SMED Report No 19 2022

Coordination of common input data for manure in the agricultural sector and for ICBM in the LULUCF sector

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Agreement: 250-22-001

Commissioned by the Swedish Environmental Protection Agency

Publisher: Swedish Meteorological and Hydrological Institute
Address: SE-601 76 Norrköping, Sweden
Start year: 2006
ISSN: 1653-8102

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Sammanfattning

Sverige tillämpar en Tier III-metod för att skatta förändringar i markens kolförråd för åkermark på mineraljordar inom sektorn Markanvändning, Markanvändningsförändring och Skogsbruk (LULUCF, CRF sektor 4). För det ändamålet använder SLU kolbalansmodellen ICBM för att beräkna årliga markkolsförändringar för åtta svenska produktionsområden (PO8) som därefter skalas upp till nationell nivå. För att initialisera kolförråden i ICBM används data för kolkoncentrationer från ett nationellt marköövervakningsprogram i samband med funktioner för att skatta markens skrymdensitet. Modellen tar hänsyn för klimatets effekt på nedbrytningen genom att använda ett rutnät av dagliga klimatdata från Sveriges meteorologiska och hydrologiska institut (SMHI). Indata till ICBM för den årliga koltillförseln till mark från växtrester och för stallgödsel skattas från årlig jordbruksstatistik om grödor, skördar, hantering av ovanjordisk biomassa och stallgödsel. Inom LULUCF-sektorn baseras kalkylerna för koltillförsel från stallgödsel på aktivitetsdata från en serie rapporter publicerade av SCB, baserade på Gödselmedelsundersökningen (GMU). Där anges total mängd stallgödsel (våtvikt) som sprids på åkermark från olika djurkategorier och olika lagringsformer. För jordbrukssektorn används en metod baserad på djurantal (”Animal Number Based”, ANB), som beräknar mängd gödsel (flyktiga fasta ämnen) vid svans som produceras per djurtyp och år.

Syftet med denna rapport var att jämföra tidsserierna för stallgödsel med de två metoderna, med målet att undersöka möjligheten att använda ANB-metoden även för LULUCF-sektorn. Detta gjordes genom att anpassa ANB-metoden och vi undersökte möjligheter att förbättra tidsserien med GMU-metoden, för vilken vi har observerat vissa inkonsekvenser. Vi genomförde dessa beräkningar för var och en av de svenska PO8s, och för riksnivå. Med en hypotes om att torrsubstanshalten i stallgödsel, som var lägre från mitten av 2000-talet på grund av mer vatten från mjölk- och tvättrobotar (dvs vatten som kommer med i gödseln), ger en bättre tidsserie med GMU-metoden, i den meningen att det borde finnas en övergripande minskande trend av mängden stallgödsel över tid, vilket överensstämmer med trenden som erhålls med ANB-metoden.

Resultaten visar att variationen i uppskattningar av mängden kol från stallgödsel mellan åren är fortfarande hög för en del av data från de senaste GMU-rapporterna, medan uppskattningarna med ANB-metoden ger en jämnare och konsekventare tidsserie. Båda metoderna presenterar olika inslag av osäkerhet beroende på tillgängligheten av aktivitetsdata. Det är

möjligt, och skulle vara fördelaktigt, att anpassa ANB-metoden för användning inom LULUCF med ICBM-modellen, för att harmonisera de aktivitetsdata som används så att de kan vara samma som de som används inom jordbrukssektorn. Detta kräver dock fortfarande en del mindre utredningar. Särskilt vad gäller mängden torv och sågspån som används som strömaterial i djurstallar och som måste läggas till mängden kol från stallgödsel beräknad med ANB-metoden.

Summary

SMED is short for Swedish Environmental Emissions Data, which is a collaboration between IVL Swedish Environmental Research Institute, SCB Statistics Sweden, SLU Swedish University of Agricultural Sciences, and SMHI Swedish Meteorological and Hydrological Institute.

Sweden is applying a Tier III method for estimating changes in soil organic carbon (SOC) stocks for cropland remaining cropland on mineral soils within the Land Use, Land-Use Change and Forestry (LULUCF) sector. For that purpose, SLU is using the Introductory Carbon Balance Model (ICBM) for calculating annual SOC stock change rates for eight Swedish agricultural production (PO8) regions and aggregating results to the national level. The initial stocks of SOC are derived from SOC concentrations data in a national soil-monitoring program and pedo-transfer functions for computing dry soil bulk density. The model accounts for the effect of climate on SOC decomposition by using gridded daily weather records from the Swedish Meteorological and Hydrological Institute (SMHI). The estimates for annual carbon inputs to soil from crop residues and manures are based on yearly agricultural census data concerning crop types, yields, aboveground biomass and manure management. In the LULUCF sector, carbon input from manures are based on activity data from a series of reports published by Statistics Sweden ("Use of fertilizers and animal manure in agriculture"), Gödselmedelsunderäkningen (GMU). The GMU is reporting the total amount of manure (wet weight) spread on arable land for different livestock categories and type of manure storage forms. The agricultural sector is using an animal number based (ANB) approach, which is calculating the amount of manure (excreted volatile solids) produced per animal type per year.

The objectives of this report were to compare the time series for manures with the two approaches, with the goal to explore the possibility of using the ANB approach also for the LULUCF sector. This was done by adapting the ANB approach and we examined possibilities for improving the time series with the GMU approach, for which we have observed some inconsistencies. We were conducting these calculations for each of the Swedish PO8s, results were also scaled up to the country level. Using a hypothesis that the dry matter content in manures were lower from mid 2000s because of more water from milk- and washing robots (i.e., which is entering the manures) provides an improved time series with the GMU approach, in the sense that there is at least an overall decreasing trend over time. This is in agreement with the trend using the ANB approach.

The variability in estimates of carbon from manures between years remain high for some of the data from the latest GMU reports, while the estimates using the ANB approach provides a smoother and more consistent time series. Both approaches are presenting various elements of uncertainty relating to the availability of precise activity data. It is feasible and would be advantageous adapting the ANB approach for use within LULUCF with the ICBM model, in order to harmonize the activity data used so that it can be the same as that used in the agricultural sector. However, this is still requiring some minor investigations. Especially regarding the amount of peat and sawdust used as bedding material, which needs to be added to the estimated amount of carbon from manures with the ANB approach.

Keywords: Manure, Dry matter, Carbon, Soil organic carbon, LULUCF, ICBM, Animal number

Background & Purpose

The ICBM model (Andrén and Kätterer, 1997) is used within the Swedish greenhouse gas inventory (NIR, 2021) for estimating annual soil organic carbon stock changes for mineral agricultural topsoils under the Land Use, Land Use Change and Forestry (LULUCF) sector. This model is integrating different sources of data for agroecosystems in a holistic framework at the IPCC Tier III level as described by Andrén et al. (2004; 2008), where the data are mainly coming from standard agricultural census at the national level and associated with the area of arable land. The soil organic carbon balance is dynamic and determined by the difference between annual carbon inputs and carbon outputs through the decay of soil organic matter as a result of soil biological activity. The annual carbon inputs are originating from above- and belowground crop residues left in the field and from the application of organic amendments.

