Estimating numbers of piglets, weaners and fattening pigs for the German agricultural emission inventory

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Abstract

The establishment of emission inventories presupposes animal populations that are homogeneous with respect to feeding and management. For weaners and fattening pigs, the official surveys for pigs do not meet these requirements. Hence, the official animal numbers have to be redistributed to serve this purpose. In this paper, the algorithms to derive the animal categories of the emission inventory (weaners, fattening pigs) from survey data (piglets below 20 kg, young pigs lighter than 50 kg, fattening pigs 50 to 80 kg, fattening pigs 80 to 110 kg, fattening pigs heavier than 110 kg) are defined. Also, the calculation of the mean population of suckling-pigs needed for the redistribution of official animal numbers is described.

The updated animal populations result in decreased overall emissions from pig husbandry in the German emission inventory.

Keywords: pigs, emission inventory

Zusammenfassung

Ableitung der Tierzahlen von Saugferkeln, Aufzuchtferkeln und Mastschweinen für das deutsche Emissionsinventar

Die Erstellung von Emissionsinventaren setzt Tierpopulationen voraus, die hinsichtlich Fütterung und Haltung homogen sind. Diese Eigenschaft weisen die in den amtlichen Tierzählungen verwendeten Schweinekategorien für Aufzuchtferkel und Mastschweine nicht auf, so dass die erhobenen Tierzahlen für die Inventarerstellung erst nach einer Umverteilung zwischen den Kategorien verwendbar sind. Die Algorithmen zur Umrechnung der Schweinekategorien der Tierzählung (Ferkel unter 20 kg, Jungschweine bis unter 50 kg, Mastschweine 50 bis 80 kg, Mastschweine 80 bis 110 kg, Mastschweine 110 kg und mehr) in Kategorien des Emissionsinventars (Aufzuchtferkel, Mastschweine) werden abgeleitet. Die zu diesem Zweck erforderliche Berechnung der mittleren Saugferkelpopulation wird ebenfalls beschrieben.

Die Neuberechnung der Populationen der im deutschen Emissionsinventar verwendeten Schweinekategorien führt zu verringerten Emissionen aus der Schweinehaltung insgesamt.

Schlüsselwörter: Schweine, Emissionsinventar

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1 Introduction

Emission inventories are constructed to serve as policy advice. As such they allow for the description of the present situation. They also provide a tool for the establishment of scenarios. Furthermore, they are the key instrument in emission reporting. For the latter purpose, emission inventories have to be compiled according to international guidance documents. The assessment of emissions and the description of emission explaining variables have to be accomplished in a consistent way (greenhouse gases: IPCC, 1996, and IPCC, 2000; air pollutants: EMEP/EEA, 2009). Time series have to be produced for all relevant entities from 1990 onwards.

The treatment of emission sources and the respective calculation procedures vary with the relative importance of the source: important sources (such as fattening pigs) have to be dealt with using detailed procedures, whereas minor sources (such as boars) can be treated with simpler methodologies.

In the agricultural emission inventory, emissions are calculated using the basic relation

$$E_i = n_i \cdot EF_i$$

that describes an emission E_i as the product of the activity n_i and the emission factor EF_i. n_i and EF_i form a matching pair. All elements of n_i must have the same properties that result in the same emission factor per element. Hence, the first step in the description of emissions from animal husbandry is to identify those populations that are homogeneous with respect to their feed.

Official surveys of pigs in Germany do not reflect production practices, in particular feeding practices, but report livestock numbers by weights and ages and – to some extent – sex.

Other than in the inventory, where suckling-pigs are treated together with the sows, and weaners form a separate category, official surveys do not distinguish between suckling-pigs and weaners. In these surveys suckling-pigs and weaners are counted together as "piglets".

"Young pigs" between 20 and 50 kg animal^{-1} form a subcategory in the survey. However, their feeding changes at weights of 25 to 33 kg animal^{-1}, depending on federal state and year. In the inventory this weight level constitutes the differentiation between weaners and fattening pigs.

Hence there is the need to re-calculate survey subcategories for the use in the emission inventory for suckling-pigs, weaners and fattening pigs.

Within the comprehensive updating of all aspects of pig production (see Dämmgen et al., 2010a (emission factors), Dämmgen et al., 2010b (air scrubbers), Dämmgen et al., 2011 (feed and excretion rates), and Haenel et al., 2011 (energy requirements)) it became obvious that the treatment of pig categories in former emission inventories (e.g. Dämmgen et al., 2009) was inadequate and that a partial redistribution of the animal subcategories of the livestock survey into inventory subcategories had to be developed. The new adjustment approaches are presented in this work.

