Characterization of animal husbandry and of livestock Nitrogen load in South Tyrol

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Abstract

Within cattle farms’ operations, management of livestock effluents has been considered of particular importance for the last two decades (Provolo, 2012; Vismara et al., 2011). The autonomous Province of South Tyrol (Italy) has no “vulnerable” zones-ZVN (Directive 91/676/EEC) (Peratoner & Stimpfl, 2012; Bottarin & Tappeiner, 2010). Proportionally to area and available UAA, the South Tyrol cattle density and the N-load are higher than the neighboring territories, which actually have ZVN defined. The research provided an estimation of nitrates-criticalities from the livestock sector. We carried out a detailed study of operational characteristics of the breeding farms in South Tyrol at first. All the collected data were analyzed in order to define three levels of characterization: Province, Municipality and single Farm. We identified three “Typical farm” categories in terms of manure, feeding and housing management. Objective of the categorization was the estimation of actual livestock effluents amount and of N-load from livestock sector, given different coefficients of proportionality for each category’s variable. We focused the analysis on sixteen Municipalities, identified for the breeding’s density; for the n° of farms with intensive settings; and for environmental characteristics of the UAA. At the farm level, we considered that balance between nutrients produced by livestock activities (Input) and the utilization-capacity of the same by agricultural lands (Output) can be a suitable method to determine the equilibrium to be achieved together with the tools to be adopted on farm. Five municipalities and several farms belonging to their areas were identified as presenting a potentially critical N-load on soil (kg (N).ha⁻¹ >200). Our study aimed at developing a method able to ensure a sustainable management of livestock effluents in the Alps and to create the conditions required to prevent water pollution and to prepare the local animal husbandry sector to more restrictive Directive.

Keywords: livestock sector, Nitrogen balance, vulnerability

1. Introduction

Plant nutrients are essential to secure worldwide food supply. Nitrogen (N), in particular, is an essential element for plant growth and a key element of agricultural input (Eickhout et al., 2006). However, in recent years, benefits of nutrient inputs in crop production systems are minimized in discussions of potential risk (Stewart et al., 2005). A key target for improved nutrient management and a more sustainable agriculture must be the more efficient use of N to maintain food production with the greater reduction of its impact on the environment (Goulding et al., 2008). Almost 30% of the N excreted is lost from livestock buildings or during storage. Approximately 19% is lost via emissions of Ammonia (NH₃), 7% via emissions of other N-gases, and 4% via leaching and run-off. A further 19% is lost via NH₃ emissions after application of the manure to land. The results indicate that only c. 52% or less of the N excreted is potentially recycled as a plant nutrient (Webb et al., 2012). Surplus of nutrients means that farmers need to treat manure/digestate to reduce its environmental impact (Amon et al., 2006; Rico et al., 2011; Webb et al., 2012). Deficit of nutrients means that parts of the world suffer
from reduced soil fertility, diminished crop production, and other consequences of inadequate N supply, and farmers need to buy mineral fertilizers or manure from outside (Mosier et al., 2004; Refsgaard et al., 2005). This fact requires a policy framework based on closing the nutrients/material loop. The problem of reducing N-losses into the environment, as leaching of Nitrates into groundwater and Ammonia emissions into atmosphere, can be only addressed through a critical and scientific analysis of manure entire production chain.

