial water streams, or if the manure content differed from that usually hypothesised (Infascelli et al., 2009a).

Manure sampling

Thirty-five farms, representing typical livestock farms in the Caserta area in terms of management and organisation, were identified and selected for the study. These farms were chosen randomly but the selection was based on availability of the farmers. The average surface covered by the chosen farms varied between 25 and 110 ha. The procedures for sampling and analysis were based on the use of the Coliwasa sampler and carried out as described by Infascelli et al. (2009b). This commercially available sampler, developed at the University of Wisconsin in the US, consists of a sampling tube, a stop-cock and a closure system. The sampling tube consists of a 1.5 m long, translucent, plastic pipe of 4.13 cm inner diameter, usually made of polyvinyl chloride (PVC) or borosilicate-glass. However, the sampler is obviously not suitable for containers deeper than 1.5 m.

The nutritional content in the buffalo manure was analysed in the laboratory by quantifying dry matter (DM) and determining total nitrogen (TKN) plus orthophosphate (PO_4). DM was measured using a muffle for the starting samples, following the method described by Wolf et al. (1997), while TKN was determined by the Kjeldahl method according to Kane (1998) and the official method (no. 978.02) recommended by the Association of Official Agricultural Chemists (AOAC). The phosphorus content was determined by the Hach colorimetric method (Infascelli et al., 2009b).

Geostatistics

The aim of the geostatistical study was to predict the average manure nitrogen production by the livestock farms based on elaboration of the data collected by the sampling of the wells. The point data, collected during the sampling campaign, were explored with geostatistical tools using the kriging predictor and Arcview 3.2 software (ESRI; Redlands, CA, USA). The intention was to obtain prediction maps and to identify the areas where the nitrate content was not measured directly. The average nitrogen production on the farms was predicted by the construction of geographical information system (GIS) maps as described by Infascelli et al. (2007, 2009a). These maps were subsequently utilised to calculate the nitrogen surplus referring to the threshold law (Italian Ministerial Decree 152/2006) making it possible to differentiate between areas where the nitrogen surplus could be handled and where it exceeded the limits. The nitrogen production was quantified by considering the number of buffaloes and bovines recorded in the Data National Bank (BDN, 2008).

Two different hypotheses were considered:

(i) the nitrogen content in buffalo manure is the same as that in bovine manure, i.e. 83 kg N per head per year for the production animals and 36 kg N per head per year for the culling heads (as reported in Italian Ministerial Decree of 7 April 2006) (Fig. 1); and

(ii) the nitrogen production is 57 kg N per head per year for the production buffaloes and 32 kg N per head per year for the culling heads, i.e. 65% of the nitrogen production in bovine manure as suggested by Campanile et al. (2010) (Fig. 2).

The spatial distribution of the average nitrogen production in each farm was visualized by using a convolution function in the GIS environment, i.e. the Kernel Density (Infascelli et al., 2009a). The most rational search radius was hypothesised to be 6 km as this is the break-even point considering transport by tank and spreading costs (Provolo, 2000).

Results

The correlation between the nitrate concentration in groundwater predicted by kriging interpolation and the spatial distribution of the annual nitrogen production in farms is shown in Fig. 1. These data were used to construct maps showing the predicted nitrate concentration in groundwater and one showing the spatial distribution of the average, annual nitrogen production in the farms. These maps revealed that there is a small negative correlation (ρ = -0.38) between the potential nitrogen production and the nitrate pollution in groundwater.

The mean values of the nutritional concentration data emanating from the analysis, conducted in 2009, characterising the nutritional content of the buffalo manure, are provided in Table 1. The value are influenced by the way of storage used (e.g. separation liquid-solid, superficial mixer, etc.) and also by livestock management, i.e. feeding. The mean value for nitrogen concentration was found to be 1.950 mg/l corresponding to 2 kg/m^3 of manure, a

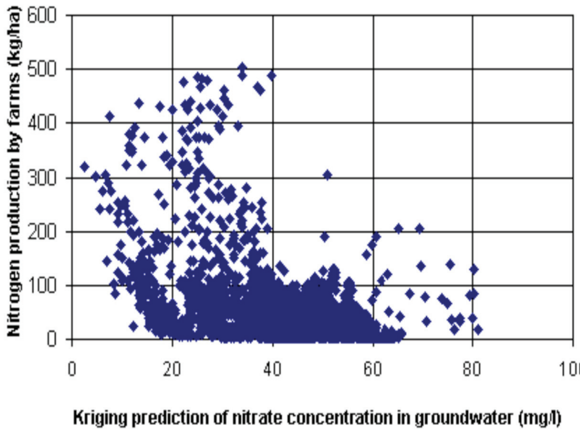

Fig. 1. Correlation between predicted nitrate concentration in groundwater and spatial distribution of the average, annual nitrogen production in farms, Caserta area, Italy.

