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# THE SPATIAL DISTRIBUTION OF AMMONIA EMISSIONS IN GREAT BRITAIN FOR 1969 AND 1988 ASSESSED USING GIS TECHNIQUES

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**Abstract** - Maps of ammonia ($NH_3$) emissions are a key input for models describing the atmospheric transport and deposition of $NH_3$. An important question is whether emissions have changed over recent decades. There is evidence that total emissions have increased, largely since 1950, but up until now no attempt has been published to quantify the historical changes in spatial distribution of $NH_3$ emissions for Great Britain. The present paper shows how livestock numbers and crop areas have changed between 1969 and 1988. Using this information in 5 km grid form, together with information on N fertilizer use and livestock emissions, preliminary $NH_3$ emission maps have been constructed for 1969 and 1988. The results show substantial changes in the sources and patterns of $NH_3$ emission, related to changing agricultural policies and practice. In particular, there is an increased spatial variation in the emissions in 1988, probably due to larger farm sizes, however, there is currently significant uncertainty in the total magnitude of $NH_3$ emissions for 1969, due to differences in N input to livestock systems.

## 1. Introduction

The regional and national distribution of $NH_3$ emission estimates is of great interest for atmospheric transport modelling and assessing the effects of $NH_3$ deposition. In principle, measurements of $NH_3$ concentrations would be the best approach to quantify dry deposition to ecosystems, for comparison with maps of critical loads (e.g. INDITE 1994). However, the extreme spatial variability of $NH_3$ emissions and air concentrations would require a very large number of monitoring stations. On a national scale, gridded $NH_3$ emission inventories, together with application of atmospheric transport models, therefore provide essential tools to quantify the distribution of $NH_3$ deposition.

The spatial distribution of $NH_3$ emissions in the UK was estimated first by ApSimon *et al.* (1987) at a 10 km grid for England and Wales, and has been estimated more recently on a 5 km grid for GB by Eager (1992) and Sutton *et al.* (1995). The latter study provided $NH_3$ emissions for 1988, however effects of nitrogen deposition occur over decades, and the magnitude of past emissions and their distribution are also relevant. The present paper addresses the question of changes in the pattern of $NH_3$ emissions between 1969 and 1988. It integrates the agricultural emission mapping of Eager (1992) with emissions from non-agricultural sources and the most recent official emission factors (DOE 1995) on a 5 km grid for Great Britain.

**Table 1:** Total $NH_3$ emissions in the UK (1993) according to DOE(1995) and equivalent emission factors.

| Source category | livestock (thousands) | total emissions (Gg $NH_3$ $yr^{-1}$) | emission factor (kg $NH_3$ $animal^{-1}$ $yr^{-1}$) |
|---|---|---|---|
| Cattle & calves | 11729.0 | 160 | 13.64 |
| Pigs | 7753.8 | 30 | 3.87 |
| Sheep & lambs | 43901.0 | 20 | 0.46 |
| Fowls | 5453.0 | 30 | 0.23 |
| Tillage & cut grass | - | 40 | - |
| Non-agric. emissions | - | 40 | - |
| Total emissions | - | 320 | - |

## 2. Methods

The main data source for spatially disaggregating $NH_3$ emissions in Britain is the June Agricultural Parish Census of MAFF. Using this information, agricultural emissions were scaled by animal numbers and crop areas, as summarized by MAFF (1973, 1990). These parish data were used in a 5 km grid format according to the reaggregation of Data Library, University of Edinburgh (Hotson 1988). Livestock emissions were scaled by emission factors per animal, and crop emissions derived information on average N application rates to crops (Boyd 1966, Church 1974, Dyer *et al.* 1989) together with an average fractional loss of applied N as $NH_3$.

Several estimates of $NH_3$ emissions in the UK have been provided recently (Sutton *et al.* 1995, Pain *et al.* 1995, pers. comm., ApSimon *et al.* 1995, *pers. comm.*). In the present study, equivalent $NH_3$ emission factors were derived from the official DOE figures (Table 1).

Non-agricultural sources were largely distributed by human population. The derived emission factors were used to scale the spatial distribution of $NH_3$ emissions according to 1969 and 1988 distribution. For this paper, the average 1993 emission factors for livestock (Table 1) were used unchanged for the 1969 and 1988 inventories, which is a signifcant source of uncertainty for the 1969 estimates. In contrast, the crop emissions for each year were calculated using data from the Survey of Fertilizer Practicefor the appropriate years (Boyd 1966, Church 1974, Dyer *et al.* 1989). Each of the components was implemented in the GIS system ARC/INFO 6.1 to provide the mapped distribution of emissions.

