ASSESSMENT OF FARM AND MANURE MANAGEMENT IN SWITZERLAND BY MEANS OF REPRESENTATIVE STRATIFIED SURVEYS

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1 INTRODUCTION

Agricultural activity is recognised as the major contributor of ammonia (NH_3) emissions to the atmosphere. NH_3 emissions cause serious negative environmental effects such as acidification and eutrophication of natural ecosystems and contribute substantially to the formation of secondary atmospheric particulates. In 1999, NH_3 was therefore included as an air pollutant in the Gothenburg Protocol aiming at reducing acidification, eutrophication and ground-level ozone, within the framework of the Convention on Long-range Transboundary Air Pollution. Member countries have to report on the development of NH_3 emissions by means of emission inventories. Farm and manure management are key parameters for modelling emissions. In most cases, calculations are based on estimates and assumptions of national experts, as statistical information on such parameters is scarce. This does not allow for detecting small changes of emissions over periods of a few years on a national scale and constrains their accurate regional differentiation.

In order to obtain an accurate resolution of NH_3 emissions in time and space, thorough information on farm and manure management is required. In this paper, we introduce a method to collect data on farm and manure management by means of surveys, provide an evaluation of the quality of the data derived from the responses and present an overview on some important parameters of farm and manure management as well as their evolution between 1990 and 2007 for Switzerland.

2 MATERIALS AND METHODS

Detailed representative investigations on farm and manure management were conducted in Switzerland by means of mail surveys for 2002 and 2007, respectively (Menzi et al., 2005; Reidy et al., 2008). A stratified random sample of 3877 and 6702 farms was used in the survey of 2002 and 2007, respectively. This number represented 7.0% and 10.7% of the Swiss farms in 2002 and 2007, respectively, which met the following defined minimum farm size criteria with respect to surface area and livestock number: agricultural surface area higher than 10 ha, surface of vegetables, fruit or vineyards higher than 1 ha or more than 6 dairy cows, 40 other types of cattle, 20 horses, 50 sheep or goats, 25 sows, 200 other types of pigs present on a farm. 12353 (2002) and 10774 (2007) farms, respectively, which did not meet these criteria were excluded from the survey representing 18 % (2002) and 17% (2007) of the total number of Swiss farms.

Farm classes were defined for the stratification accounting for five farm types (arable farms, cattle farms, pig or poultry farms, mixed farms, other farms), three geographical regions and three altitude zones. The minimum number of datasets required for each farm class was set to 20. Assuming an average return rate of completed questionnaires being at 40%, the minimum sample size of 50 farms per farm class was determined.

The selected farms received a 12-page questionnaire containing around 300 questions on major farm and manure management parameters regarding housing systems, feeding, manure storage and application which are considered as relevant for NH_3 emissions. The questionnaire was designed to allow straightforward completion by farmers within about half an hour and automated data registration of completed questionnaires. Data of the survey was complemented with existing, routinely collected livestock numbers and crop surface areas. Parallel to sending

out the questionnaire to the farms, an information campaign on the project was launched in agricultural journals. As an incentive to participate, a prize lottery for the participating farmers was organised.

Within the survey, a return rate of 50% and 48% of the distributed questionnaires was obtained yielding 1950 and 3133 datasets for 2002 and 2007, respectively. All data was then transferred in an anonymous form to a database, which was used for all further analyses. Tests regarding plausibility and correction were established for missing and ambiguous entries in the questionnaire. Missing or ambiguous entries were replaced by values occurring predominantly or deeming most plausible (e.g. aviary housing systems with manure belts for farms with 500 laying hens or more). Parameters with a significant influence on emissions (e.g. coverage of slurry stores, manure spreading) were replaced by values that would result in highest emission (e.g. for missing information on manure spreading techniques, broadcast spreading would be used). A more detailed description is given in Anonymous (2010). A concerted evaluation of the returned questionnaires of 2007 with respect to missing or ambiguous entries was carried out. It included the most important entries of housing systems, exercise yards, grazing, storage and application of manure aiming at assessing the reliability of the questionnaire entries and thus the robustness of the survey results.

The evaluation of the obtained data on farm and manure management for 2002 and 2007 were compared with the situation in 1990 and 1995. For the latter, information from the literature and expert judgments were used.