1.1 The situation of nitrates in South Tyrol

A recent classification of soils based on the Nitrate Directive (Directive 91/676/EEC of the Council of 12 December 1991) showed the absence of “vulnerable” zones in the autonomous Province of Bolzano (BZ, Italy) (Peratoner & Stimpfl, 2012; Bottarin & Tappeiner, 2010; Gamper, 2008; Scarperi & Vidoni, 2008). Proportionally to area and available UAA, the South Tyrol cattle density (BZ = 81.4%; TN = 72.0%; Veneto = 65.1%; Emilia Romagna = 55.2%; Friuli VG = 52.1%; Lombardia = 51.2%) and the N-load (BZ = 93.4%; TN = 74.5%; Veneto = 56.9%; Emilia Romagna = 52.8%; Friuli VG = 44.8%; Lombardia = 55.4%) are higher than the neighboring territories, which actually have NVZ defined (elaboration from ISTAT, 2010). Nevertheless, a provincial regulation (D.P.P. 6/21.01.2008), based on the Nitrates Directive (Council Directive 91/676/EEC of 12 December 1991) acknowledgment and accounting for the special nature of this territory, imposes limits tighter than normal to the N-rate spreadable: 213, 170, 127.5 kg (N).ha⁻¹ for agricultural lands respectively <1250, >1250 and >1800 m a.s.l. The Province of South Tyrol has typically alpine orography: 64% of the surface is deployed over 1500 m a.s.l. The geographical and climatic conditions have enabled the development of the Province’s animal husbandry, which is often the only form of efficient use of territories at higher altitudes. Cattle are the main bred animals (Bottarin & Tappeiner, 2010). An uncontrolled spreading of animal effluents on the territory unbalance the alpine ecosystems. The nutrients present in the effluents (especially N) can easily leach into the superficial and the underground waters (Soana et al., 2011). Areas as Brunico, where the catchment is small and the concentration of intensive animal husbandry and arable crops such as maize is high, have recently shown significant increase of the N-level (Peratoner et al., 2013). Moreover, an estimation of the aquifer vulnerability (e.g. with SINTACS method or GNDCI-CNR method) and a complete and detailed soil map of the Province are missing, even if the territory could generally be classified as with rather light soils. The lack of a strict monitoring of the MVD (Minimum Vital Flows), of the feeding and of the housing types in the South Tyrol Province increases the necessity of a deep assessment of the livestock’s features and pressure on the territory. In synthesis, causes of potentially critical situations are: (i) the considerable anthropic and animal pressure on flat areas of valleys, where the population is concentrated, and (ii) the lacking of lands for effluents disposal according to environmentally sustainable strategies (Bottarin & Tappeiner, 2010; Peratoner et al., 2012).

2. Materials and methods

We carried out a detailed study of operational characteristics of livestock farms in South Tyrol, in order to draw up the state of local animal husbandry. The analysis was focused on cattle farms for milk production, being the most representative category in the Province. All the collected data were analyzed in order to define three levels of characterization: Province, Municipality and single Farm. Gis maps (ArcMap 10.1, Esri) were created as synthesis of the livestock sector’s characterization. All data were elaborated using coefficients and average values taken from literature review and in particular from the summary tables of CRPA and the Annexes of the DM 07/04/2006 for different types of excreta. In order to develop a nutrients balance (NB) calculation, balance between nutrients produced by livestock activities (Input) and the utilization-capacity of the same by agricultural lands (Output) was calculated. Municipal inputs derived from sum of nutrients supply from organic fertilizers (livestock effluents) produced in each farm. The contribution of mineral N-fertilizers was not considered, since it concerns only fruits or vegetables cultivated lands. Instead, the contribution of N from acid rain and N-fixation by Leguminosae was added. For the N-wet deposition, an average of 10 kg (N).ha⁻¹yr⁻¹ was calculated. For grazing lands and meadows, with an average of 3-5% of Leguminosae, a rate of fixed N of 15 kg (N).ha⁻¹year⁻¹ was estimated. About 30-35 kg (N).ha⁻¹yr⁻¹ are mineralized for each percentage point of humus in the soil. This results in a value of 60
kg (N).ha\(^{-1}\).yr\(^{-1}\), which was included in the calculation. Outputs, instead, were considered equivalent to the amount of nutrients removed by crops up-take (152.5 kg (N).ha\(^{-1}\) = grazing lands; 200 kg (N).ha\(^{-1}\) = corn silage crops; 28 kg (N).ha\(^{-1}\) = farm meadows and mountain meadows; 70 kg (N).ha\(^{-1}\) = winter crops). The model, the criteria and the formula for calculating the N-balance relies to the Code of "Good Agricultural Practice" (Ministerial Decree of 19 April 1999). The NB-formula gives an estimation, which in some cases may be slightly superlative, in other cases slightly lower than the actual value of N-load. A negative NB was called deficit, a positive balance was defined as surplus. The BN was expressed in kg (N).ha\(^{-1}\) in positive and negative. To visually and quickly recognize the result of the NB, a combination of colors like a traffic light system has been associated to values. The green color was assigned to ± 22 kg (N).ha\(^{-1}\) or to ± 0.2 LU.ha\(^{-1}\). The color yellow to N-deficit (≤ 22 kg (N).ha\(^{-1}\) or < 0.2 LU.ha\(^{-1}\)). The colors orange and red, instead, to N-excess, respectively, for a not significant surplus (color orange, 22-110 kg (N).ha\(^{-1}\) or 0.2-1.0 LU.ha\(^{-1}\)), and for significant N-surplus (> 110 kg (N).ha\(^{-1}\) or > 1.0 LU.ha\(^{-1}\)).

