Historical development of ammonia emissions from agriculture in Switzerland over the past 150 years

Klossner Maria, Thomas Kupper, Beat Reidy, Menzi Harald
Berne University of Applied Science, School of Agricultural, Forestry and Food Science (HAFL), CH-3052 Zollikofen, Switzerland
*Corresponding author: harald.menzi@bfh.ch

Abstract
Reliable data about the historical development of ammonia (NH_3) emissions from agriculture is needed for a better understanding of the development of the environmental pressure resulting from nitrogen (N) deposition and for a meaningful comparison of agricultural emissions with other anthropogenic emissions. The aim of this study was a historical analysis of agricultural ammonia emissions back to around 1870. This analysis was based on a detailed review of farming practice and statistical information. Emissions were modelled with the N flow model Agrammon. Emissions increased by around a factor 3 (provisional rough estimate at the time of submission of this manuscript) between 1866 and 1990. Since 1990 they decreased by 16%. The changes were due changes in faming practice and productivity as well as the development of animal numbers.

Introduction

Reliable data about the historical development of ammonia (NH_3) emissions from agriculture is needed for a better understanding of the development of the environmental pressure resulting from nitrogen (N) deposition and for a meaningful comparison of agricultural emissions with other anthropogenic emissions. Such comparisons are often done based on a multiplication of animal numbers with current emission factors and for the past few decades only (e.g. Menzi et al. 1996, Stadelmann et al. 1998). The reliability of such comparisons is very limited because constant changes in agricultural management practice will lead to significant changes of the multitude of factors that influence the complex emission processes. Therefore, for a reliable modelling of the historical development of emissions, detailed information on livestock production and manure management practice should be taken into account, e.g. feeding practice, animal performance, grazing, housing and manure collection systems, manure utilisation, fertilising practice. The aim of our study was to perform such a historical analysis of agricultural ammonia emissions based on a detailed review of farming practice and using modern N flow emission modelling.

Material and Methods

The major steps of the project consisted of 1) the compilation of statistical data on the development of livestock numbers, 2) a detailed review of different forms of publications on livestock production and manure management practice, 3) an assessment of the development of nitrogen (N) excretions from different livestock categories, 4) model calculations on the development of ammonia (NH_3) emissions, 5) interpretation of the results. The historical studies went back to about 1860. Livestock and manure management data was compiled for six distinct periods: 1866-1900, 1900-1920, 1920-1940, 1940-1966, 1966-1978, 1978-1990. In these periods, emission calculations will prospectively be done for the follow intervals: 1866-1906 every 20 years, 1916-1946 every 5 years, 1946-1966 every 10 years, 1973-1988 every 5 years. From 1990 onwards, the existing emission inventories will be used (Kupper et al. 2012).

Livestock numbers

For the development of animal numbers the data compiled by Spiess (personal communication) could be used. The data was based on statistics of the Federal Office of Statistics and the Swiss Farmers Union as well as on Brugger (1968).

Review on livestock production and manure management practice

A multitude of historical sources was consulted, especially publications for farmers about good management practice (e.g. the “farmers calendar” Wirzkalender) and extensive reviews of agricultural production systems (e.g. Brugger 1978, 1985). They were mined for a broad range of relevant information about livestock and manure management such as livestock numbers, livestock weight and production parameters, typical rations, grazing, housing types and manure management systems, mineral fertilizer use etc.

Assessment of the development N excretions from different livestock categories

Originally it was planned to define typical rations for every livestock category and historical period. However, it turned out that this was not realistic because information on the amount and content of different feeds was insufficient. For the major livestock categories recommendations about the daily protein requirements were therefore used (mainly cattle, pigs, sheep; Wirzkalender different years). Partially these recommendations differentiate between basic requirements and requirements for milk yield or between different production stages (e.g. different stages of pig fattening or gestating and nursing sows). For the 1980is the N excretions derived from this data was compared to the corresponding excretions in the fertiliser requirements (Landwirtschaftliche Forschungsanstalten, 1994; Agroscope, 2009) to assure that the old and the new emission calculations are comparable. For dairy cows the comparison showed that the linear correction for N excretions according to the milk yield, suggested by Agroscope (2009) are well comparable back to the 1860ies. The milk yield and the linear correction were therefore used for all calculation periods.

Animal numbers for each livestock category and excretions per animal place per year were multiplied to get the total N excretions.

Model calculations on the development of ammonia emissions

For emission calculations the model Agrammon was used (Kupper et al., 2010). Agrammon is an N flow model. Emission factors in per-cent of total ammoniacal N (TAN) are included for housing, manure storage, manure application and for each livestock category. All factors influencing emissions are considered in the form of correction factors. Emissions from mineral fertilisers and agricultural land are also considered. For our calculations, the Agrammon version for regional calculations was used.

Interpretation of the results

At the time of submission of this contribution calculations were still in full progress. Only very limited and preliminary results can therefore be presented here.

Selected preliminary results

Livestock numbers and production intensity

With respect to the most important animal categories, the livestock numbers for dairy cows and fattening pigs almost steadily increased until the seventies of the last century (Figure 1), with the exception of a slight reduction during the Second World War. This reduction was due to the limited availability of concentrate and special policy measures. Between 1900 and the maximum around 1980 the increase was approximately 32% for dairy cows and 227% for fattening pigs. Compared to the dairy cow herd, the development pattern for fattening pigs was much more pronounced from the end of the Second World War until 1980: +177% and +11% for fattening pigs and dairy cows, respectively. Since the historical maximum of livestock numbers in the seventies, numbers for both animal categories are decreasing. A different pattern could be observed for horses. From 1866 until the Second World War the number of horses increased steadily. Thereafter horse numbers declined drastically, primarily because of the rapid and wide spread introduction of tractors and power engines during the second half of the last century. Between 1980 and 2000 animal numbers decreased quite drastically for dairy cattle and pigs.