3 RESULTS AND DISCUSSION

3.1 Robustness of the survey results

The average portion of missing entries ranged between 10 and 20% for most of the questions on housing systems, exercise yards and grazing. The percentage of ambiguous entries for questions allowing for multiple entries reached up to 50 % while it was clearly below 10 % for questions requiring single entries. Missing entries occurred more frequently for respondents operating small farms while the opposite applied to ambiguous entries for questions with multiple entries. This is probably due to the higher occurrence of several systems (e.g. different housings systems) for big farms. The sum of average portions for missing and ambiguous entries in the questionnaire was 15%. Similar numbers applied to storage and application of manure. In summary, the sum of average portions for missing and ambiguous entries of the entire questionnaire was ca. 10 %. This can be considered as moderate. The uncertainty generated thereby and its impact for the resulting data on farm and manure management is likely to be limited.

3.2 Evolution of farm and manure management between 1990 and 2007

N-excretion dairy cows: The main influencing factors for N-excretion emerged as follows. The milk yield used as an indicator for the N-output increased from 4940 to 6790 kg per head and year between 1990 and 2007. Feeds influencing excretion of nitrogen (concentrates, hay, maize silage, maize pellets) were used more frequently. In 2007, the daily amount of concentrates used per cow was lower in the mountain area by 27% and by 9% in summer and winter, respectively, compared to the valley zone. Pigs: Due to a progress in genetic selection the standard N-output was reduced by approx. 15 % between 1990 and 2007. As compared to the data of Kessler et al. (1994) for 1990, the average crude protein content of the rations declined by 12%, 11%, 4% and 14% for dry sows, nursing sows, weaned piglets and fattening pigs, respectively, until 2007. The resulting average crude protein contents of 148 g/kg, 161 g/kg, 169 g/kg and 160 g/kg for dry sows, nursing sows, weaned piglets and fattening pigs, respectively, as calculated for 2007 comply well with the study of Bracher and Spring (2010).

Grazing: The percentage of grazing animals and the duration of the grazing period were extended between 1990 and 2007. For dairy cattle, the portion of grazing animals increased from about 67% to 98%. For other cattle, the trends were less pronounced. In the mountain area, the yearly duration of grazing was lower by 5% for dairy cows, by 9% for heifers and by 27% for suckling cows, respectively, compared to the valley zone.

Housings and exercise yards: Between 1990 and 2007, tied housing systems were continuously replaced by loose housing systems. The portion kept in loose housing systems increased from 6 % to 41%, for dairy cows, from 29% to 60% for heifers and from 71% to 87% for suckling cows. Beef cattle exhibited an almost unchanged level of 95% for animals kept in loose housing systems (Figure 1). In 2007 the percentage of dairy cows kept in loose housing systems was much higher in the valley zone (49%) compared to the mountain area (26%). In the mid 1990s, statutory regulations regarding animal welfare were implemented which required for animal movement outside of the housings over the whole year. As a consequence, exercise yards were established, especially for cattle

kept in tied housing systems. Concomitantly, the new agricultural policy and the related direct payments program promoted animal-friendly production systems on the farms. Between 1990 and 2007, the proportion of cattle having access to exercise yards strongly increased in all areas. In the mountain zone, the yearly duration dairy cows accessed an exercise yard was lower by 35% for dairy cows compared to the valley zone in 2007.

The trend towards animal-friendly housing systems was similar for pigs as for cattle. Conventional housings with partly or fully slatted one-area pens were largely replaced by multi-area pens with littered areas or combined lying and feeding cubicles connected to outside yards (Figure 2). They reached an occurrence of 82 % for dry sows and 63% for fattening pigs by 2007. On the other hand, conventional systems with partly slatted floors without outside yards were still used for approximately 80% of the nursing sows and weaned piglets. For growing hens and laying hens, aviary housing systems with manure belts, often combined with a veranda and/or a free range were increasingly operated and reached a percentage of about 80 % by 2007 (data not shown). This trend went in parallel with a decline of deep litter and deep pit systems. The trends regarding the evolution of housing systems as characterized above are largely in line with the statistical numbers on promotion of animal-friendly conditions for livestock (Federal Office for Agriculture, 2009).