3. Results and Discussions

3.1 Farms Types

Valleys typically suited to animal husbandry and feeding (e.g. Val Pusteria, Valle Isarco, Val Sarentino) and others to fruit-growing (e.g. Val d'Adige and Val Venosta) might be distinguished. This stems from management motivations, such as lower steepness of lands, most favorable conditions for foraging, proximity to centers of distribution of products (milk, meat, eggs) and greater productivity of crops. The Province of BZ counts 13,467 farms (ISTAT, 2010), of which 8,314 are cattle farms (ASTAT, 2010). Being the cattle category the most important for the livestock sector, an average value of 15.7 LU-fertilizers per farm can be considered. The LU.UAA\(^{-1}\) index per farm throughout the entire Province has value between 0.5 and 2.5. The 116 Municipalities significantly differ as result of geographical and environmental characteristics (altitude, slope). Detailed data with respect to housing and feeding types of single farms are missing. However, the following considerations may be given. a) Different effluents management methods exist: manure and slurry separated, in sewage or mixed. b) The most common housing type is traditional fixed, being still representative in those medium farms (between 20 and 50 heads), which are typical in South Tyrol. Free housing type, now required in new stables and therefore representative of future trends, is generally used in stables with heads consistency greater than 50. c) Feed is composed by hay of first and second cuts, corn silage, silo grass and cereals. d) Only heifers are normally sent to alp-grazing (23% of the total bovine consistency), so only for 77% of the cattle density, a constant annual production of effluents in stalls can be expected. We identified three "Typical farm" categories in terms of manure, feeding and housing management. 1) Traditional extensive breeding: n\(^{a}\) of animals less than 15, fixed housing, summer grazing for all animals, separate feeding supply based primarily on farm forage (no corn silage), separate management of manure and slurry, internal replacement. 2) Intensive breeding with large use of meadows and grazing lands: medium-sized farms (20-50 animals), with free housing or fixed housing, traditional diet (farm forage) with only a fraction of feed externally purchased (e.g. grass silage), summer grazing for heifers, mixed manure management and partially internal replacement. 3) Farms with intensive setting, stalls with number of animals between 80 and 100 or more, free housing barns in modern stalls, feeding technique such unified with important part of the rations bought outside (corn silage, grass silage, cereals), internal and external replacement, rarely grazing, mixed manure management.

3.2 Thematic maps

Fig.1 shows the thematic map (ArcMap 10.1, Esri) representing the number of farms per Municipality. Sarentino (686) and Castelrotto (449) have the greater number of farms. Fig.2 shows also a map of South Tyrol in which Municipalities and river basins are represented. Fig.3 shows the thematic map representing the consistency of cattle farms by class of consistency per Municipality. Fig.4 represents the total N-load (considering all type of breeding) per Municipality. From the GIS data elaboration, the research highlighted the following Municipalities as inter-