These calculations are carried out by SLU, and in our current methodology we are estimating the input data of carbon from manures to the ICBM model using a series of reports published by Statistics Sweden (SCB) called “Use of fertilizers and animal manure in agriculture”, Gödselmedelsundersökningen (SCB, 2020), hereafter abbreviated as GMU. Statistics Sweden is publishing the GMU reports biannually since 2001 and every third year since 2013. These statistics describes the total amount of manure spread on arable land for each of the eight agricultural production regions (PO8) in Sweden during a year, by presenting data for different livestock categories and type of manure storage forms for each PO8. The GMU reports are expressing the amounts of manure for each livestock category and manure storage forms in terms of wet weight. We convert these data to carbon inputs by applying a coefficient for dry matter (DM) content for each livestock category and manure storage forms, and assuming a carbon content of 45%. This is a standard procedure for estimating the amount of carbon inputs from manures. However, we are observing some inconsistencies in the time series of annual carbon inputs from manures.

Alternatively, it is possible estimating the amount of carbon inputs from manures by using an animal number based (ANB) approach such as in the Finnish greenhouse gas inventory (Palosuo et al. 2016). This procedure is calculating the amount of manure produced per animal per year (kg volatile solids dry matter per head). The total amount of carbon from manure is thereafter scaled up using the number of animals for a given livestock

category and year. In Sweden, SCB is using an ANB approach in the agricultural sector for their calculations of methane emissions (Manure Management, CRF 3.B), which requires data for manure production (kg volatile solids dry matter per head). It appears relevant to coordinate, and if possible, use the same data source for manure in both the LULUCF and agricultural sector.

The purposes of this development project were to:

- Investigate reasons for the inconsistencies observed when using data from the GMU reports and explore possibilities for improving the time series of annual carbon inputs from manures with this approach
- Use the ANB approach to estimate annual carbon inputs from manures for each of the PO8s and
- Make a comparison between the two approaches

Materials & Methods

The GMU (Gödselmedelsundersökningen) approach

The statistics used here to calculate total annual manure carbon inputs from the GMU reports is covering the years 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2016 and 2019 (input data to ICBM for intermediate years are linearly interpolated). When running the ICBM model, we are also using statistics available for the years 1991, 1993 and 1997 but these are not presented herein because they were associated with some assumptions (made earlier by other persons developing the approach and not easily traceable), making them less suitable for comparing the GMU and ANB approaches. The GMU reports are collecting data from various types of survey protocols, websites, telephone interviews etc. (for details, see SCB (2020) and previous reports in the same series).

The GMU reports are presenting data as use of different kinds of animal manure (e.g., Table 4 in SCB (2020), idem in all reports in the same series). They are expressed in 1 000 ton on a wet weight basis spread on arable land for the whole country and sub-divided by each PO8s for three livestock categories, cattle, swine and other (poultry, sheep and horses). The statistics are further dividing data into different storage forms for cattle (solid, liquid, semi-liquid and deep litter) and for swine (solid and liquid) manures.

In the current ICBM methodology, we are using DM contents from Steineck et al. (1999) in order to convert the manure data from wet weight into manure on a DM basis. These values are as follows: solid cattle manure (16.6%), liquid cattle manure (9.9%), semi-liquid cattle manure (14%), deep litter cattle manure (30%), solid swine manure (23.4%), liquid swine manure (8.4%) and other livestock (16.6%). Furthermore, for converting data to amounts of carbon from manures we are assuming a carbon content of 45% in DM for all livestock categories and manure storage forms.

The storage forms have changed over the years. On a DM basis, in the early 2000s (2001-2005) about 30% of cattle manure was stored in solid form and about 55% in liquid form, whereas today the corresponding proportions are approximately 15 and 75%, respectively. Semi-liquid and deep litter cattle manure are relatively marginal storage forms (i.e., with less than 5% and around 10%, respectively), and have remained more or less unchanged from

the early 2000s up until today. For swine manure, in 2001-2003 about 35% was stored in solid form and 65% in liquid forms, whereas today the corresponding proportions are approximately <10% and >90%, respectively. On a wet weight basis, liquid cattle and swine manure represented 85 and 95% of the total, respectively.

Furthermore, other changes have occurred and that are affecting the characteristics of the stored manure. In contemporary Swedish agriculture, dairy production systems are using milk robots in about 40% of the stables, and washing robots are becoming more and more common in swine production systems. This implies that the amount of washing water increases, which is entering the manures and the DM content (as well as nutrient content) is decreasing in both cattle and swine manures (for details see Andrist Rangel et al. (1990), and reference sources cited therein). It is difficult to determine exactly when these changes were occurring. In this report, we hypothesized the DM content changed from 2007 onwards, and updated DM contents of manures for this period by using data from *Stallgödselkalkyen* 2.0 (www.greppa.nu).

The animal number based (ANB) approach

Annual amount of carbon from manure was calculated from activity data used in the inventories of greenhouse gases and air pollution of the Swedish agricultural sector. Only a brief description is given here but details on the underlying data sources and assumptions are described in the NIR (2021) and in the IIR (2021), respectively. The calculations also involved other underlying data that are unpublished as well as some additional assumptions necessary for completing the estimations. There was no assessment made concerning the uncertainty, however, it is often relatively high at the regional level (i.e., PO8).

The total amount of annual carbon from manures (Cl_{manure}) for each of the Swedish PO8s was calculated as follows accordingly with equation 5 from Palosuo et al. (22016) for the period 1990 to 2021.

$$Cl_{\text{manure}} = \sum_{i} N_i \times VS_i \times CC_{\text{manure}}$$

Where N_i corresponds the number of animals in the livestock category i, VS_i is the mean annual excretion of volatile solids in manure per animal in each livestock category. It is assumed the carbon content of manure was 50% of VS, where VS is representing the DM organic fraction of total solids in manure that will oxidize at a temperature of 600 ^{o}C. Information concerning the number of animals is mostly coming from the Swedish Farm Register but sometimes involves other sources such as slaughter statistics for poultry. In

particular, since the Farm Register tends to underestimate the number of horses (i.e., horses for private leisure activities are excluded), these data are taken from three separate surveys conducted in 2004, 2010 and 2016 for the total number of horses (see NIR (2021) for details). We were also using the Farm Register to determine the division of number of animals between PO8s from the year 2005 onwards, and we assumed that the division for the period 1990 to 2004 was the same as that for the year 2005.

For the cattle and swine livestock categories, data for VS were the same as those used in the agricultural sector for calculating greenhouse gas emissions. We were taking default VS data for the livestock category other animals from appendix10A.2 (Table 10A-9) of the IPCC (2006) guidelines. We were assuming that VS for lambs and kids was half the amount of that for sheep and goat, whereas we assumed VS for laying chicken to be the same as that for slaughter (broiler) chickens. It is uncertain how applicable the default VS data used here for Swedish animals are for the category other livestock and there is a risk for under- or overestimations. The IPCC 2019 Refinement presents a new methodology where VS is derived from live weight of the animals but it was not considered here.

In addition to the total amount of annual carbon from manures, we were also calculating the total amount of manures produced only during the period when the animals are in the stable, i.e., by subtracting the grazing period. The data for stable and grazing periods are coming from the statistics presented in the GMU reports. It is assumed that even during grazing for dairy cows, 38% of the manure still ends up in the stable (i.e., during milking), and that VS for foster cows differs between stable and grazing periods.