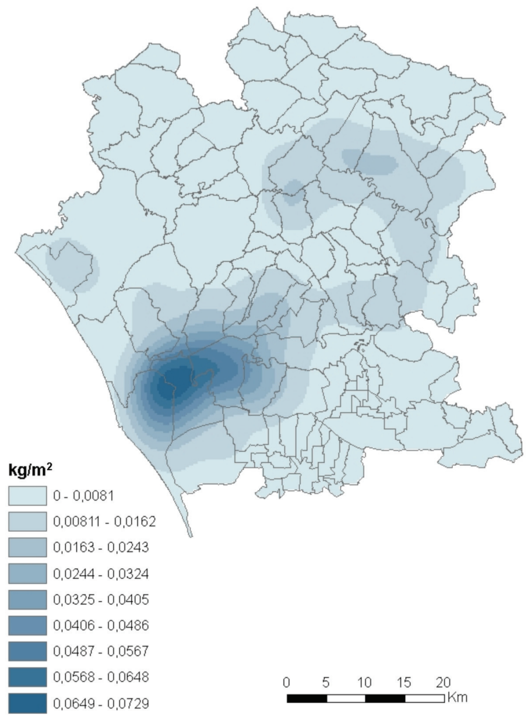

Fig. 2. Spatial distribution of nitrogen production, based on physiological similarity between buffaloes and bovines (search radius = 6 km).

value considerably lower than what is recorded in the literature. For example, Burton and Turner (2003) claim values at the level of 2.5-4.5 kg/m^3 which is usually considered the referral value for legislation. The 30% variation of the data in Table 1 is probably due to the non-homogeneous livestock in the area and the unusual high rainfall that characterised the study area during 2009. Generally, the ammonia nitrogen mean value is less than that commonly seen in the literature (0.6 kg/m^3 vs. 1-4 kg/m^3).

Further geostatistical studies showed that the nitrogen concentrations in areas characterised by high spreading activities ranged between 0.05 and 0.07 kg N per m^2 corresponding to 500 and 700 kg N per ha per year. Figure 3 shows an area of about 20,000 ha where the average nitrogen production in the manure is higher than 350 kg N per ha. As the threshold for nitrogen spreading is 170 kg N per ha in vulnerable areas, we hypothesise that the study area can support no more than an average of 100 kg of nitrogen manure per hectare of UAA according to the limits set by law. The map showing the surplus (considering a compliance threshold of 100 kg N per ha) is shown in Figure 4. As can be seen, the excess ranged around 200 kg N per ha.

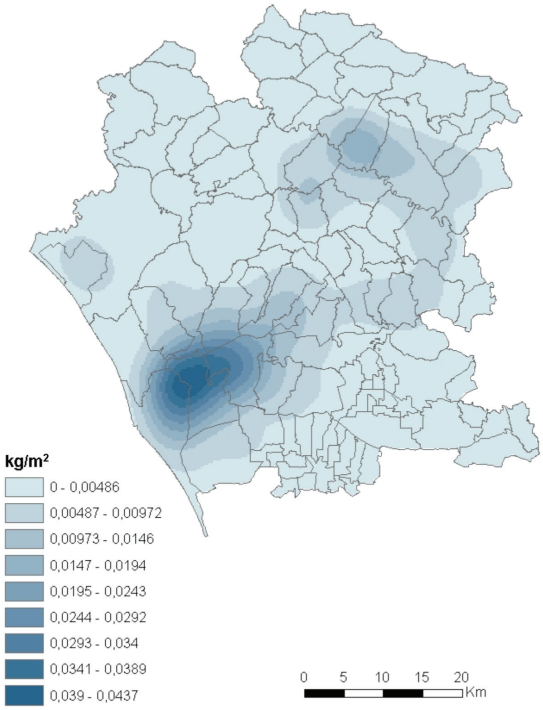

Fig. 3. Spatial distribution of nitrogen production, considering that the nitrogen production in buffalo manure is about 65% of the nitrogen production in bovine manure (search radius = 6 km).

Discussion

Studies in the Campania region indicate that the connection between theoretical nitrogen production in farms and nitrate content in groundwater is unclear. This study contributes to the enquiry of the impact of livestock on the environment, a question studied in many countries around the world such as Australia, France, Italy and USA with the aim to

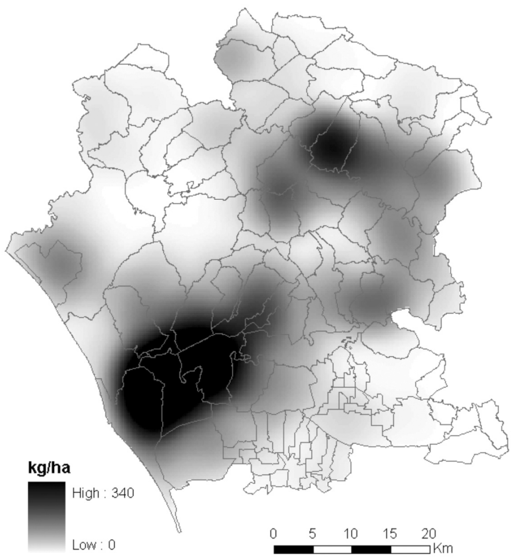

Fig. 4. Nitrogen surplus considering a threshold of 100 kg N per ha.