3.3 Effluents amount estimation

Data were processed based on Peratoner et al., 2011. Malles, Brunico and Nat-Sciavez present the higher values of LU.UAA\(^1\) index: those cities are the same Municipalities presenting, after detailed analysis at the farm level, potential criticality in terms of N-surplus. These Municipalities also belong to two of the most vulnerable valleys, due to their proximity to glaciers (Val Venosta) and to the size of the catchment area (Val Pusteria). The correct evaluation of the amount of livestock effluents, divided into manure and slurry, is very important for the proper determination of the actual amount of N excreted and consequently for determining the amount spreadable over available acres (Figg.5-6). The estimates considered only cattle farms, for a total quantity of slurry and manure respectively equal to 279,575 ton.yr\(^{-1}\) and 609,155 ton.yr\(^{-1}\). Municipalities with larger production of slurry and manure are Sarentino, Malles, San Lorenzo, Ultimo, Racines, Castelrotto and Valle Aurina (the ones with intensive farms). In order to carry out a check on the total production of slurry and manure previously defined, verification based on dry matter (TS) excreted by single animal was carried out. Tests conducted by CRPA (CRPA, 2012) have shown that the production of TS excreted from dairy cattle is proportional to the daily amount of milk produced. The study provides an indication of the average quantities of dry matter excreted (TS) for different cattle categories. The specific TS content estimated for dairy cows with fixed housing is equal to 8.4 kg (TS).head\(^{-1}\).d\(^{-1}\): that is in line with the value 9.5 kg (TS).head\(^{-1}\).d\(^{-1}\) provided by the study of CRPA. Even for the other considered cattle categories, the specific TS production is in line with those cattle categories of similar live weight and housing type studied by CRPA. This result indicates that the total production of slurry and manure estimated for the 16 Municipalities is plausible and in line with literature data. It should however be noted that these estimates and assumptions are based on average values. Because of that, the computed data may slightly differ from the actual ones.

3.4 Index UAA

The actual compatibility between the local territory and the animal husbandry pressure was assessed by calculating the necessary UAA to enable the proper disposal of manure produced by each Municipality. The doses of slurry and manure applicable on soil are expressed in terms of N-content and are fixed by the Nitrates Directive in 170 kg (N).ha\(^{-1}\).yr\(^{-1}\) for Vulnerable Zones (NVZ) and 340 kg (N).ha\(^{-1}\).yr\(^{-1}\) for ordinary areas (OZ). For each farm and for each Municipality (by summing each farms’ N-load), the N-output (kg (N).yr\(^{-1}\)) was calculated. By dividing the municipal N-load for the limiting value of N spreadable, it is possible to derive the agricultural area (UAA) required for the disposal of manure in OZ and NVZ. From the difference between the available municipal UAA and the required UAA in NVZ, Index UAA can be calculated (Fig.7) as: \(I_{UAA} = (UAA_{av} - UAA_{NVZ})/1000\). The 16 Municipalities have a total \(I_{UAA}\) of +16.87 ha (UAA\(_{av}\)=32,263; UAA\(_{NVZ}\)=15,386). From the analysis, some critical situations emerge. The sustainability of animal husbandry is, in fact, particularly critical in the Municipality of Naz-Sciavez, which requires additional agricultural surface. On the other hand, Sarentino, Racines and Valle Aurina have a surplus UAA. Varna is borderline to the constraints related to the maximum allowed N-load in NVZ.

3.5 Nutrient balance calculation

In the 16 considered municipalities, mountain meadows and grazing lands are the prevalent types of surface, followed by corn silage and on farm meadows. Brunico and Nat-Sciavez are the only ones with predominance of corn-crops hectares. Those are also the areas with the greater \(LU.UAA\). Even considering the overall UAA, mountain meadows prevail, followed by grazing lands. The 16 Municipalities have an average of 15.33 ± 15.21 LU and 1.9 ± 1.79 LU.ha\(^{-1}\). The average milk production per day is 70,404.61 kg. N applied on the selected municipalities’ territories assume the average value of 102 kg (N).ha\(^{-1}\). NB results showed that grazing lands and mountain meadows are particularly vulnerable to N, which remains on soil. Tab.1 summarizes NB values calculated per hectare of land use type, using the values of organic fertilizer calculated as shown in Figg.5-6. It can be seen, from the significant presence
of red color, that potentially critical situations from Nitrate pollution exist (although the values remain in most cases below the limits set in NVZ, and still below the limits provided in OZ). Naz-Sciavez is the most critical Municipality for all types of land use, while Racines is the most balanced. Malles, Brunico, Chienes, Naz-Sciavez and Varna are potentially vulnerable in terms of N-load. Tab.1 shows also the NB-results applied on the total municipal UAA and the corresponding LU.UAA -1 index, as required by the method. NB Method is comparable to results obtained on the basis of data from 6th Census ISTAT, 2010, although the N-load ha -1 (NB) is on average 10 kg minor than the one based on ISTAT. This discrepancy is attributable to the mediated values for the cutting of grazing lands.