Results & Discussion

Carbon from manures with the GMU (*Gödselmedelsundersökningen*) approach

The total amount of manures in wet weight from all livestock categories from the GMU reports are showing an increase in 2007 and remain high in the following three reports (year 2009, 2011 and 2013), and thereafter decreases in the last two reports 2016 and 2019 (Fig. 1). As explained in SCB (2017), an increasing amount of manures used for biogas production in combination with a decreasing number of animals could partly explain the decrease in 2016 (compared to 2013). Indeed, the statistics concerning the amount of biofertilizer (*Biogödsel*, i.e., the final product from a biogas plant) produced in Sweden are showing an increase of about 75% between 2013 and 2016 (Statens Energimyndighet, (2016); rapportserie ER 2005-onwards). The amount of manure used as a substrate in biogas plants was approximately 1 000 kiloton (kt) wet weight in 2019 and it was about 900 kt in 2015, which is corresponding to about 4.5% (wet weight basis) of the total amount of manure produced.

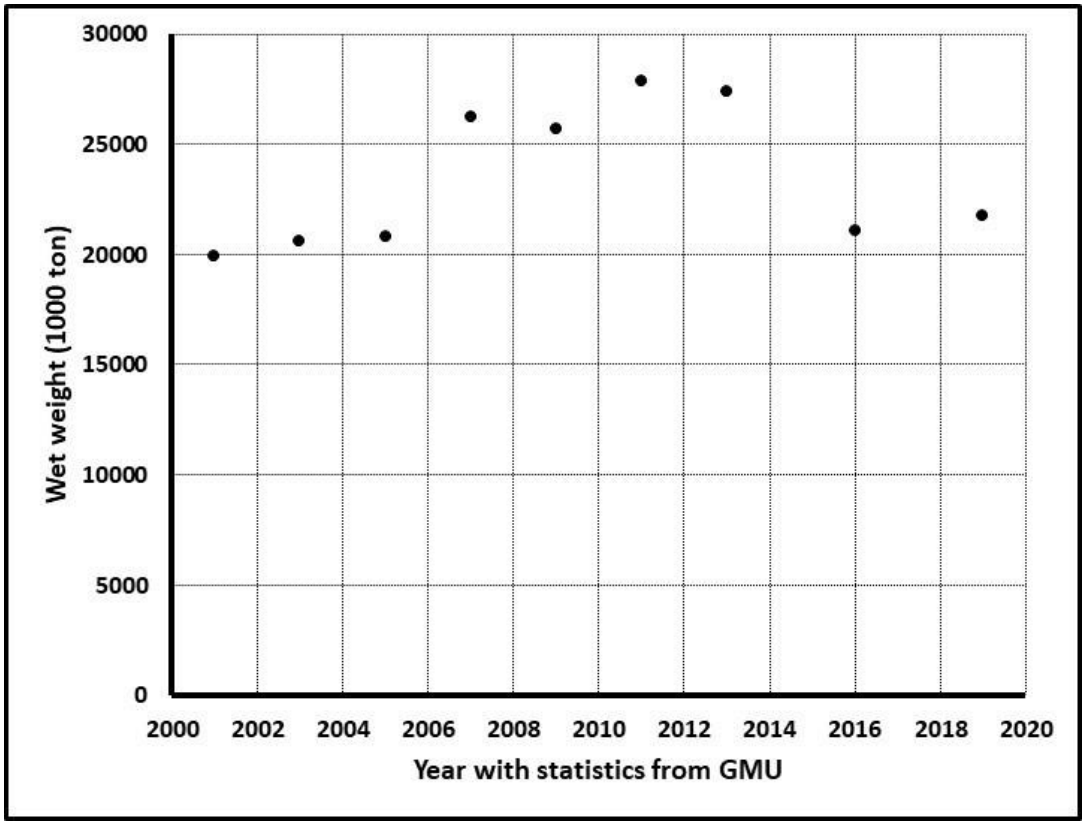

Fig. 1. Total amount of manures in wet weight from all livestock categories spread on arable land in Sweden. Data from Table 4 in SCB (2020) and previous reports in the same series of *Gödselmedelsundersökningen* (GMU).

We are observing the same pattern when expressing the total amount of manures from all livestock categories on a DM basis using the DM content from Steineck et al. (1999) for all years (Fig. 2. left). The amount for 1997 was more or less identical to that for 2001, while the amount for 1993 and 1991 was about 8 and 14% lower compared to 1997 (data not shown).

Figure 2 (right) is showing the results when hypothesizing that the DM content changed from 2007 onwards, by using updated DM contents of manures for this period with data from *Stallgödselkalkyen* 2.0 (www.greppa.nu). The new values for the period 2007 onwards were as follows: solid cattle manure (17.2 instead of 16.6%), liquid cattle manure (7.3 instead of 9.9%), semi-liquid cattle manure (15.6 instead of 14%), deep litter cattle manure (25.4 instead of 30%), solid swine manure (25.5 instead of 23.4%), liquid swine manure (5.0 instead of 8.4%) and other livestock (unchanged). For some livestock categories and manure storage forms, the DM content were actually slightly higher. However, the DM content was always lower for liquid manure, which is the dominant storage form. On a relative basis, the DM content for liquid cattle manure and liquid swine manure were 26 and 41% lower, respectively. These calculations are

improving the time series for the total amount of manures in DM from all livestock categories (Fig. 2. right). However, the data for 2011 and 2013 remain high.

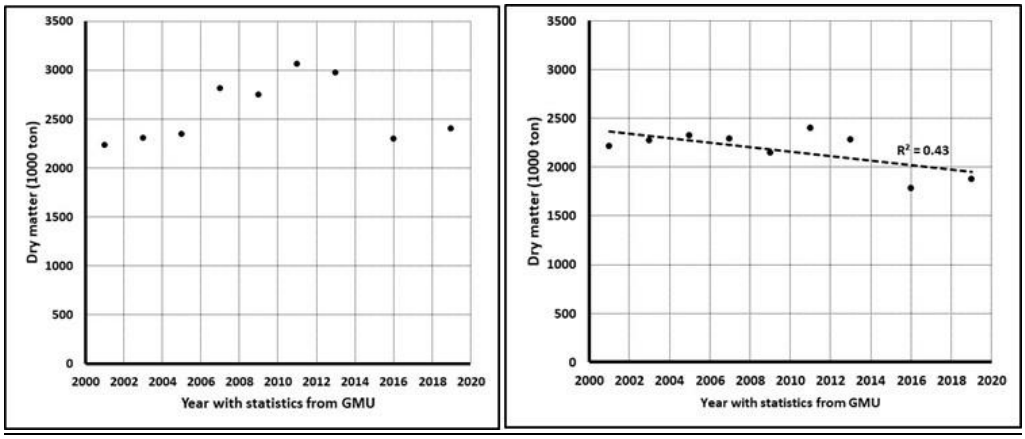

Fig. 2. Total amount of manures in dry matter (DM) from all livestock categories spread on arable land in Sweden. Data from Table 4 in SCB (2020) and previous reports in the same series of *Gödselmedelsundersökningen* (GMU). Calculated with DM content from Steineck et al. (1999) for all years (left), and calculated with DM content from Steineck et al. (1999) for the years 2001, 2003 and 2005, and with DM content from *Stallgödselkalkyen* 2.0 (www.greppa.nu) from 2007 onwards (right).

For example, the decrease from 2013 to 2016 is representing 500 kt DM manure. Assuming that biogas plants are only using solid cattle manure as a substrate (a conservative estimate since this storage form has the highest DM content), this corresponds to about 150 kt. DM manure in 2016, (i.e., 900 kt wet weight see text above). However, the amount of manure used for biogas production was already relatively important in 2012 (454 kt) and 2013 (573 kt) representing about 500 kt wet weight; following the same assumption this corresponds to about 80 kt DM manure in 2013. Consequently, the actual decrease is less than 150 kt DM manure (i.e., it would only represent around 70 (150 minus 80 kt DM)).

