Experimental Evaluation of Manure Evaporation in The Paddock for a Management Algorithm Development

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Abstract

The aims of this study was to evaluate the possibility of reducing the weight of manure in paddocks by natural evaporation according to an appropriate management plan. The weight of buffalo manure was recorded by an experimental platform equipped with load cells and installed within the paddock. The data was used for assessing the real evaporation of manure in situ. A model for predicting manure evaporation was developed by adapting a soil evapotranspiration model. On the basis of the model an optimal management strategy was established, which corresponds to minimizing the use of the scraper from the 100^{th} day of the year (DOY) to the 250^{th} DOY. This lead to a potential reduction in weight of the manure by 650 kg/m^2/year which corresponds to management cost reduction of about 30%. This approach is effective for reducing the bulkiness of buffalo manure for which the spreading costs per kg of nitrogen and the fuel needs for land application is very substantial considering its low nitrogen content of about 2 mg/m^3.

Key words: Manure management, Buffalo manure, Spreading cost.

1. INTRODUCTION

Globalization leads to availability of a lot of information, algorithms, and management techniques that can be used to increase agricultural production and to improve product quality. Buffalo husbandry is one of the major economic activities in the Campania region of Southern Italy. It is estimated that there are over 250,000 buffalo heads in the region. They are reared for production of Buffalo Mozzarella cheese, which is one of the major food products of the region, accounting for an estimated annual turnover of 400 million Euros (Infascelli et al., 2010). The intensive nature of the activity leads to the production of high quantities of manure, which pose an enormous management challenge in terms of costs, time needs, equipment and related environmental aspects. The current manure management approach employed to prevent non point source (NPS) pollution due to nitrogen is by using it as fertilizer (Infascelli et al., 2009). This approach needs a very complex manure management plan, involving storage in huge tanks during winter times followed by surface spreading or incorporation into the soil using specialized equipment. One of the problems related to the agronomic management of manure is nitrogen volatilization, mainly in the ammonia form, which can be as high as 68% of the total ammoniacal nitrogen (TAN), when surface spreading application method is used (Huijsmans et al., 2003). The problem of ammonia emissions is particularly important because agricultural ammonia emissions in Italy are considered among the highest in Europe (Clarisse et al., 2009). Moreover, a manure management plan that minimize nitrogen leaching is always preferred (Burton and Turner, 2003).

Campanile et al., (2010) analysed the nitrogen content of fresh buffalo manure taken in Campania Region. The findings suggests that the nitrogen content in buffalo manure is about 2 kg/m^3, that is about 50 % less than that for cattle. This could be explained by the difference in feeding regimes and differences in the physiology of the two species. Consequently, ammonia emission from buffalo manure is less than that of cattle manure. The low nitrogen concentration also means that costs for spreading have to be reconsidered. Results of our assessment show that using splash plate spreader to apply 10 m^3 would cost about 14.14 €. The complete cycle takes about 21 minutes with associated fuel consumption of 2.35 litres. However, the fuel consumption for immediate incorporation increased to 4.93 litres, but ammonia volatilization reduces considerably (Huijsmans et al., 2004, Osei et al., 2003, Provolo G, 2000 and Webb et al., 2010). So the effective nitrogen uptake in the soil per litre of fuel consumed is about 7.5 kg of nitrogen per litre of diesel.

Therefore, to evaluate the best buffalo manure management strategy, it is necessary to know the evolution of the manure volume while still in the paddock. Assuming the lower nitrogen content reported, it could be convenient to reduce management cost by minimising the use of the scraper during some periods in order to exploit natural evaporation of manure in situ. A prediction model of the manure evaporation in the paddock was developed . Data of the manure weight over an experimental platform installed in paddock was used to calibrate the model. The model was used to evaluate possible alternative strategies for the management of buffalo manure in the paddock.

2. MATERIALS AND METHODS

The study was carried out in farm located in Serre, about 30 km to the south of the City of Salerno. This farm was purposely selected since it is representative of a typical buffalo farm in the Campania Region in terms of livestock numbers and management practices. The buffalo manure and soil characteristics, crop and fertilization cycles, were examined.

2.1 BUFFALO MANURE CARACHTERISTIC

For the present study, we used results of Buffalo manure nutrient content determined by researchers in the Department of Agricultural Engineering of University of Naples Federico II. The study was funded by Campania Region through a project named “Actions for an integrated strategy for the management of some biomass produced in agriculture”. Mean concentration of total nitrogen and ortphosphate determined from 200 samples, are reported in Table 1.