4. Conclusions

The identification of potentially vulnerable areas is a strategic tool in land use planning, in particular in frail alpine regions. Livestock farms density is high throughout the Province. Frequent are those farms with an UAA extension lower than 5 ha. Farms with greater extension are mainly located in the North part of the Province (Val Pusteria, Val d’Isarco, Val Venosta). Geographic characteristics, combined with farm settings, may cause an increased risk of pollution from N-surplus (consequently Nitrates). Thanks to the categorization of “Typical farms” in South Tyrol, it was possible to estimate the actual livestock effluents amount and the N-load from livestock sector. Five municipalities and several farms belonging to their areas were identified as presenting a potentially critical N-load on soil (kg (N).ha -1 >200). Our results highlight that the relationship between cattle density and N-load in South Tyrol can result in local criticalities. In fact, the Valley and the Municipalities that have larger cattle herds (Sarentino, Venosta, Aurina, Pusteria, Ultimo, Passiria e Marebbe), but not necessary UAA for satisfying N-load limit on NVZ, present N-surplus, which has to be managed according to a nutrients balance concept. Our study aimed at developing a method capable of ensuring the sustainable management of livestock effluents and thought of creating the conditions required to prevent water pollution and to prepare the local animal husbandry sector to more restrictive Directive.

5. Acknowledgements

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6. References


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**Figure 1:** Number of livestock farms per municipality of the Province of Bolzano (ISTAT 2010 data elaboration).

**Figure 2:** Municipalities of South Tyrol with the surface belonging to the specific river basin (NIGIS 2010 data elaboration).
Figure 3: consistency of cattle farms by class of animals per Municipality with total cattle density ≥ 1000 (ISTAT 2010 data elaboration).

Figure 4: total N-load (kg) from different livestock sources (ISTAT 2010 data elaboration).

Figure 5: division between slurry and manure production in the 16 Municipalities of the Province of Bolzano, depending on type of housing for dairy cows (ISTAT 2010 data elaboration*).

Figure 6: division between slurry and manure production in the 16 Municipalities of the Province of Bolzano, depending on type of housing for calves + heifers + replacement cows (ISTAT 2010 data elaboration*).
Note: in the case of bovine herds with fixed housing, considering the presence of straw in almost all of the farms in South Tyrol, as specific effluent production the following values were considered: slurry=8.2 ton/ton of life weight/year; manure=26 ton/ton of life weight/year for dairy cows. Slurry=2.1 ton/ton of life weight/year for replacement cows, heifers, and calves. In the case of bovine herds with free housing, the different types of free housing with bunk described by the DM 7 April 2006 were averaged. On this assumption, the following values were considered: slurry=22 ton/ton of life weight/year; manure=18.5 ton/ton of life weight/year for dairy cows. Slurry=17 ton/ton of life weight/year; manure=14.5 ton/ton of life weight/year for replacement cows, heifers and calves. Farms with n° of animals <20 were assumed to have fixed housing. Farms with n° of animals between 20 and 50 were assumed to have fixed or free housing depending on the municipal trend (Sarentino, Malles, Racines, Moso in Passiria and Castelrotto tend to convert stalls to free housing); farms with n° of animals >50 were considered to have free housing.

Fig. 7: Index UAA per Municipality of the Province of Bolzano. Calculated as: $I_{\text{UAA}} = (UAA_{\text{AV}} - UAA_{\text{NAV}})/1000$. SD refers to $UAA_{\text{NAV}}/1000$.

Table 1 - Municipal values of N-load per hectare of land use type of available UAA, calculated using the NB formula and the values of organic fertilizer calculated for each Municipality. Municipal values of kg (N).ha$^{-1}$ averaged on type of land use; calculated Index LU ha$^{-1}$ (UAA), compared with the actual LU UAA$^{-1}$ (ISTAT data 2010 elaboration).

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Grazing lands</th>
<th>Corn crops</th>
<th>Farm meadows</th>
<th>Mountain meadows</th>
<th>Winter Crops</th>
<th>Average</th>
<th>Standard Deviation ($\sigma$)</th>
<th>LU UAA$^{-1}$ (Nutrients Balance)</th>
<th>Actual average LU UAA$^{-1}$</th>
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<td>Sarentino</td>
<td>-4.28</td>
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<td>120.22</td>
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<td>202.47</td>
<td>160.47</td>
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<td>2.2 ± 1.84</td>
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<td>207.01</td>
<td>165.01</td>
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