Regarding the decrease in manure because of decreasing number of animals, as a rough estimate accordingly with statistics for the number of animals presented in NIR (2021), the number of cattle and swine decreased with about 4 and 10%, respectively; roughly representing a total of 150 kt DM manure. With these approximations, it appears that the amount of manure used for biogas production and the decreasing number of animals with the GMU approach is explaining less than half (i.e., 70 plus 150 kt DM manure) of the decrease between 2013 and 2016.

Carbon from manures with the animal number based (ANB) approach

For comparing the ANB and GMU approaches, we were expressing the results as the total amount of carbon in manures (Fig. 3. and 4., and appendix I and II). With the ANB approach, the figures are presenting two time series: the total amount of manure excreted and the total amount of manures excreted only during the period the animals are in the stable.

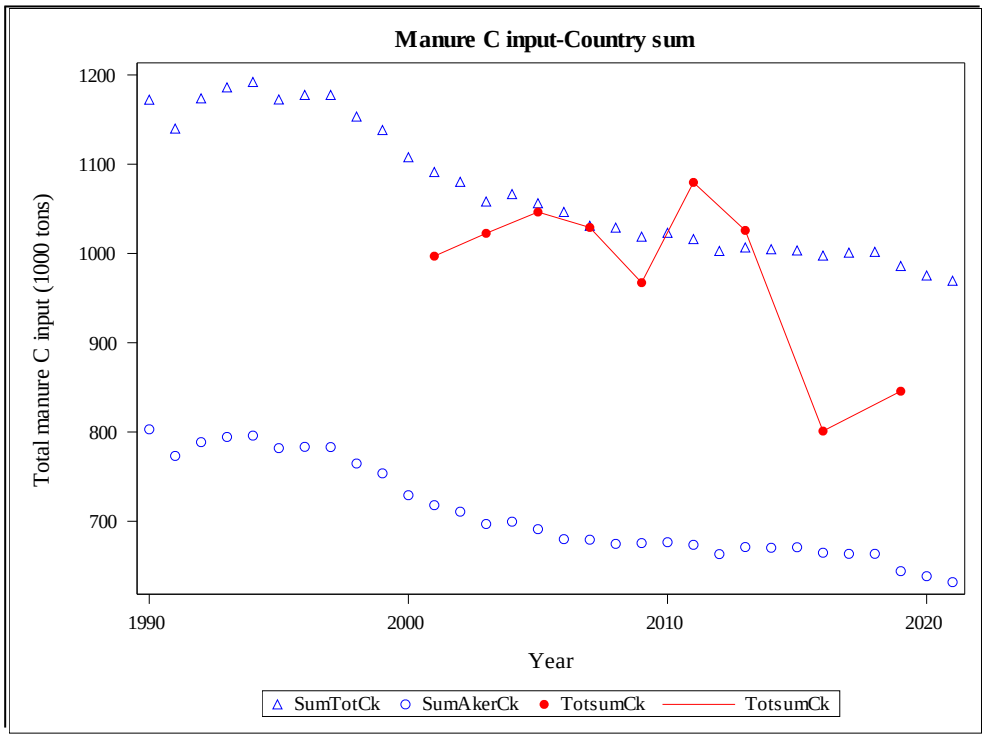

Fig. 3. Total amount of carbon produced in manures for Sweden from all livestock categories calculated with the animal number based (ANB) approach (upper blue line in triangles) as well as the amount produced only during the period when the animals are in the stable by subtracting the grazing period (lower blue line in circles). The filled red circles are presenting total amount of carbon calculated with the *Gödselmedelsundersökningen* (GMU) approach using corrected dry matter contents for 2007 and onwards (as described in Fig. 2).

The GMU and ANB approaches are not here considered being directly comparable in absolute amounts because this requires additional calculations, i.e., it would be necessary making assumptions of carbon also coming from the litter in bedding materials such as straw, peat and sawdust. Our purpose here was to give a relative indication for the evolution of the total amount of manure produced over time provided the time series obtained with the ANB approach. Furthermore, we assumed that the amount of litter used in bedding

is proportionally the same over time for the different livestock categories. This may of course not necessarily be the case since as it depends on the type of litter used as well as the manure storage forms, which depends on the production system used, both of which may change over time. In particular for the period 1990 up to approximately 2005.

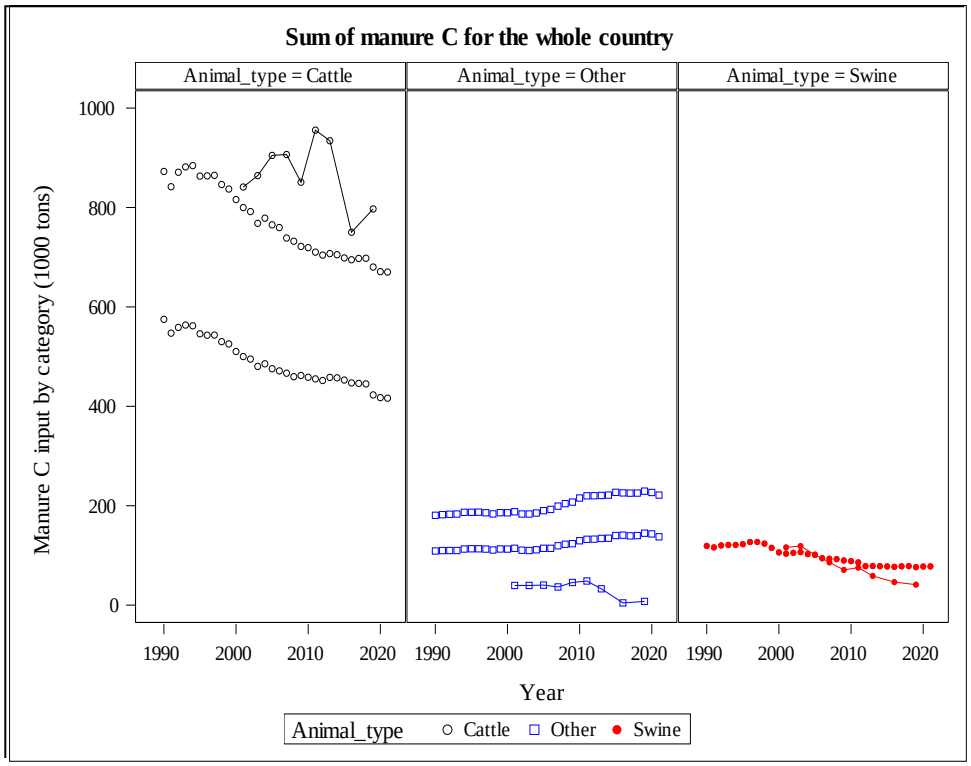

Fig. 4. Total amount of carbon produced in manures for Sweden from each of the livestock categories calculated with the animal number based (ANB) approach (upper circles) as well as the amount produced only during the period when the animals are in the stable by subtracting the grazing period (lower circles). The interpolated line is presenting total amount of carbon calculated with the *Gödselmedelsundersökningen* (GMU) approach using corrected dry matter contents for 2007 and onwards (as described in Fig. 2).