## 4. Results and discussion

The figures in Table 1 show that livestock agriculture represents by far the largest source of $NH_3$ in Great Britain. Hence changes in livestock numbers and distribution will be the main factors affecting the pattern of $NH_3$ emissions between 1969 and 1988. Changes in the total numbers and demographic structure of livestock between these years are shown in Table 2. The figures indicate that, with the exception of sheep, only relatively small changes in total numbers of livestock have occurred. However, there have been substantial changes in the demographic structure of each of the animal types. For example, there has been a decrease in the fraction of dairy cattle since 1969. This can be related the introduction of milk quotas (1984). Such changes in policy will have affected $NH_3$ emissions per animal because of the different N excretion from different animal sub-classes.

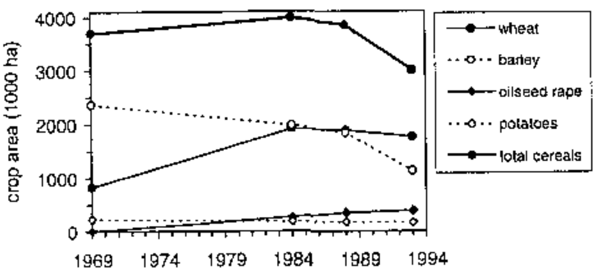


**Figure 1:** Changes in crop area in Great Britain between 1969 and 1993. Derived from MAFF (1973,1994).

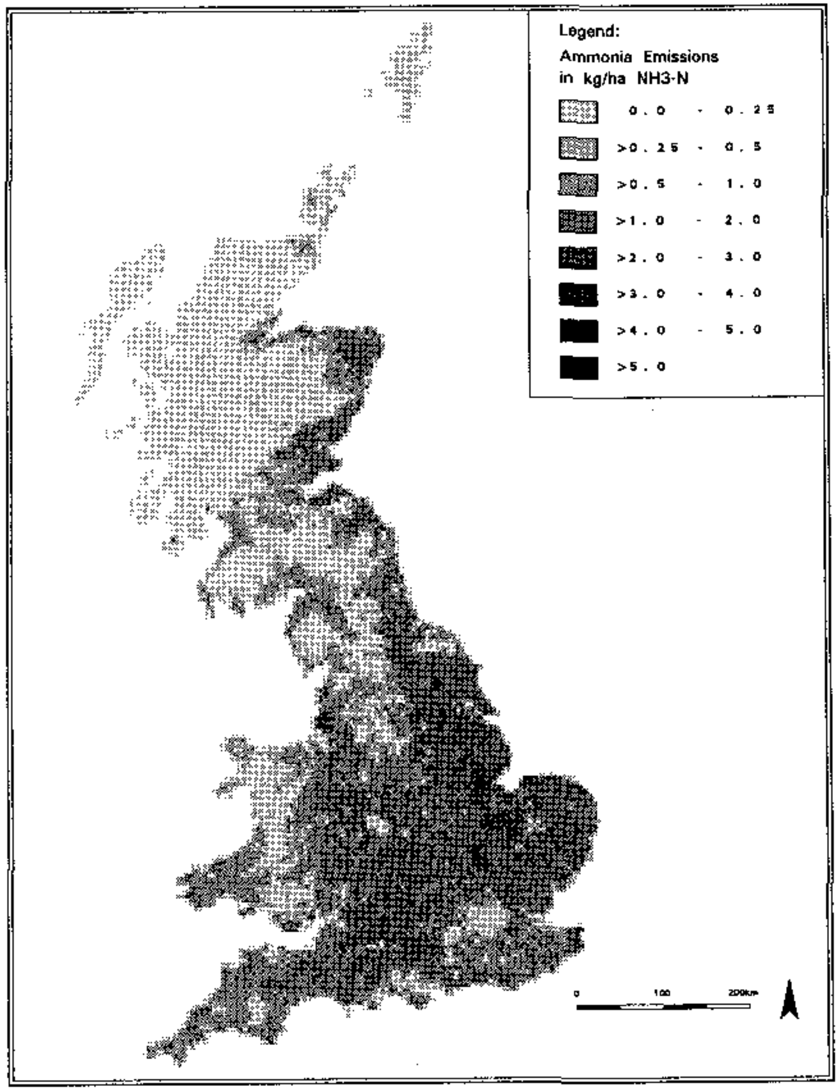


**Figure 2**. Ammonia emissions from fertiliser application and crops for 1969.

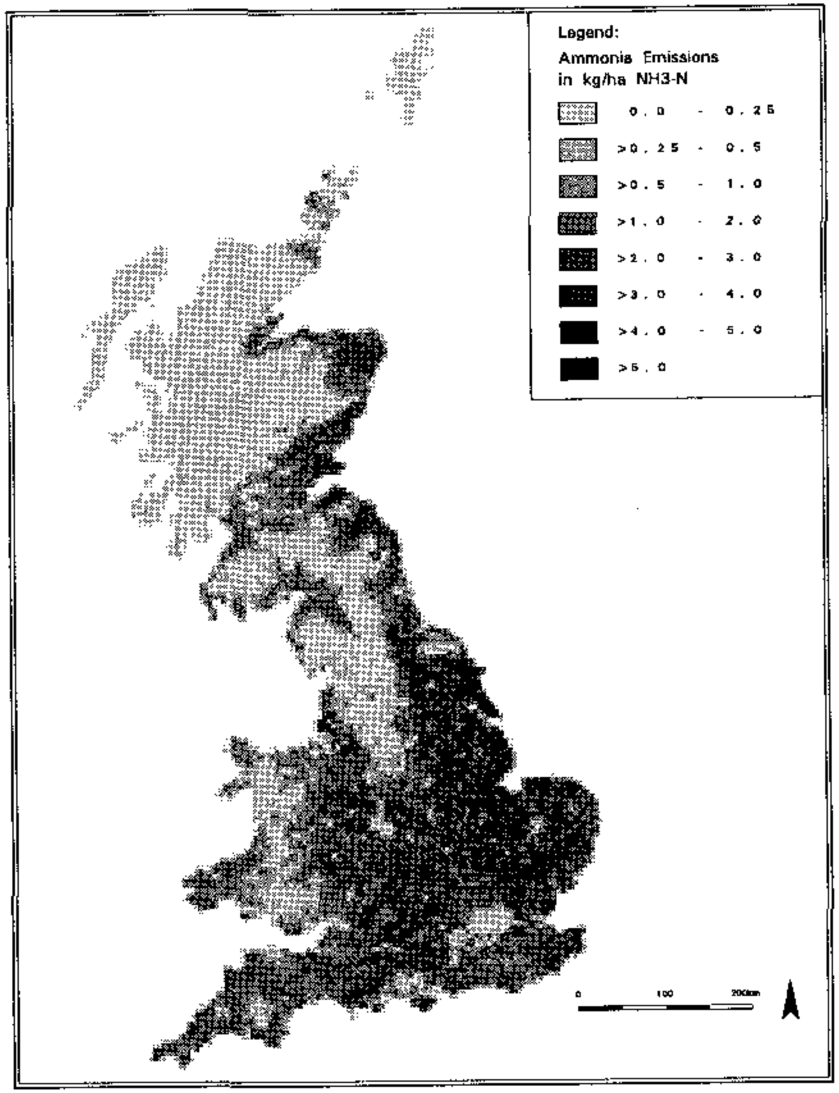


**Figure 3**. Ammonia emissions from fertiliser application and crops for 1988

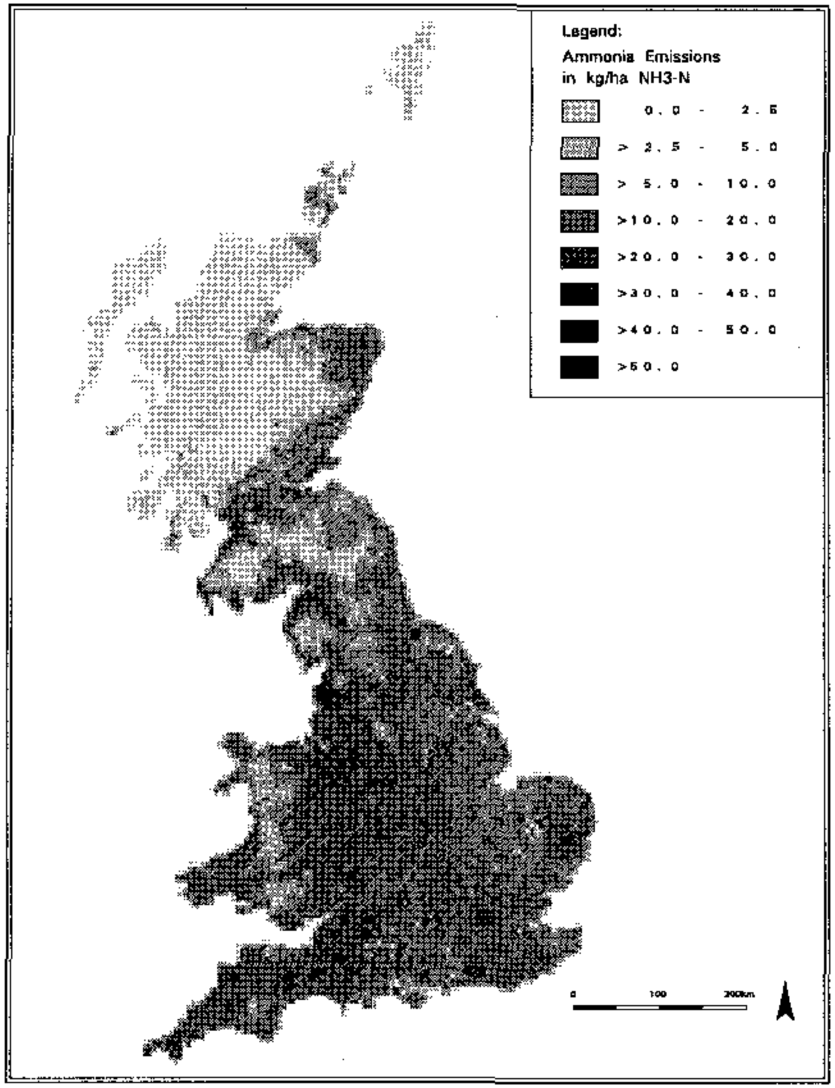


**Figure 4.** Total $NH_3$ emissions from agricultural and non-agricultural sources for 1969.

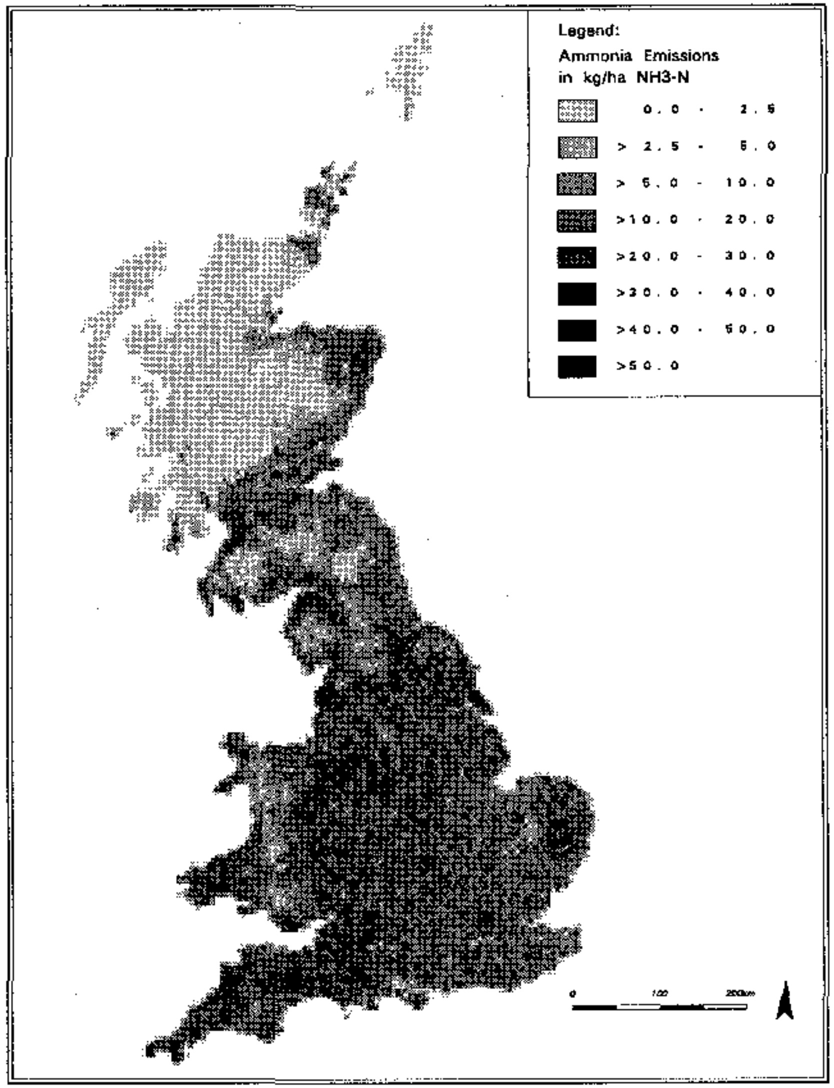