The biggest change in production systems could be observed between 1950 and 1980 with a rapid increase in the production intensity. Within this period, for example, the average milk yield per dairy cow almost doubled from 3000 to 6000 kg per cow. The increase in production intensity had strong effects on animal performance, feed rations, mineral fertilizer use and the appreciation of the nutrient value of manure. An impressive illustration of this is the dramatic increase in mineral fertilizer use, in the use between 1950 and 1980, of mineral nitrogen, phosphorus and potassium fertilizers, which was +711%, +79% and +244% for nitrogen, phosphorus and potassium, respectively.

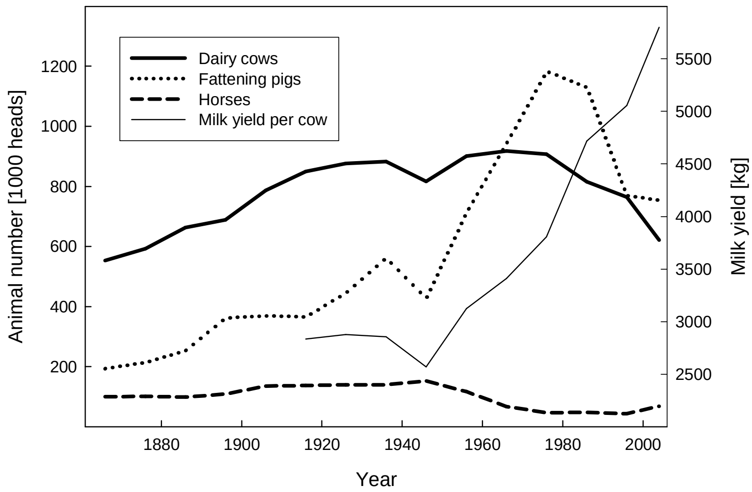

Figure 1. Development of dairy cow and fattening pig numbers from 1866 to 2000 in Switzerland. Average milk yield per dairy cow is from 1916 to 2000.

Nitrogen flows

For the development of N flows we can exemplarily look at N excretions of cows and fattening pigs (Figure 2). Except for war years, there was a more or less steady increase. Between 1866 and 1980 N excretions increased by about 230% for cows and by about 850% for fattening pigs. While this increase was predominantly due to the increase in performance (milk yield) for dairy cows, it was mainly due to increasing animal numbers for fattening pigs.

The biggest growth was between 1950 and 1980, about +65% for cows and about +135% for fattening pigs. During this period both the number of animals and the production per animal increased strongly. For fattening pigs the change from traditional production in small units and based on local resources and intensive production largely based on concentrate mainly took place between 1930 and 1960.

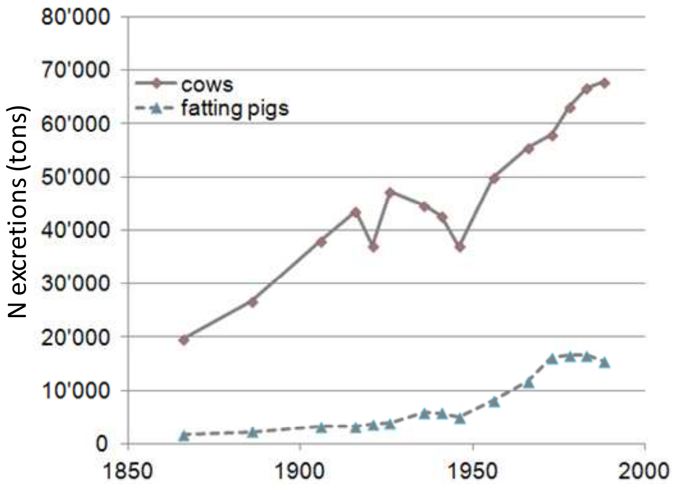

Figure 2. Development of N excretions from dairy cows and pigs (sows, piglets and fattening pigs) in Switzerland from 1866 to 1988 (t per Year)

Prospective estimate of increase of ammonia emissions

If we consider that dairy cattle (dairy cows and heifers) and pigs were responsible for around 80% of the NH_3 emissions from livestock and manure management in 2007 (Kupper et al. 2010; in 1990 close to 90%) and that N excretions of dairy cows plus pigs increased by nearly a factor 4 between 1866 and 1980, we can prospectively estimate that total NH_3 emissions from Swiss agriculture increased by around a factor 3 during the same period of time or by a factor between 2.5 and between 1866 and today.

The development of emissions since 1990 can be obtained from the newest inventory calculations (Kupper et al., 2012). While total NH_3 emissions decreased by 13%, the reduction was 16% for agricultural emissions. Thus, the share of agricultural emissions relative to the total emissions declined from 94% to 92%.

Difficulties

One of the greatest difficulties during the review study and the compilation of the input data on production technique for the calculation of N excretion and NH_3 emission was the evaluation how far the information was based on prevalent farming practice and how far it mainly reflected good practice as described in historical technical documents. Expert judgement and "brave estimates" often were important elements of this evaluation. However, the analysis of different sources and time series were essential aids in this process. Furthermore, it was assuasive to realise that most assumption only have a quite negligible influence on the total result.

Conclusion and perspectives

The study shows that NH_3 emissions from Swiss agriculture strongly increased until about 1990 and could since be moderately reduced. Changes were due to increasing livestock numbers, a strong increase in productivity and different changes in farming practice.

Even though the project was initiated in the framework of ammonia emission inventory work, the potential use of the information goes far beyond. It will help to create a better understanding of the evolution of current farming and manure management systems, and to assess the development of gaseous emissions, as well as other negative environmental aspects of intensive agricultural systems.

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