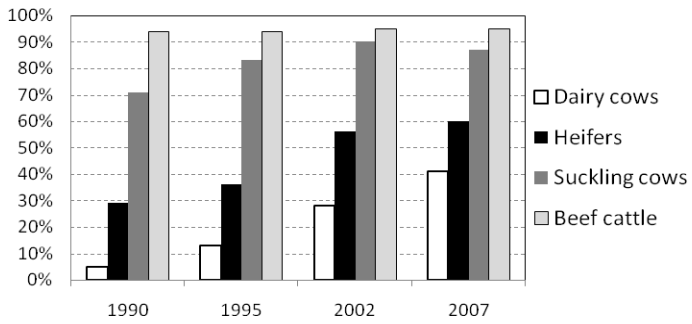

FIGURE 1 **Evolution of the percentage of cattle kept in loose housing systems between 1990 and 2007**

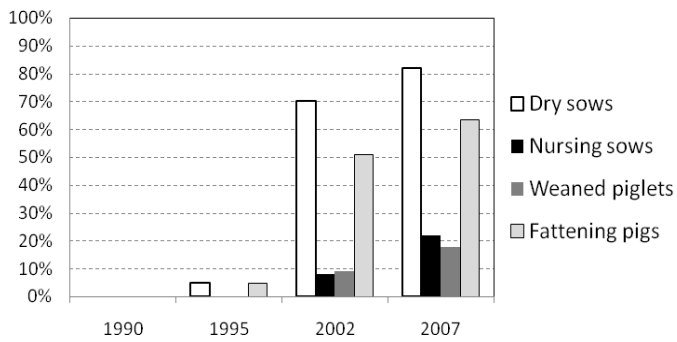

FIGURE 2 **Evolution of the percentage of pigs kept in multi-area pens with littered areas or combined lying and feeding cubicles between 1990 and 2007**

The total volume of slurry stores was 12.4×10^6 m^3 (Meyre et al., 2000) and increased to 17.1×10^6 m^3 by 2007 (Table 1). This growth was due to stricter the enforcement of minimal storage capacities. Between 2002 and 2007, a slight decrease of the storage volume was observed. This might reflect a real decrease as a result of abandonments of farms (decline of number of farms: ca. 3% per year) or to a bias between the samples of the two surveys. The percentage of uncovered storages increased from 13% to 17%.

The proportion of slurry applied with trailing hoses increased from 8% in 2002 to 12% in 2007. Trailing shoes and slurry injection are still of minor importance in Switzerland. Soft measures such as spreading of manure in the evening are increasingly applied. Incorporation of solid manure after application is also emerging and the time period between spreading and incorporation tend to become shorter. These trends are likely to be the result of growing awareness of the farmers and of recent voluntary programs aiming at reducing gaseous nitrogen losses.

TABLE 1 **Percentage of slurry storage coverings and evolution of total storage volume from 1990 to 2007**

	1990	1995	2002	2007
Uncovered	13%	13%	17%	17%
Solid cover	87%	87%	71%	69%
Perforated cover	0%	0%	12%	13%
Tent, floating cover	0%	0%	0%	0%
Total volume relative to volume of 1990	100%	120%	146%	139%

4 CONCLUSIONS

The ability to reliably characterize farm and manure management is crucial for assessing the evolution of ammonia emissions under the Gothenburg protocol. The approach of the survey on farm and manure management based on (i) a stratified sample, (ii) a coherent questionnaire allowing straightforward and rapid completion by farmers and (iii) an adapted procedure for plausibility tests and corrections yielded plausible data on farm and manure management.

Major factors for the evolution of farm and manure management were statutory regulations regarding the new agricultural policy and the related direct payments program promoting ecological benefits and animal-friendly management. Consequently, grazing, loose housing systems and exercise yards for cattle, multi-area pens connected to outside yards for pigs and aviary housing systems with manure belts combined with a veranda and/or a free range for growing hens and laying hens were enhanced. Economical constraints contributed to the emerging of grazing cattle and loose housing systems. Statutory orders regarding the protection of surface waters and growing awareness of the farmers as well as recent voluntary programs aiming at reducing gaseous nitrogen losses after application were major influencing factors for increasing slurry store volumes and the use of low emission spreading techniques and practices. The trends observed in this study are largely confirmed by other investigations.

It can thus be concluded that a survey carried out regularly as presented here provides a reliable base for the calculation of ammonia emissions from agriculture and for an accurate resolution of NH_3 emissions in time and space. However, the implementation of the survey is laborious. Once established, the method can be periodically applied thereby compensating the initial expenditures.

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