**Figure 5**. Total $NH_3$ emissions from agricultural and non-agricultural sources for 1988.

Table 2: Changes in livestock demography 1969-1988

| Livestock | Livestock class | Animal numbers (1000s) 1969 | 1988 | % change |
|---|---|---|---|---|
| Cattle | <2 years | 2,234 | 2,747 | 23 |
| | dairy cattle & calf cattle | 4,685 | 3,662 | -22 |
| | bulls | 85 | 48 | -44 |
| | fattening calves | 1,597 | 1,627 | 2 |
| | young fattening cattle | 1,477 | 774 | -48 |
| | other cattle > 2 years | 1,054 | 1,496 | 42 |
| | total | 11,132 | 10,355 | -7 |
| *Pigs* | *breeding & other sows* | 818 | 805 | -2 |
| | boars | 41 | 40 | -2 |
| | fattening pigs >50 kg | 996 | 2,351 | 136 |
| | fattening pigs 20-50 kg | 3,048 | 2,086 | -32 |
| | piglets (<20kg) | 1,844 | 2,042 | 11 |
| | total | 6,747 | 7,324 | 9 |
| Sheep | ewes | 13,711 | 18,274 | 33 |
| | rams | 327 | 783 | 139 |
| | lambs | 11,635 | 19,442 | 67 |
| | total | 25,673 | 38,512 | 50 |
| Poultry (Fowls) | laying hens < 18 weeks | 53,996 | 10,326 | -81 |
| | laying hens > 18 weeks | 11,784 | 33,931 | 188 |
| | all hens for breeding | 5,626 | 5,607 | 0 |
| | cocks & other table fowl | 1,636 | 995 | -39 |
| | broilers | 35,519 | 69,460 | 96 |
| | total | 108,561 | 120,319 | 11 |

Ammonia emissions and agricultural policy are closely linked. Asman *et al.* (1988) reported an 81% rise in $NH_3$ emissions across Europe between 1950 and 1980, which was estimated on the basis of changes in livestock numbers and fertilizer use. However, intensification is also expected to have increased $NH_3$ emissions per animal, particularly