The time series with the ANB approach for all livestock categories combined are much smoother compared with the GMU approach, and they are steadily decreasing from 1997 (Fig. 3.). As for the GMU approach (data not shown), there is a small increase from 1991 to 1997. When looking at the three different livestock categories separately, it shows the cattle manure is driving these trends because of its dominant contribution to the total amount of carbon from manure (Fig. 4.). For the category other livestock, there is actually a small increasing trend, while it is the opposite with the GMU approach. The swine livestock category is showing the best match in trends over time with the ANB and GMU approaches (note that there is only one time series with

the ANB approach for this category since there is no grazing period). It is also clear that data for 2011, 2013, 2016 and 2019 with the GMU approach is particularly different from the trend compared to the ANB approach, especially for 2016 and 2019.

The time series with the ANB and GMU approaches for all livestock categories combined for each of the eight production regions (PO8s) separately are presented in Appendix I. Data from the GMU approach for PO5 and PO6 are more or less aligning around the time series with the total amount of manure excreted using the ANB approach, while that for PO7 and PO8 are above this time series. For PO1 through PO4, data from the GMU approach are more or less in between the two time series using the ANB approach (i.e., that for the total amount of manure excreted and that for the total amount of manures excreted only during the period the animals are in the stable). This may suggest there are potentially some inconsistency in the GMU approach between regions.

When looking at the three different livestock categories separately for each of the eight POs separately (Appendix II), it is showing more or less the same patterns as for the country (i.e., as in Fig. 4). Cattle manure is contributing the most to the amount of carbon from manure for each of the PO8s with both GMU and ANB approaches, and thereby explains most of the trends in Appendix I. Similarly, the category other livestock is often showing a small increasing trend with the ANB approach (while it is the opposite with the GMU approach), and the swine livestock category is generally showing the best match in trends over time between the ANB and GMU approaches.

Furthermore, in most cases, the high values for 2011 and 2013 as well as the low values for 2016 and 2019 with the GMU approach are reflected in both Appendix I and II. However, not always, and there are some noticeable differences for some of the PO8s.

Future Prospects & Conclusions

Using the GMU approach, with the hypothesis that the DM content changed from 2007 onwards, is giving a better time series for carbon from manures, in the sense that there is an overall decreasing trend. This in agreement with the general trend observed with the ANB approach. However, there remains a high variability, particularly in the data from the last four GMU reports, both for the whole country and for some of the PO8s. In this report, we cannot say anything about why this is the case, and it was not the purpose of this work. Nevertheless, our observations lead us to consider that it might be the data for 2011 and 2013 that are eventually overestimated, rather than that the data for 2016 and 2019 are too low. It should also be underlined that there is a lack of detailed data for the evolution of the DM content in different manure storage forms through time, what we did here can be seen as a rough estimate for that hypothesis. The assumption we are making in the calculations with the GMU approach by considering a carbon content in manures of 45% is also simplistic. In fact, the carbon content can be influenced by the amount of ash (i.e., non-volatile solids originating from soil particles, salts and recalcitrant plant compounds in animal feeds), and it may vary between livestock categories, storage forms and storage time (Larney et al. 2005), but there are no such activity data available. Furthermore, other factors involved in the GMU approach may play a role, on which the authors have no expertise. For example, uncertainties relating to how the statistics are produced.

The time series of carbon from manures using the ANB approach are much smoother. An advantage with the GMU approach is that the amount of carbon from litter in bedding materials are included, and the estimates are reflecting the actual amounts of manure applied annually on arable land. There is a need to consider this when adapting the ANB approach as input data to the ICBM model. It is possible to achieve this by completing the ANB time series of data when the grazing period is excluded, by adding data for the amount of small-grain cereal straw, peat and sawdust used for litter. However, this would not include the losses of carbon during manure storage, contrary to the estimates with the GMU approach, where these are (indirectly) already included.

Since the major part of straw exported from the fields are used in animal production systems as bedding material, it would be possible to account for this by running the ICBM model simply by assuming all straw is left in the field. There remains to determine the quantity of peat and sawdust used as litter in Sweden, and to verify if we can obtain reliable activity data from national statistics over time. Another issue, that is relating to both approaches, is that during the grazing period, the animals are not necessarily grazing only on land classified as pastures, i.e., animals can be grazing on arable land after

the last (or in between) ley cuts. Both approaches for estimating carbon from manures have their advantages and disadvantages because of difficulties in activity data. However, it is a better option adapting the ANB approach so that the LULUCF sector is using as similar methods and activity data as possible compared to that of the agricultural sector. For the moment, we are using the GMU approach with the hypothesis that the DM content changed from 2007 onwards but we will continue our work to adapt the ANB approach with the intent of using this as input data for the ICBM model.

