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Proposal of an integrated system for the monitoring of N flows from breeding in the autonomous Province of Bolzano – Northern Italy

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1 ABSTRACT

The Province of Bolzano (Italian alpine area) has a density of people and animals comparable to other regions of Northern Italy. Anyhow, due to the special nature of its mountainous lands, there are potentially-critical situations to be monitored: (i) the anthropic and animal pressure is considerable on valleys, where the population concentrates; (ii) there are few lands for spreading animal slurry according to environmentally-sustainable strategies (i.e., limiting N-rate). Therefore, an integrated system for monitoring the N-rates spread on the territory is proposed. Analogous systems were recently experienced in other Italian regions where specific research projects proposed solutions to monitor the production and distribution of slurry from intensive breeding and to automatically compile field-activity registers, in accordance with current regulations. The system presented here also foresees tools for managing grazing systems through virtual fences (GNSS-equipped collars).

Keywords: Animal wastes; N-leaching; automated monitoring; extensive breeding; information systems.

2 INTRODUCTION

2.1 The situation of the autonomous Province of Bolzano

A recent classification of soils based on the Nitrates Directive (91/676/EEC) showed the absence of "vulnerable" zones in the autonomous Province of Bolzano (Italy) (Bottarin & Tappeiner, 2010; Braioni et al., 2001; Gamper, 2008; Peratoner & Stimpfl, 2012; Peripoli, 2008; Salvati, Alessi, & Licopodio, 2005; Scarperi & Vidoni, 2008). Nevertheless, a provincial regulation (D.P.P. 6/21.01.2008) based on the Nitrates Directive acknowledgment and accounting for the special nature of this territory, essentially mountainous[1], imposes limits tighter than normal to the N-spreadable: 213, 170, 127.5 kg(N)·ha^{-1} for agricultural lands respectively <1250, >1250 and >1800 m a.s.l. Agricultural activities interest two distinct areas: (i) woody crops in valleys and foothills, (ii) animal husbandry (especially cattle) and fodder crops in mountainous areas above 900 m (Bottarin & Tappeiner, 2010). An uncontrolled spreading of animal

[1] 80% of the territory has a slope >25%; the grazing land is the 61.2% of the Usable Agric. Area-UAA, 64% of the land is over 1500 m a.s.l.

slurries on the territory could unbalance the alpine ecosystems. The nutrients present in the slurry (especially N) could easily leach into the superficial and the underground waters (Coldiretti, 2009; Soana et al., 2011) causing serious alterations of the water quality and of the entire ecological chain, with negative impacts even on the touristic/recreational functions of the alpine environment, with related economic and social consequences (Peratoner and Stimpfl, 2012). K and P-rates should also be monitored. Although official statistics indicate a density of people and animals comparable to other regions of Northern Italy (Table 1), there are local potentially-critical situations that have to be monitored. The first causes 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 slurry disposal according to environmentally-sustainable strategies (Peratoner et al., 2012). Extensive and intensive breeding is indeed a very widespread activity for more cultural rather than economic reasons, and uses a relevant part of lands free from forests and reliefs. Traditional agriculture typically used to integrate livestock and cultivation activities, using effluents as fertilizers. Modern agriculture shows instead an increased specialization, dividing definitely manure management from cultivation activities (Provolo, 2012). Some very narrow valleys areas (e.g., around Bruneck) presenting lots of cattlesheds and maize farms, show significant increases of the N-level (Peratoner et al., 2013). Moreover, the Province's hydrology and the great availability of surface and underground water have contained possible pollution from N-overloads till now, thanks to efficient dilution. However, due to increase of annual mean temperature (Walker and Del Moral, 2003) evaluated that 75% of glaciers have been retreating for the last 150 years and a future reduction of the hydrological runoff is expectable. A study concerning the aquifer vulnerability and a detailed soil map of the Province are missing, as well as a monitoring of rivers' Minimum Vital Flows and of animal feeding and housing types.