where these are fed grass with increased nitrogen content. These and other changes (changes in demography, animal breeding) make the identification of correct figures for historical livestock $NH_3$ emissions highly uncertain, and this is the subject of ongoing investigation.

It is clear that agricultural policy has had an increasing influence on farming in Britain. This trend was accentuated since the entry of the UK into the EC (1973), with the subsequent intervention of the Common Agricultural Policy (CAP). In addition to the effects on livestock, direct changes in crop production have also affected $NH_3$ emission. The areas of the major arable crops under cultivation in Britain over the period 1969-1993 are shown in Figure 1. This shows an increase in area under wheat and oilseed rape, both crops receiving high levels of N fertilizer. In addition, N inputs (kg N $ha^{-1}$ $year^{-1}$) have generally increased over the period (Boyd 1966, Dyer *et al.* 1989). In contrast, the area of barley and of total cereals has decreased since 1988, as a result of CAP changes in response to overproduction of food, resulting in the introduction of 'set aside' (1988).

Examples of the mapped distribution of $NH_3$ emissions at 5 km x 5 km grid resolution for Great Britain are shown in Figures 2-5. The most dramatic changes have occurred for emissions from fertilizers and crops. Total crop emissions for 1988 are estimated at 43 Gg $NH_3$ $year^{-1}$ as compared with 32 Gg $year^{-1}$ in 1969, and this comparison is shown in mapped form in Figures 2-3. The change is a result of both changes in crop areas and increase in fertilizer application rate. Total ammonia emissions for 1988 and 1969 are estimated at 300 Gg $year^{-1}$ and 287 Gg $year^{-1}$, respectively. Although this is not a large difference overall, Figures 4 and 5 show how the spatial pattern of $NH_3$ emissions has changed substantially over the period. In 1988, there is a much larger spatial variability in emissions, probably associated with the increase of larger livestock farms as well as reduced activity on marginal land. This would be expected to have provided an increased impact of local $NH_3$ emissions in source areas.

It should be noted that the 1969 total emission map (Figure 4) is very largely affected by the contribution of $NH_3$ emissions from livestock. Given the changes in fertilizer application rates to grassland (and hence to animal feeds), there is considerable uncertainty over the emission factors to be applied, particularly for cattle and sheep. The present values were made using the same emission factors for different years, based on Table 1 for the most recent estimates. For example, although demographic changes would have favoured larger emissions in 1969 for cattle, smaller rates of fertilizer N input probably mean that emissions per animal were significantly smaller at this time. This aspect together with an assessment of the reliability of the spatial disaggregation are both areas requiring further study.

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