Table 1:
Pigs, categorisation and characterization (Haenel et al., 2011, modified)

Animal subcategory according to official survey		Animal subcategories used in the inventory			
type	subcategory	type [a]	subcategory	weight 1 [b] (in kg animal^{-1})	weight 2 [b] (in kg animal^{-1})
M	piglets below 20 kg	sp	suckling-pigs	1.5	8
N	young pigs lighter than 50 kg live weight	we	weaners	8	25 - 33 [c]
O	fattening pigs 50 to 80 kg	fp	fattening pigs	25 - 33 [c]	105 - 120 [d]
P	fattening pigs 80 to 110 kg				
Q	fattening pigs heavier than 110 kg				
R	young sows gestating	so	sows	mean weight: 220	
S	other sows gestating				
T	young sows not gestating				
U	other sows not gestating				
V	boars	bo	breeding boars	mean weight: 200	

[a] type: codes used to describe the animal categories in the German livestock survey of pigs and in the German emission inventory
[b] weight 1: weight at the beginning of the respective period, weight 2: weight at the end of the respective period
[c] see Table 3
[d] see data compilation in Haenel et al. (2010)

2 Pig subcategories in the German livestock survey and the German emission inventory

In the official German statistics, pigs are categorised according to their sex, weight, destination and age. For the emission inventory, subcategories have to be formed that are homogeneous with respect to feeding (Haenel et al., 2010). Table 1 compares the categories used in the livestock survey and in the inventory.

In the emission inventory, the category "sows" covers all subcategories of sows for breeding irrespective of their age and weight and is based on a concept that considers a sow and its suckling-pigs as a unit with respect to the calculation of energy and feed requirements. For birth and weaning weights of suckling-pigs the inventory uses typical values (1.5 kg animal^{-1} and 8 kg animal^{-1}, respectively, see Haenel et al., 2011).

Weaners are young pigs between weaning and the beginning of fattening at about 25 to 33 kg animal^{-1}.

All pigs with weights above this weight threshold, until slaughtering at ca. 105 to 120 kg animal^{-1} live weight, fall into the inventory subcategory "fattening pigs".

For breeding boars, a mean live weight of 200 kg animal^{-1} is assumed (Haenel et al., 2011).

The following three equations are derived from Table 1:

$$n_{sp} + n_{we} + n_{fp} = n_M + n_N + n_O + n_P + n_Q \quad (1)$$

$$n_{so} = n_R + n_S + n_T + n_U \quad (2)$$

$$n_{bo} = n_V \quad (3)$$

where

$n_M, \ldots, n_V$ number of animals in the categories M to V of the German livestock survey (see Table 1) (in place)
n_{sp} number of suckling-pigs in the inventory (in place)
n_{we} number of weaners in the inventory (in place)
n_{fp} number of fattening pigs in the inventory (in place)
n_{so} number of sows in the inventory (in place)

The German official survey counts animals at a qualifying date. In the inventory, these animal numbers are interpreted as occupied animal places. The inventory assumes that the number of occupied animal places is constant within a year, an assumption which is necessary as the inventory time step of one year does not allow for intra-annual changes of livestock numbers.

These animal places are equivalent to the elements of the populations as defined by IPCC (1996), pg. 4.7. Hence, in the following the unit "place" will be used rather than "animal".

While Equations (2) and (3) directly yield the animal numbers for sows (n_{so}) and boars (n_{bo}) as needed in the inventory, the relationships underlying Equation (1) need further processing in order to separately obtain the animal numbers of suckling-pigs (n_{sp}), weaners (n_{we}) and fattening pigs (n_{fp}).

Table 2:

Number of piglets raised per sow and year, $n_{piglet,\ year}$ (primary statistical information) BW: Baden-Württemberg; BY: Bayern; BB: Brandenburg; HE: Hessen; MV: Mecklenburg-Vorpommern; NI: Niedersachsen; NW: Nordrhein-Westfalen; RP: Rheinland-Pfalz; SL: Saarland; SN: Sachsen; ST: Sachsen-Anhalt; SH: Schleswig-Holstein; TH: Thüringen; StSt: Stadtstaaten (total of Hamburg, Bremen and Berlin)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
BW									19.20	19.10	18.20	18.67	18.90	17.89		20.00	20.50	21.10	
BY	18.00	18.00	17.70	17.60	17.80	18.50	17.60	18.40	19.60	19.60	19.60	19.40	19.60	19.60		20.40	19.90	20.10	
BB								17.80	18.20	18.90	19.50	19.70		20.30	20.80	21.70	22.20	22,50	22.80
HE	17.00	17.10	16.60	16.90	17.10	17.10	16.90	17.90	18.00	18.60	18.50		19.10	19.00	19.90	21.10	21.60	21.20	
MV								19.10	19.60	20.80	21.10		21.30					23.29	23.84
NI	18.90	18.90	18.90	18.70	18.50	18.70	18.40	18.90	19.30	19.50	19.70		19.60	20.30	20.60	21.30	21.40	21,20	
NW	19.00	17.80	18.40	18.90	19.00	18.90	19.10	19.70	20.10	20.20	20.30	20.40	20.30	20.30	21.80	22.10		22.60	
RP	17.20	17.30	17.20	17.30	17.40	17.50	17.60	17.90	18.00	18.20	18.50		18.40	19.10	19.00				
SL	17.20	17.30	17.20	17.30	17.40	17.50	17.60	17.90	18.00	18.20	18.50		18.40	19.10	19.00				
SN				17.80	18.40	18.70	18.64	19.18	19.88	20.41	20.45	20.56	20.67	21.04	21.40	21.49	22.38	23.40	23.31
ST								18.50	18.50	19.90	20.00	19.60	20.66	20.52	21.01	21.46	22.00	22.26	22.99
SH		18.80	18.60	18.40	18.70	19.00	18.80	19.30	19.70	19.80	20.10		20.30	20.70	21.60	22.60		23.20	
TH							18.30	19.00	20.10	20.45	21.23	20.43	21.25	20.78	21.66	22.19	22.72	23.28	23.94
StSt																			
Germany		18.50	18.50				19.10	19.10				19.80	19.80						

For data sources see Haenel et al. (2010)

3 Suckling-pigs

In the emission inventory (Haenel et al., 2010), suckling-pigs are considered a unity with their sows ("sow plus litter") and the emissions reported for sows include those of their suckling-pigs. The underlying energy requirement calculations (see Haenel et al., 2011) take the number of suckling-pigs into account. As the official livestock survey of pigs does not provide numbers of the suckling-pig population, the inventory uses the number of piglets raised per sow and year collated from various sources (see Haenel et al., 2010) as shown in Table 2.

The number n_M of piglets below a weight of 20 kg animal^{-1} as counted in the official livestock survey of pigs includes the suckling-pigs. Hence, in order to avoid double counting of the suckling-pig population, their number has to be estimated and subtracted from n_M when estimating the number of animals in the inventory subcategory of weaners (see Chapter 4).

3.1 Former approach

In the former approach (e.g. Dämmgen et al., 2009), the number of suckling-pigs was derived from the number of piglets raised per sow (as shown in Table 2) assuming a fixed number of births of 2.2 a^{-1}, in agreement with KTBL (2004). No attempt was made to relate the resulting numbers to the number of piglets provided by the official livestock survey of pigs and subtract the population of suckling-pigs from the officially counted number n_M.

3.2 New approach

The data in Table 2 can be used to derive the annual mean of the suckling-pig population at the federal state level:

$$n^*_{sp} = n_{so} \cdot n_{piglet,\,year} \cdot \frac{\tau_{sp}}{\alpha} \qquad (4)$$

where

n^*_{sp} annual mean of the suckling-pig population at the federal state level (in place)
n_{so} number of sows (in place), see below,
$n_{piglet,\,year}$ number of piglets raised per sow and year (in place place^{-1} a^{-1}), see Table 2
τ_{sp} duration of lactation (τ_{sp} = 28 d, see Haenel et al., 2011)
α time units conversion factor (α = 365 d a^{-1})

In the inventory the number of sows is given by Equation (2). Figure 1 displays n^*_{sp} in relation to the officially reported piglets number (n_M) where n^*_{sp} data points have been calculated for all federal states and years as far as the input data have been available (see Table 2).

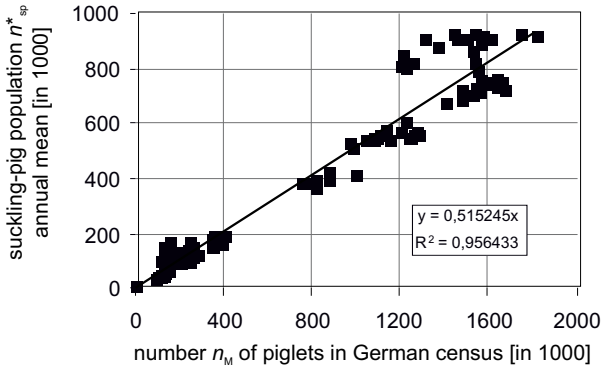

Figure 1:
Mean population of suckling-pigs (n^*_{sp}) over piglets number in the official livestock survey (n_M) at the federal state level. Linear regression: slope 0.5771, R^2 = 0.96.