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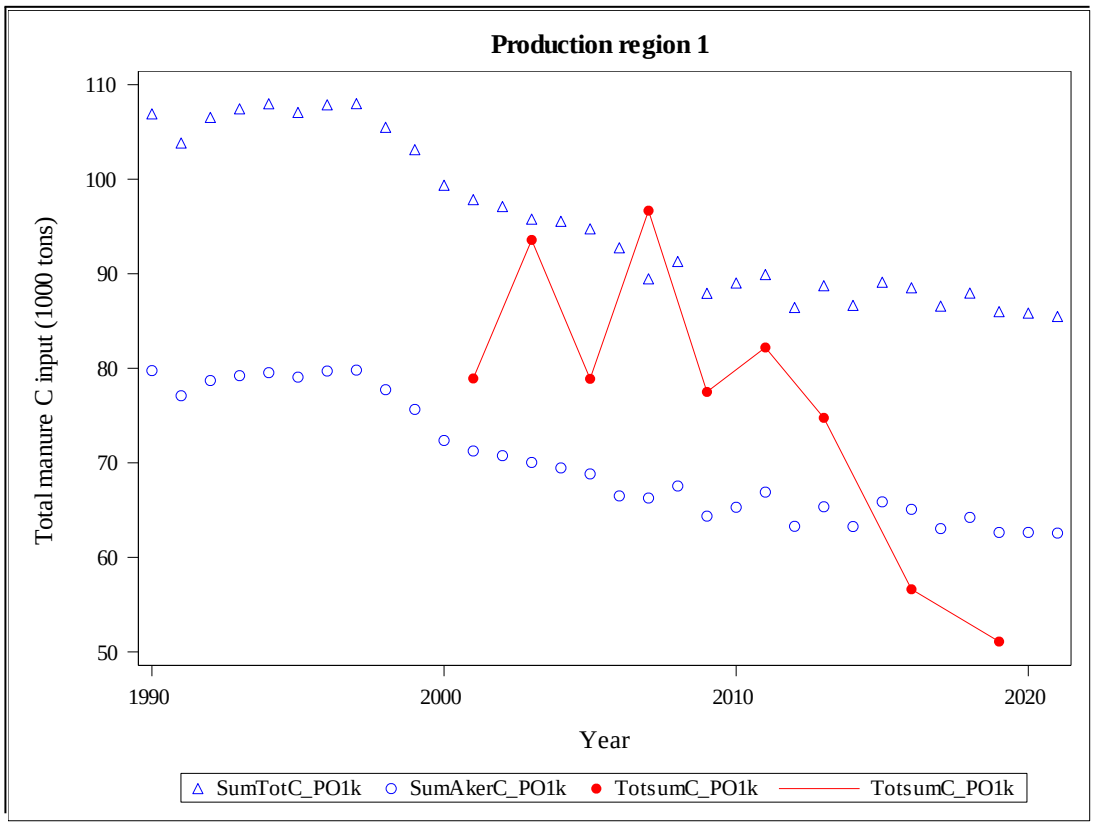
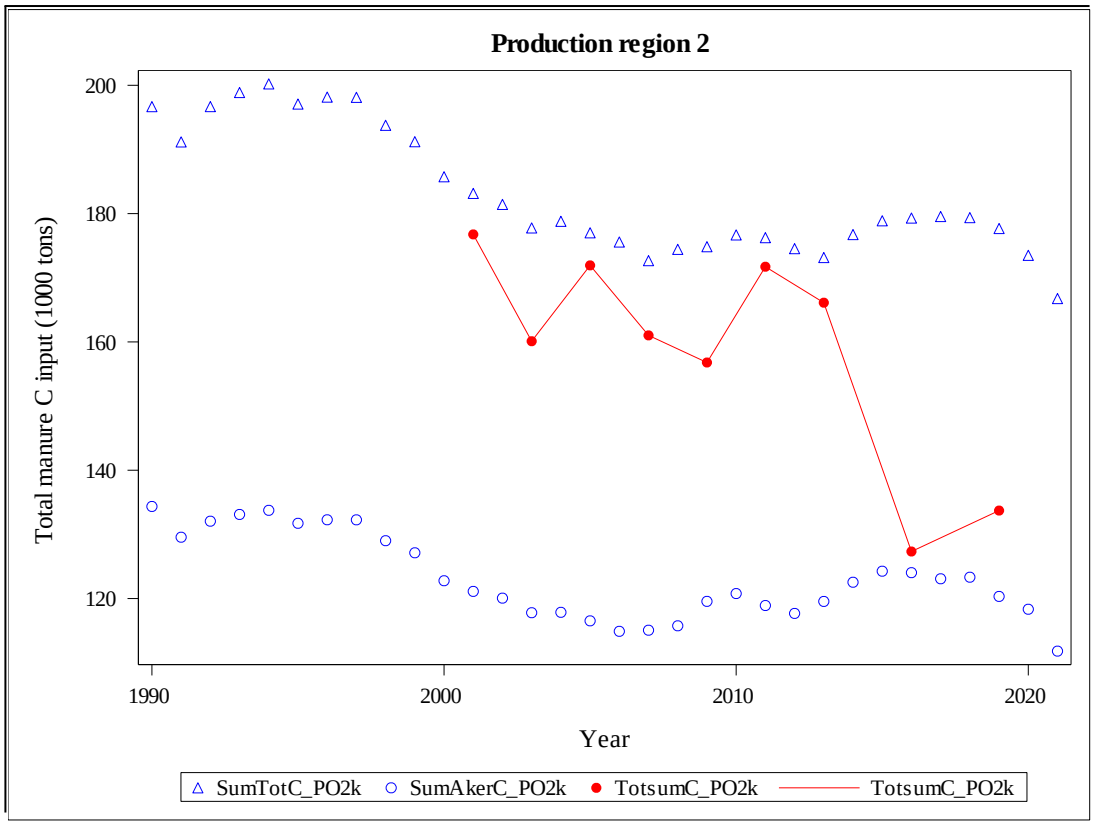
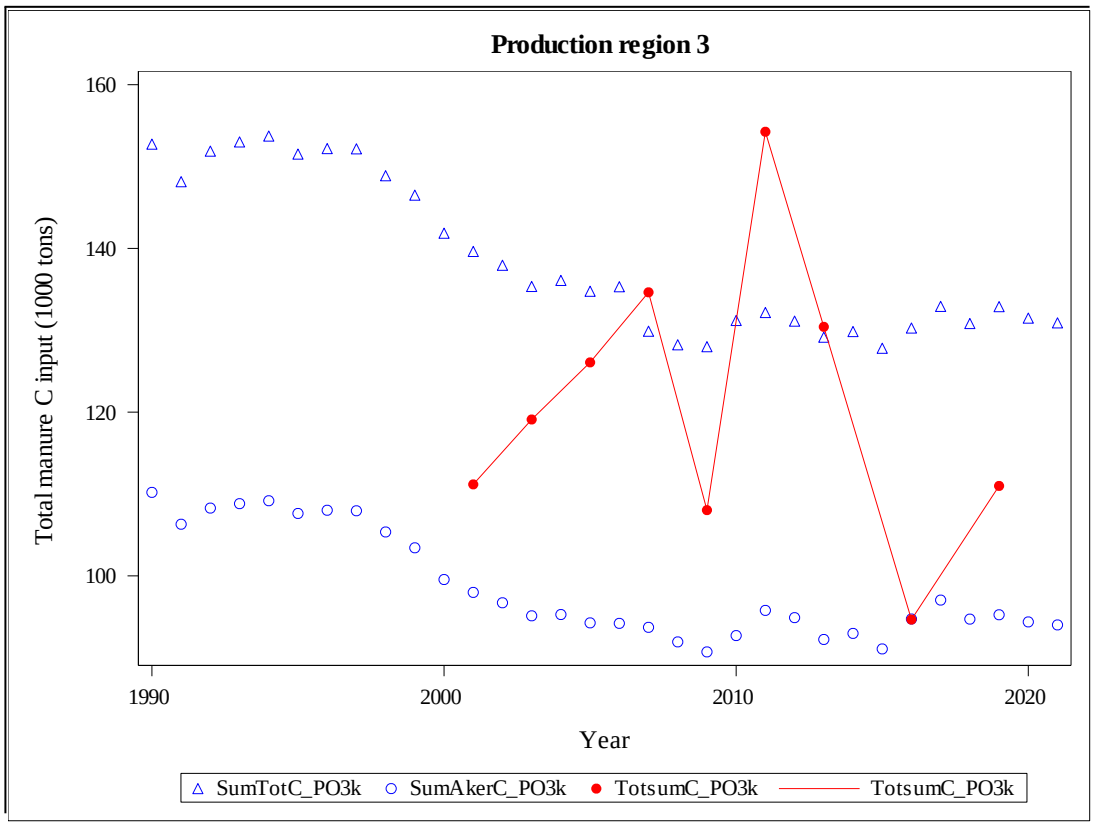
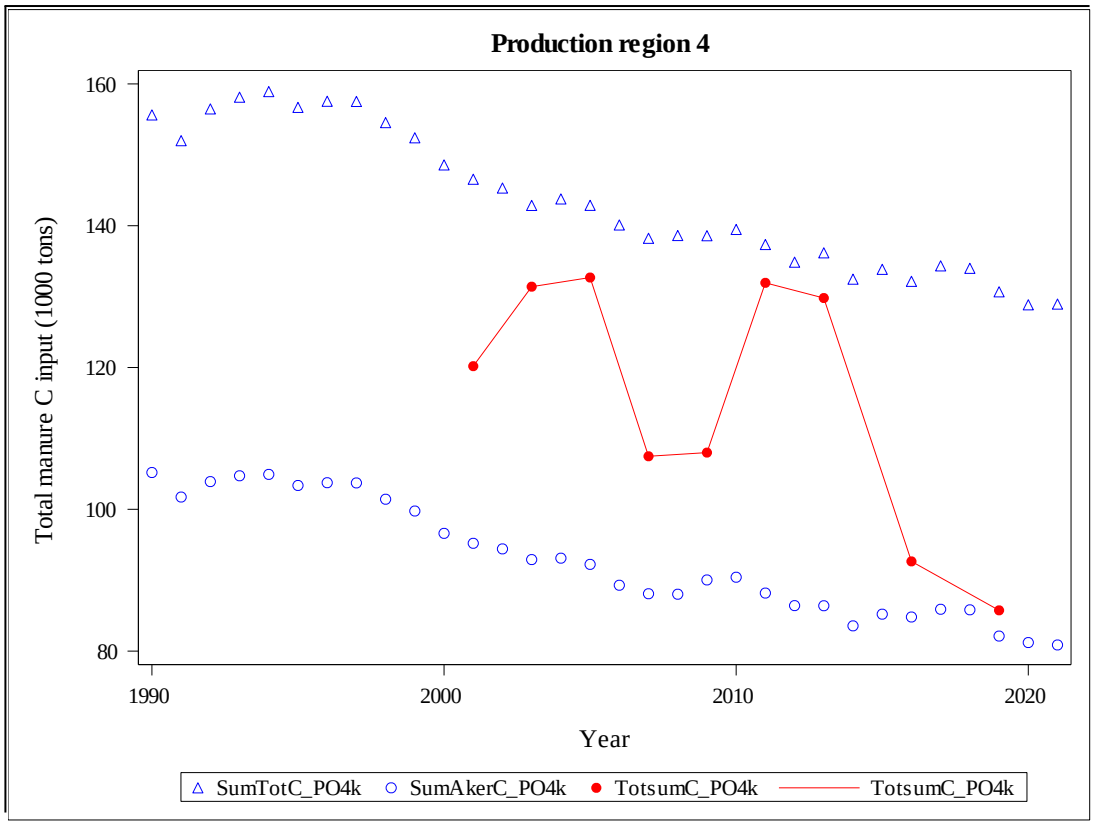
Appendix I