TABLE 1: Average total nitrogen and orthophosphates content in buffalo manure

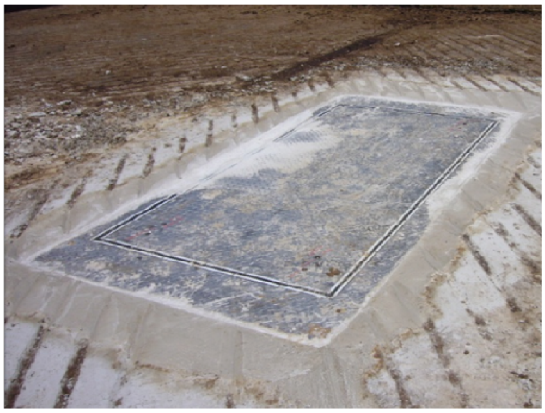
	mg/l
total N	1960
PO_4	995

2.2 MANURE INSTRUMENTATION SYSTEMS

Manure evaporation from the paddock was evaluated basing on measurements of the weight of manure that accumulated over a platform equipped with load cells and installed in the floor of the paddock. The platform was built of stainless steel AISI 316, knurled and placed to flush with the floor, and supported by four load cells Figure 1.a). The assembly was installed in the paddock under normal operating condition. The system was provided with an overload protection against weights greater than 500 kg. This situation can arise in case buffaloes or tractors moves on the platform. The combined error of each load cell is less than 0.02 % when loaded with a 500 kg nominal load, that is an expected resolution of 0.1 kg per cell. The data acquisition was made every 15 minutes by a CR10X data logger manufactured by Campbell Scientific. An agro meteorological station was also installed within the farm premises to collect data of the microclimate of the study area. It was equipped with a radiometer, relative humidity and temperature sensors, tipping bucket rain gauge and anemometer, all connected to the data logger. The level of manure sludge collected in the storage tank was measured using a stream gauge, while the quantity of water used for milking and washing was measured using a volumetric counter.

The weight recorded by the platform were filtered to remove extra range values caused by buffalo or tractors crossing over it. Data of manure weight considered for analysis were those recorded by the platform in the first quarter hour after midnight of each day. For rainfall the total amount per day was considered, and mean daily values were considered for all the other meteorological data.

a)



b)

FIGURE 1: Instrument for measuring manure weight a) arrangement of load cell; b) complete assembly of the platform

2.3 PHISICAL MODEL FOR THE EVAPORATION

The main assumption for developing the model is that manure evaporation from the paddock is related to the same parameters that controls both evapotranspiration from bare soil and evaporation from a wet surface. The predictive evaporation model developed by Tombesi Lauciani (Leone, 2004) was used because it expressly considers relative humidity (RH), and was found to be suitable for estimating ET in Southern Italy. The Tombesi-Lauciani model is given by Equation 1;

$$EV_{TL} = a \times T^{0,91} \times 10^{-0,8 \times RH} \times F \quad , \qquad (1)$$

where, EV_{TL} is the evapotranspiration in mm/day, a is an environmental constant equal to 1.13, T is the average daily temperature in ℃, RH is the mean daily relative humidity, F is an astronomy factor Thornthwaite. Corrective values for different months of the year are reported in Table 2.

TABLE 2: Astronomy corrective values Thornthwaite

Lat.	Months											
North	J	F	M	A	M	G	L	A	S	O	N	D
40°	0,84	0,83	1,03	1,11	1,24	1,25	1,27	1,18	1,04	0,96	0,83	0,81

It was assumed that the manure evaporation from the paddock is equal to EV_{TL} multiplied for a constant K. The daily manure production per head (A_d) was assumed to be 40 kg, 20 kg of which was assumed to be evenly distributed over the paddock area and other 20 kg in cubicles and feeding area. The paddock surface area per buffalo head is about 5 m², so the average daily manure generation per head is about 4 kg/m². The total amount of manure in the paddock is given by Equation (2):

$$AW_i = AW_{i-1} - K \cdot EV_{TL} + A_d \qquad (2)$$

where, AW_i is the manure weight measured on day *i*. The initial weight at the beginning of measurement, AW_0 is the offset of the load cell. Values of *K* was evaluated through the statistical analyses made using the software CoStat and Microsoft Excel.

3. RESULTS AND DISCUSSION

The value of the coefficient, K was found to be 0.42, and the corresponding coefficient of determination, R^2, was 0.85. The resulting model is presented by Equation. (3):

$$AW_i = AW_{i-1} - 0.42 \cdot EV_{TL} + 4 \text{ (kg/m}^2\text{/d)} \quad (3)$$

Figure 2 shows plots of the predictive model given by Equation (3) compared to the filtered data. The spikes observed in the measured manure weight can be explained by accumulation of manure over the platform caused by physical movements of manure by the animals.