Table 1 – Situation of breeding in the north-east of Italy (ISTAT, 2010, 2012).

Quantity		**Territory (P=autonomous province, R=region)**					
		Bolzano (P)	*Trento (P)*	*Veneto (R)*	*Emilia Romagna (R)*	*Friuli V. Giulia (R)*	*Lombardia (R)*
Surface (ha)	Total	740 000	620 700	1 839 100	2 245 600	785 500	2 386 100
	UAA	**241 952** *(32.7%)*	**137 219** *(22.1%)*	**811 440** *(44.1%)*	**1 064 214** *(47.4%)*	**218 443** *(27.8%)*	**986 826** *(41.4%)*
Estimated animal life weight per UAA unit (kg·ha^{-1})	Total	273.8	186.9	581.0	385.4	318.3	1 193.0
	Of which:						
	Cows	222.8 *(81.4%)*	134.7 *(72.0%)*	378.4 *(65.1%)*	212.6 *(55.2%)*	165.7 *(52.1%)*	611.0 *(51.2%)*
	Pigs	1.5 *(0.5%)*	3.0 *(1.6%)*	74.3 *(12.8%)*	88.5 *(23.0%)*	74.8 *(23.5%)*	364.1 *(30.5%)*
Estimated N-load* (t·(ha·year)$^{-1}$)	Total	**29.445**	**22.296**	**82.004**	**49.683**	**45.611**	**136.135**
	Of which:						
	Cows	27.495 *(93.4%)*	16.616 *(74.5%)*	46.689 *(56.9%)*	26.233 *(52.8%)*	20.449 *(44.8%)*	75.391 *(55.4%)*
	Pigs	0.158 *(0.5%)*	2.958 *(13.3%)*	22.768 *(27.8%)*	10.617 *(21.4%)*	12.729 *(27.9%)*	10.747 *(7.9%)*

* Total productions of slurry estimated from official tables (attachments of D.Lgs.152/06 Part III).

C0206
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Livestock effluents are an agronomical opportunity not yet fully exploited, even if easily available and rich in nutrients (Bietresato and Sartori, 2013); however they are chemically-physically inhomogeneous, unevenly distributed on lands, and economically worthless (Bietresato et al., 2012). Monitoring how and where slurries are spread could help the institutions to understand whether farmers need adequate information on the utility of using them properly as organic fertilizers.
Slurries have also an energetic potential if used for producing biogas. The actual production of South-Tyrol is more than 16 million cubic meters but almost half of them are produced in only 30 farms, which feed the digesters with the cattle effluents (Tis Innovation Park, 2011). This scenario can be surely improved if only having a greater knowledge concerning the distribution of sheds and digesters on the province.
Therefore, the necessity to perform a monitoring of the N-rate spread and, consequently, to conceive a system suitable for this purpose arises from several standpoints (environmental, legal, operational and management).

2.2 Aims of the research

The aim of this work is to propose an integrated system for monitoring the slurry's production and distribution and for automatically compiling field-activity registers, in accordance with current regulations. Analogous systems were recently experienced in other Italian regions, where specific research projects proposed solutions for intensive breeding (Mazzetto, Calcante, and Salomoni, 2009; Mazzetto, Calcante, Sacco, et al., 2009; Mazzetto et al., 2010; Sartori et al., 2010); this system fits also extensive alpine breeding and foresees tools for managing grazing systems through virtual fences (GNSS-equipped collars).

3 MATERIALS AND METHODS

To define a monitoring system, it is necessary to highlight:

- *requirements* and *technology/components* that the system must respectively satisfy and provide, limiting its complexity and enhancing its integration;
- *any aspects* related to the processing and security of the sensitive data collected.