Table 1. Nutritional content in buffalo manure.

	Ntot (mg/l)	N-NH3 (mg/l)	PO_4 (mg/l)
Average value	1 960	508	995
σ^2	334 716	36 241	38 695
σ	580	190	197
σ * (average value)$^{-1}$	30%	37%	20%

provide guidelines for farmers, politicians and other stakeholders. As shown in Brittany, the approach should be integrated and implemented by a multifunctional team (Gascuel-Odoux et al., 2009).

It is widely believed that buffalo manure is chemically similar to dairy bovine manure. However, there is a large gap between the 3-4 kg/m^3 in liquid manure (5.5 kg/m^3 in solid manure) claimed by Burton and Turner (2003) for both species and the total nitrogen content of 2 kg/m^3 determined by our laboratory analysis of buffalo manure. One of the explanations is the different nitrogen metabolism between the buffalo and bovine species. This is mainly due to the tropical provenance of the buffalo species (Campanile, 1997) and its general feeding typology but may also be due to the less protein-rich fodder preferred by buffalo. In addition, the period of lactation is longer for the bovine (305 days) than for the buffalo (240 days) explaining the reduced feeding need of the latter. Our experimental results confirm findings of research on the nutritional balance and animal physiology by Campanile et al. (2010), who claim that buffalo manure only contains 65% of the nitrogen amount found in comparable amounts of bovine manure. It is highly likely that this mismatch explains the inconsistency between the pollution found in the field and that predicted by kriging interpolation based on cattle livestock manure loads found by the convolution function (Infascelli et al., 2009a). The observed lack of a positive correlation between the predicted nitrogen production and the nitrate pollution determined in the groundwater reveals a possible weakness in current practise. Dealing with manure without considering the species producing it, as seen in many scientific papers and indeed proposed by legislative bodies, leads to problems that can only be corrected by determining and defining the nitrate content of manure for each species.

Considering the nitrogen from manure only and accepting to reach, but not to exceed, the 50 mg/l NO_3 concentration threshold set by European and local rules, the maximum amount of manure that can be managed in keeping with the GLEAMS model, developed by Boccia et al. (2003), can be estimated at about 1,000 kg/ha of manure. This amount corresponds to the total load of manure produced by about 12 bovine heads per ha or, based on the results obtained here, by about 15 buffalo heads. However, this level already touches the upper acceptable limit and can only be permitted with the understanding that the shallow groundwater is not potable. Alternatively, it could also be tolerated in places where it can be assured that the manure load is sufficiently diluted, for example through absorption by being absorbed into greater aquifer strata. This means that higher loads are acceptable in theory but only if swift dilution can be guaranteed, i.e. a detailed hydro-geological study is needed in the individual case to assure the feasibility of the practice chosen.

The laboratory analysis of the nutritional content in buffalo manure showed an average content less than 60% of the standard nutritional content adopted for the bovine species. The low nutritional content can possibly be explained as dilution due to the increased average rainfall in the study area in 2008-2009 (about 150 mm per month) which resulted in 50% more water than usual. Indeed, the samples measured in this study showed low values of nutritional concentration too. However, the excess rain water, which normally represents about 25% of the storage tank but which increased to 38% in the 2008-2009 period, cannot completely explain the low nutritional concentration measured in this study, but only around 15% of the value.

Conclusions

The nitrate content in buffalo manure appears to be different from that of the bovine species. Fertilization plans and agronomic utilisation plans need to be reassessed and updated in light of the current findings. The need to update the guidelines should be considered also for the European and national rules.

The research presented here indicates that the assessment of livestock impact, in terms of nutritional excretion and consequent risk of pollution for the environment, has to be revisited. Dealing with manure without considering the species producing it, as articulated in many scientific papers and proposed by legislative bodies, leads to problems that can only be corrected by determining and defining the nitrate content of manure for each species.

Based on the outcome of simulations, the territory investigated seems not to be excessively vulnerable. Annual crop rotation and the variability of the climate minimize the problem connected to nitrate leaching which has indeed been confirmed by the observed amounts of nitrate pollution in groundwater. Thus, although it would be out of line with European regulations, it would be theoretically possible to increase the livestock in the field.

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