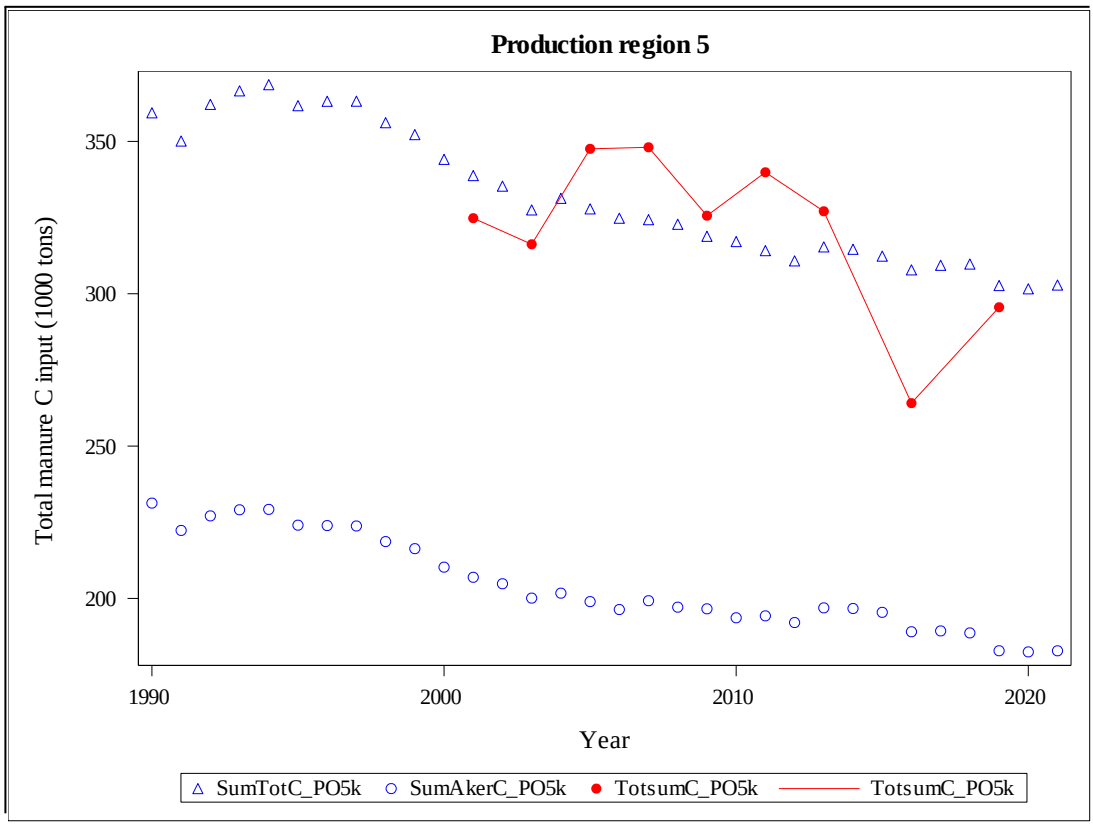
Figures: Total amount of carbon produced in manures for each agricultural production region (PO8) in Sweden from all livestock categories calculated with the animal number based (ANB) approach (upper blue line in triangles) as well as the amount produced only during the period when the animals are in the stable by subtracting the grazing period (lower blue line in circles). The filled red circles are presenting total amount of carbon calculated with the *Gödselmedelsundersökningen* (GMU) approach using corrected dry matter contents for 2007 and onwards (as described in Fig. 2).

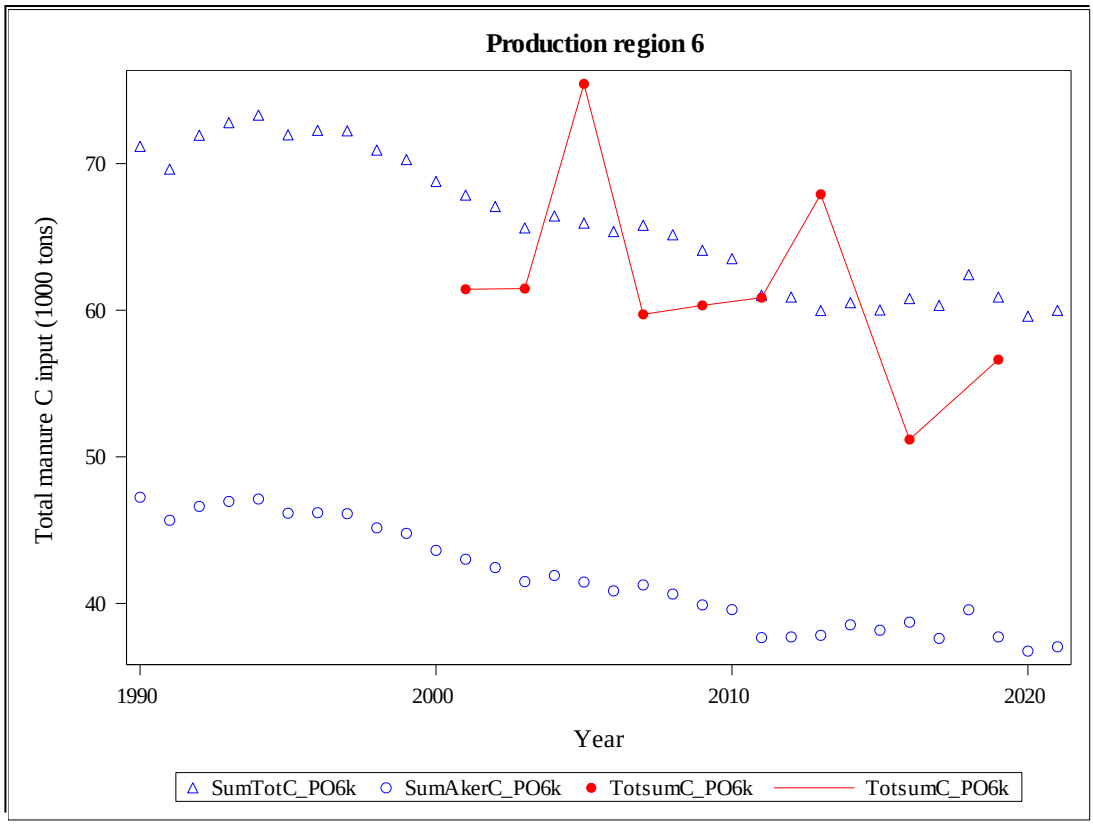

Production region 1
Total manure C input (1000 tons)
110
100
90
80
70
60
50
1990
2000
2010
2020
Year
SumTotC_PO1k
SumAkerC_PO1k
TotsumC_PO1k
TotsumC_PO1k