In order to obtain a robust method to estimate the numbers of suckling-pigs from the number of piglets provided by the official livestock survey, a linear regression with zero intercept was applied to the n^*_{sp} data displayed in Figure 1, yielding

$$n_{sp} = c_{sp} \cdot n_M \qquad (5)$$

where

n_{sp} number of suckling-pigs to be used in the inventory (in place)
c_{sp} constant (c_{sp} = 0.5771 place place^{-1})
n_M number of place in official livestock survey (in place), see Table 1

In the inventory, Equation (5) is applied to data at the district level. A non-zero intercept would not improve results.

4 Weaners

4.1 Former approach

Previous inventories (e.g. Dämmgen et al., 2009) wrongly assumed that suckling-pigs were not included in the number of piglets reported in the official livestock survey. Instead, all piglets officially counted as "piglets up to 20 kg animal^{-1}" were attributed to the inventory subcategory "weaners",

$$n_{we,\,old} = n_M \qquad (6)$$

where

$n_{we,\,old}$ number of weaners in the former approach (in place)
n_M animal number of type M (etc.) in official livestock survey (in place), see Table 1

4.2 New approach

The numbers n_M of piglets (see Table 1) provided by the statistical offices of the federal states (StatLA C III 1 – vj/xx 4 with, xx denoting the year of the census) comprise the numbers of suckling-pigs (n_{sp}, see Chapter 3) and of weaners up to an animal weight of 20 kg animal^{-1}. As the final weight of weaners is substantially higher than 20 kg animal^{-1} (see Chapter 2) a certain share of the inventory animal category "weaners" must be included in the officially reported numbers of young pigs (n_N, see Table 1). This is reflected by the following relation:

$$n_{we} = n_M - n_{sp} + n_{we,x} \quad (7)$$

where

n_{we} number of weaners in the new approach (in place)
n_M number of piglets in official livestock survey (in place)
n_{sp} number of suckling-pigs (in place), see Equation (5)
$n_{we,x}$ share of officially counted young pigs regrouped into the inventory subcategory of weaners (in place)

The share of officially counted young pigs to be regrouped into the inventory subcategory of weaners is given by

$$n_{we,x} = x_{we,x} \cdot n_N \quad (8)$$

where

$n_{we,x}$ share of officially counted young pigs regrouped into the inventory subcategory of weaners (in place)
$x_{we,x}$ fraction (in place place^{-1}) with $0 \le x_{we,x} \le 1$
n_N number of young pigs in German census (in place)

No official data on animal numbers is available to derive the fraction $x_{we,x}$. However, as animal weight data are known, the plausible assumption of a continuous animal growth rate allows for the construction of the following simple estimate of $x_{we,x}$:

$$x_{we,x} = \frac{w_{we,fin} - w_{yp,start}}{w_{yp,fin} - w_{yp,start}} \quad (9)$$

where

$x_{we,x}$ fraction (in place place^{-1}) with $0 \le x_{we,x} \le 1$
$w_{we,fin,}$ weaner weight at the end of the production period (in kg animal^{-1}), see Table 3
$w_{yp,start}$ lower weight boundary of the official subcategory of young pigs ($w_{yp,start}$ = 20 kg animal^{-1}, see Table 1)
$w_{yp,fin}$ upper weight boundary of the official subcategory of young pigs ($w_{yp,start}$ = 50 kg animal^{-1}, see Table 1)

The data available on the final weight of weaners, $w_{we,fin}$, is shown in Table 3. Based on these data, $x_{we,x}$ amounts to about one third.

Table 3:
Weaners, final weights $w_{we,fin}$ (in kg animal^{-1})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
BW	28	28	28	28	29	29	30	29	29.3		29.9		29.5		30	30	30.9	32.3	
BY	27	28	28	28	29	29	29	29	29	29	29.4	29.6	29.8	28.3			30.4	30	
BB								27	27	27	27	27	27				28	28	
HE	26	27	27	27	27	28	28	28	28	29	29	29	30				30		
MV								28	27	27	27	27	27				28.8	29	
NI	25.5	26	26	27	28	28.5	28.5	28.5	28.5	29	29	29	28.5	30	30	30	30		
NW	24	24	25	26	27	27	27	28	28	28	28	28	28	28	28	29	29.1	30	
RP	25	26	26	27	28	28	28	29	28	29	30	31	33	31	32	32.3	33.5		
SL	25	26	26	27	28	28	28	29	28	29	30	31	33	31					
SN				28	27			28	28	28	27	27	27				28.8	29.8	
ST																			
SH	25	25	26	26	27	28	28	28	28	28	28	28	28	29	29	29.5	29.8	30	
TH							28	27	28	28	28	27	27				28.0	28.5	27.5
StSt																			
Germany																			