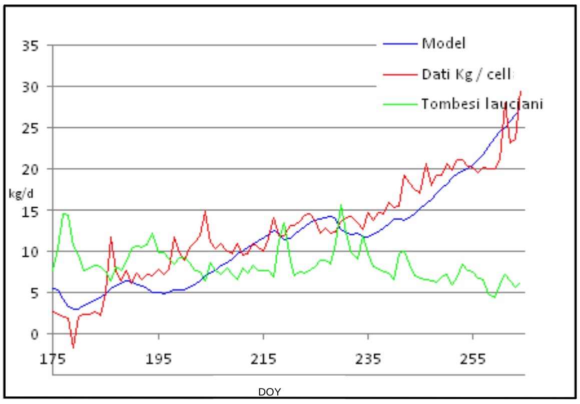


FIGURE 2: Data measured by the experimental platform scale compared to manure weight predicted by the model

Historical meteorological series of the nearest weather station was used to predict the manure weight in the paddock. Figure 3 shows predicted values of manure weight that accumulated in the paddock without being scraped off. Daily rainfall data of the nearest weather station, with mean annual values of about 800 mm/year, were added to the daily manure weight. The model was executed over a period of five years from 2006 to 2010.

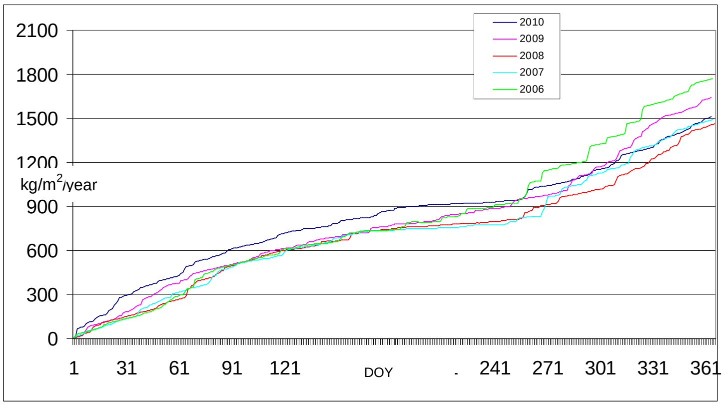


FIGURE 3: Manure weight prediction without using the scraper added to the daily rainfall of the nearest weather station

Figure 4 shows a comparison between two different management strategies. The series “scrapers turned off” was developed from the cumulative manure weight in the storage tank without scrapping manure from the paddock, while “scrapers turned on” is when scrapping is carried out. Each data represent the average cumulative value over a period of five years. From this simulation it possible to deduce that there is a potential reduction in manure weight of about 650 kg/m^2/year, that is, about the 30% of the yearly manure weight. Obviously this management strategy is not suitable from the point of view of the animal health and the ammonia emissions. The optimal management strategy correspond to operating the scrapers in the period between the two inflection points of the graph, that is operating manure scrapers from 1st to 100th DOY, minimizing the use of scrapers from 100th to 250th DOY and operating the scrapers again from 250th to 365th DOY. It reiterates that the model requires long series of experimental data for verification and calibration, but the results seem logical.

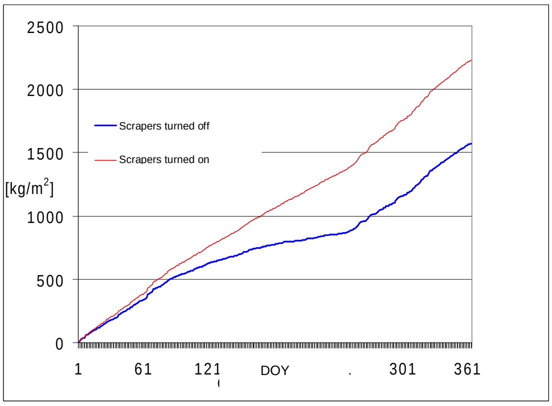


FIGURA 4: Prediction of the weight manure in the storage tank under two different manure management regimes.

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4. CONCLUSIONS

Conclusions of the present study work are limited to the case of manure with low nitrogen content as in the case of the buffalo manure with nitrogen content of about 2 mg/m^3. If the actual Nitrogen content of buffalo manure is related to the costs and times for spreading activities the balance is not positive. Moreover the manure storing period is very long compared to the agronomic schedule during which is possible to go to the land.

Basing on the prediction model developed, it would be possible to reduce about 650 kg/m^2 of manure weight through evaporation, that is about the 30% of the total amount. From this first set of experimental data it was deduced that the period used to improve the model and forecasts range from 100th to 250th DOY. The algorithms generated is easy to apply and conceptually robust. Therefore, management decisions with this algorithm are not likely to be contradicted by improvements in the determination of the coefficients. The algorithm, which is briefly summarized as daily rainfall, which is subtracted from a fraction of potential evapotranspiration K, calculated with Tombesi Lauciani, is physically rigorous. Further research will focus on the coefficient K, but the trends do not change and therefore the decision-making scenes remains relevant.

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