The definition of these specifications has many practical implications and includes both managerial and technological innovations. A clear definition of the different types of animal wastes used in agriculture is firstly needed: unprocessed slurries (*direct use*) or slurries coming from anaerobic digesters (*indirect use*). According to the key-steps of the whole flow (slurry chain from animal to field), the monitoring system must consider each entity involved (collars; functional sites as sheds, tanks or digesters; tractors and slurry spreaders etc.), providing a general framework acting as a part of an integrated information system able to deal and combine all the relevant information achieved. The involved entities are part of the management control chain of the zootechnical effluents and will be organized in a multilevel network operating in accordance with a client-server logic (Mazzetto et al., 2010).
The proposed monitoring system is composed of three basic elements:

- *hardware devices*, for collecting and/or storing the data (sensors, data-loggers

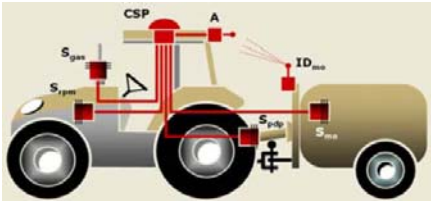
with geolocalization and communication capabilities, servers with storage units) and regulating valves and pumps on the slurry tankers (actuators) according to previously set prescription maps;
- a set of *computing and inferring procedures*, to obtain information in several tabular and graphical formats from the raw data achieved (Measured data→ Intelligible raw data→ Inferred data→ Information usable by an operator);
- *interfaces*, to enable the users the access and use of information in control activities related to management decision-making processes.

Three application scales were defined (Table 2), performing different tasks and managing different information (Pierce and Elliott, 2008; Mazzetto et al., 2010):
- at a *field level (Monitoring and Control System – MCS)*, on a single machine (e.g., slurry tanker, fertirrigation plant), on a farm installation (e.g., slurry collection pool; Figure 1) or on a cow's collar (for extensive breeding, thus enabling virtual fences tasks; Figure 1)→ data loggers, GNSS devices, remote transmitters (Wang et al., 2006), sensors (Mazzetto et al., 2012; Bietresato and Sartori, 2013), CAN-BUS/ISO-BUS interfaces, actuators (on valves, pumps);
- at a *farm level (Farm Information System – FIS),* in every dairy farm and also in arable farms placing their land at disposal for spreading slurry→ servers, remote transmitters/receivers, TCP-IP interfaces, farm-management software (Mazzetto et al., 2012);
- on a *territory (Territory Information System – TIS)*→ servers, remote transmitters/receivers, TCP-IP interfaces, territory-management software.

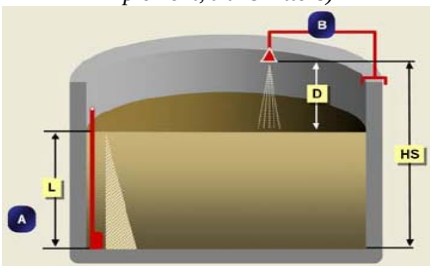
Table 2 – monitoring and controlling systems for slurries

System	Scale of operation	Requirements	Technology and components
Monitoring and Control System - MCS	*at a field level*, placed on a single machine (e.g., slurry tanker, fertirrigation plant) or on a farm installation (e.g., slurry collection pool) or on a cow's collar (only for extensive breeding)	• Acquiring and sending data related to the production of slurry by monitoring the storage facilities (*productive monitoring*) • Acquiring and sending data related to all the operations carried out by the spreading units (movements, spreading on the field; *operational monitoring*; Figure 1) • Acquiring and sending geographical data related to the position of cows in extensive breeding (*pasture monitoring*; Figure 1) • Actively controlling the spread quantities by regulating machines' valves and pumps (*site-specific farming*)	• Data acquisition units (data loggers) with temporary storage memories (Figure 1) • GNSS satellite devices • Remote transmitters (GPRS, Bluetooth devices, RFID) • Sensors (flow, level, total mass, nutrient content) • CAN-BUS/ISO-BUS interfaces • Actuators (on valves, pumps)