(for abbreviations BW, BY, etc., see Table 2)
For data sources see Haenel et al. (2010)

Table 4:
Numbers of weaners (in 1000 places), calculated with the former and new approaches

year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
former approach	4986.2	4483.2	4501.8	4432.9	4101.3	3869.5	4013.2	4098.2	4381.9	4578.5
new approach	5789.1	4245.5	4236.5	4319.5	4241.9	4140.3	4150.8	4415.5	4694.5	4691.6
year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
former approach	4611.2	4612.7	4586.5	4506.9	4753.5	4739.7	4782.5	4138.5		
new approach	4640.7	4672.4	4781.4	4762.8	4767.0	4973.8	5047.0	5193.7	5003.8	

Table 4 compares the weaner numbers obtained with the former approach to those based on the new approach. In most years the latter exceed the numbers obtained with the former approach. However, as the animal numbers in the new approach depend both on the suckling-pig population and the young pig population and as the fluctuations of both populations are only loosely correlated, it is possible within the new approach to yield weaner numbers falling below those obtained with the former approach.

5 Fattening pigs

5.1 Former approach

Hitherto (e.g. Dämmgen et al., 2009), the subcategory "fattening pigs" comprised the officially reported populations for young pigs between 20 and 50 kg live weight (n_N), fattening pigs 50 to 80 kg (n_O), fattening pigs 80 to 110 kg (n_P) and fattening pigs heavier than 110 kg (n_Q).

$$n_{\mathrm{fp,\,old}} = n_N + n_O + n_P + n_Q \tag{10}$$

where

$n_{\mathrm{fp,\,old}}$ number of fattening pigs in the former approach (in place)

n_N etc. animal numbers of type N (etc.) in official livestock survey (in place), see Table 1

As a consequence, the former approach ignored that fattening commences at weights between about 25 and 33 kg animal^{-1} (see Table 3).

5.2 New approach

The redistribution of animals considers that a share of the young pigs' population is to be attributed to the weaners' population:

$$n_{\mathrm{fp}} = n_N + n_O + n_P + n_Q - n_{\mathrm{we,\,x}} = n_N \cdot (1 - x_{\mathrm{we,\,x}}) + n_O + n_P + n_Q \tag{11}$$

where

n_{fp} number of fattening pigs (in place)

n_N etc. animal numbers of type N (etc.) in official livestock survey (in place), see Table 1

$n_{\mathrm{we,\,x}}$ share of officially counted young pigs regrouped into the inventory category of weaners (in place), see Chapter 4.2

$x_{\mathrm{we,\,x}}$ fraction (in place place^{-1}) with $0 \le x_{\mathrm{we,\,x}} \le 1$, see Chapter 4.2

In many years the ratio of n_N to the total of n_O, n_P, and n_Q is in the order of one half. Hence, considering that $x_{\mathrm{we,\,x}}$ amounts to about one third, n_{fp} can be estimated to be lower than the total of n_N, n_O, n_P and n_Q by the order of one tenth. The exact reduction of the numbers of fattening pigs as obtained by the new approach can be seen from the comparison shown in Table 5.

Table 5:
Numbers of fattening pigs (in 1000 places), calculated with the former and new approaches

year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
former approach	20033.9	16322.8	16675.0	16527.9	15851.3	15326.7	15642.2	15961.9	16990.5	16485.0
new approach	17407.8	14921.2	15294.2	15020.4	14211.1	13641.0	14037.1	14146.1	15075.7	14697.8
year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
former approach	16202.9	16542.1	16810.2	16333.5	17138.9	16883.4	17405.9	16625.0		
new approach	14510.9	14455.7	14686.7	14956.8	14425.5	15180.5	14843.0	15246.0	15270.3	

6 Summary and conclusions

A consistent approach has been derived to redistribute officially counted numbers of piglets, young pigs and fattening pigs into the animal categories of the emission inventory, i. e. weaners and fattening pigs.

The new model avoids the double counting of suckling-pigs in the former approach where suckling-pigs were taken into account within the unit sow/suckling-pigs but also in the category of weaners. It also results in modified numbers of weaners and, in any case, reduced numbers of fattening pigs, as shown in Tables 4 and 5.

Clearly, elimination of animal double counting reduces the calculated emissions. Further reductions of the calculated emissions are achieved by assigning a share of the officially counted young pigs to the weaner subcategory instead of the fattener subcategory as emissions per weaner are smaller than those per fattening pig (see Haenel et al, 2010).

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