System	Scale of operation	Requirements	Technology and components
Farm Information System – FIS	*at a farm level*, positioned in every dairy farm and also in all non-zoo-technical farms that place their land at disposal for spreading slurry	• Filing all the operations carried out by the spreading units • Updating and filing the volumes of the effluents in the storage facilities (measured from machines and infrastructures' devices) • Collecting and updating the data related to the principal farm resources (land, machinery, workforce, buildings, etc.) • Monitoring events occurring in specific parcels (fields, pastures) by creating virtual fences • Generating documents for internal/external audits (summary reports, registration extracts, thematic maps)	• (Farm)servers equipped with storage units • Remote transmitters/receivers (GPRS) or TCP-IP interfaces for interconnecting FIS with MCSs and TIS • Farm management software with: o database of spreading units and slurry collection pools o GIS interface
Territory Information System – TIS	*on a territory*	• Managing all the principal data relating to a specific portion of the territory • Integrating all the archives concerning the spreading activities • Consulting and modifying any spreading restrictions or limitations associated with specific vulnerable areas • Updating the zoo-technical N levels • Generating documents for internal/external audits (summary reports, registration extracts, thematic maps)	• (Territorial) servers equipped with storage units • Remote transmitters/receivers (GPRS) or TCP-IP interface • Territory management software (StoreEyes®, TractorEyes®, Farm Configurator®) with: o database of farms, spreading units o GIS interface o inference engine



MCS for tractors and slurry tankers
(with GNSS, sensors on engine and implement, transmitters)



MCS for slurry collection pools
(two different solutions to detect the level)

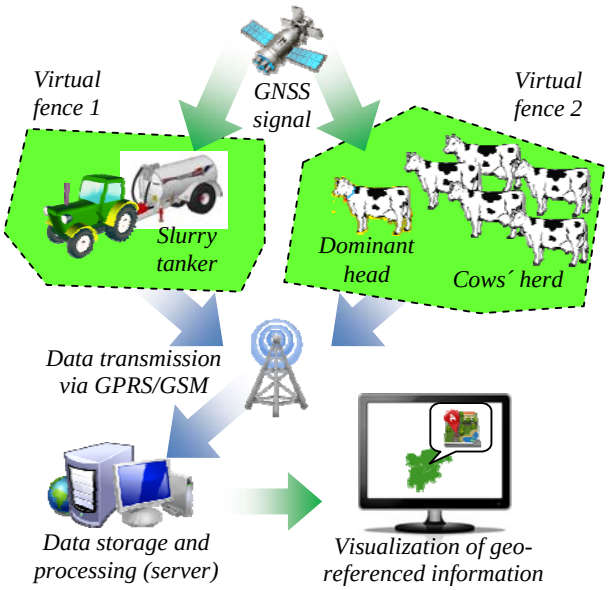


Figure 1 – (*left*) example of two MCS devices; (*right*) operational and pasture monitoring performed through the proposed system.

C0206
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4 DISCUSSION AND CONCLUSIONS

The above approach is expected to be applied on a set of pilot farms in South-Tyrol. Every distribution or storage unit should be provided with an independent MCS device, while each dominant head in grazing groups should be provided with a GNSS-collar enabling virtual-fences functions. Virtual fences will be used to enclose crop field but also pasture areas. This will permit to calculate the N-rate derived by the breeding, giving the farmer some indication for periodically changing the grazing areas according to a turnover logic. FIS acts as a terminal usable for consulting the system and managing the effluents according to TIS's assessment methods.
TIS processes the data from the farms, while integrating them with digital cartography; users can also query it and download raw data via wireless or cable connections. The kernel of TIS is an inferential engine able to recognise slurry productions and machines operations (loading/unloading events in slurry storages, transfer and spreading activities) through a series of conditional instructions on the collected data (e.g., vehicle speed, slurry electrical conductivity). The software interfaces provided by TIS are expected to be useful both for farmers and for local administrators for checking the status of the nitrogen spread in the territories under control and certifying the compliance of the spreading activities with the current environmental laws.
This architecture is very flexible: the system can manage also farm contractors and it is suitable for third-parties distribution; both FISs and TISs can generate many types of documents (summary reports, registration extracts, thematic maps).

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C0206
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C0206
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