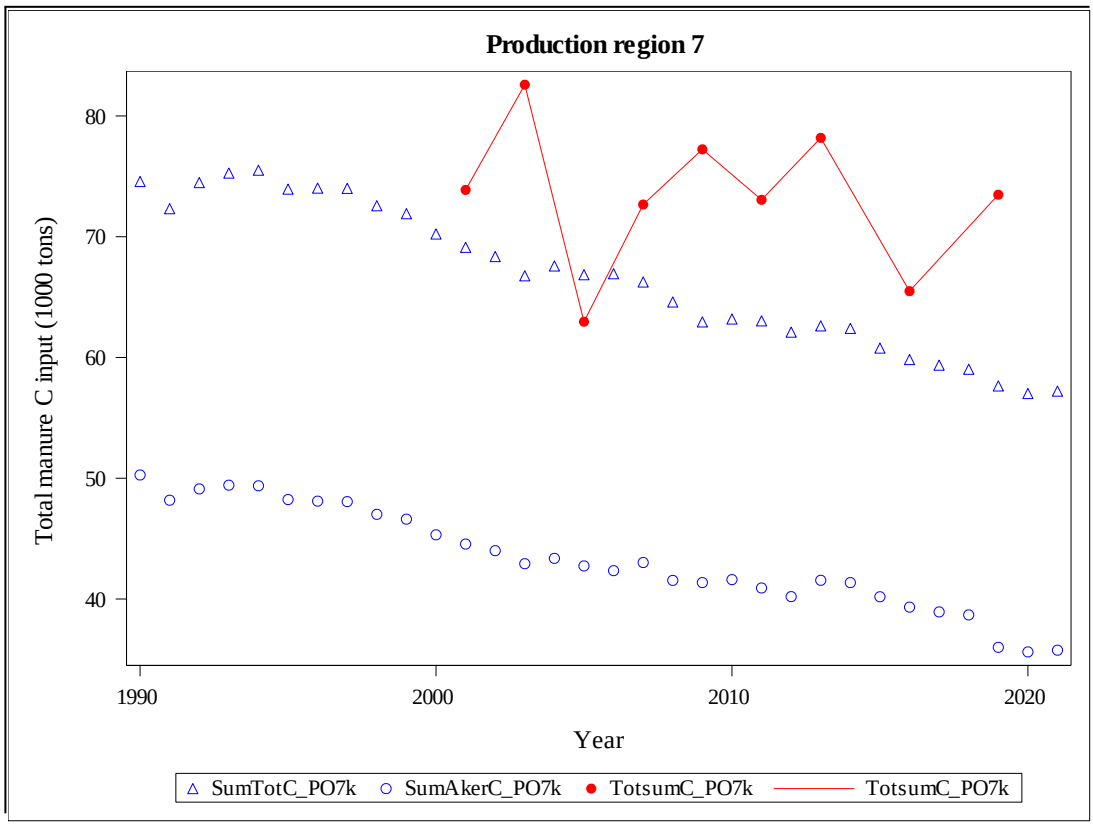

Production region 2
Total manure C input (1000 tons)
200
180
160
140
120
1990
2000
2010
2020
Year
SumTotC_PO2k
SumAkerC_PO2k
TotsumC_PO2k
TotsumC_PO2k

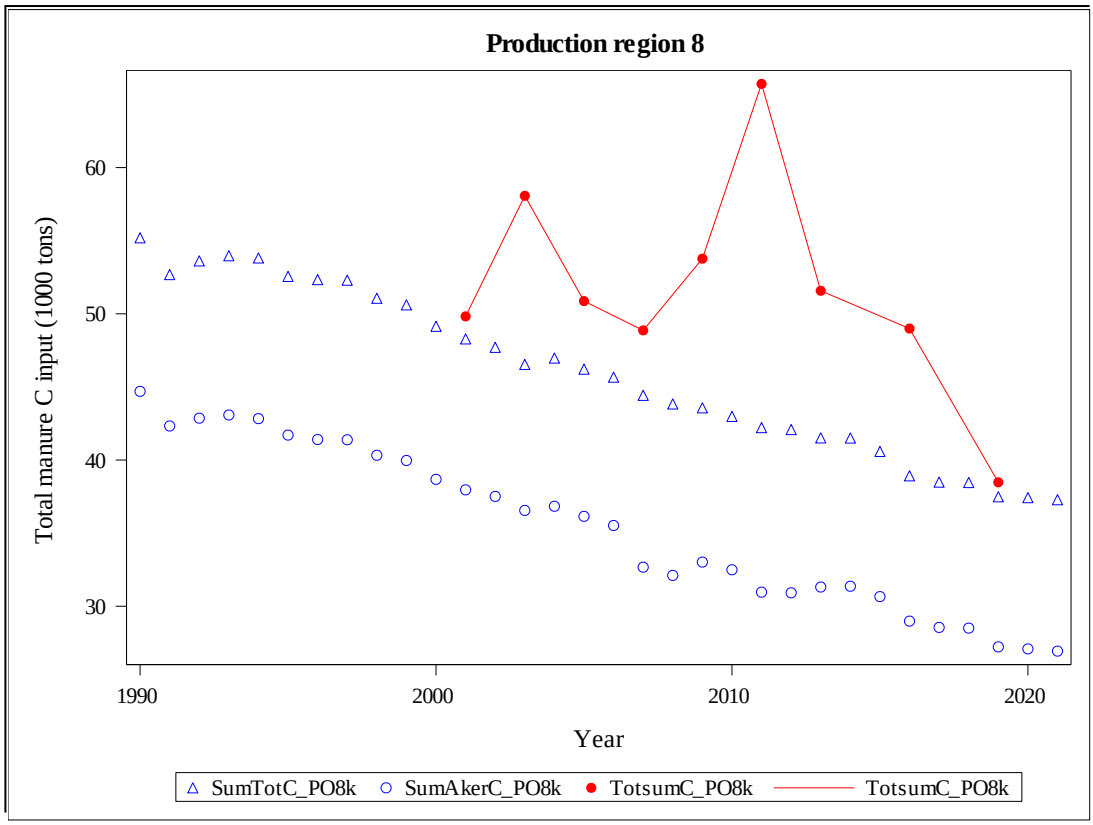

Production region 3
Total manure C input (1000 tons)
160
140
120
100
1990
2000
2010
2020
Year
SumTotC_PO3k
SumAkerC_PO3k
TotsumC_PO3k
TotsumC_PO3k


Production region 4
Total manure C input (1000 tons)
160
140
120
100
80
1990
2000
2010
2020
Year
SumTotC_PO4k
SumAkerC_PO4k
TotsumC_PO4k
TotsumC_PO4k


Production region 5
Total manure C input (1000 tons)
350
300
250
200
1990
2000
2010
2020
Year
SumTotC_PO5k
SumAkerC_PO5k
TotsumC_PO5k
TotsumC_PO5k

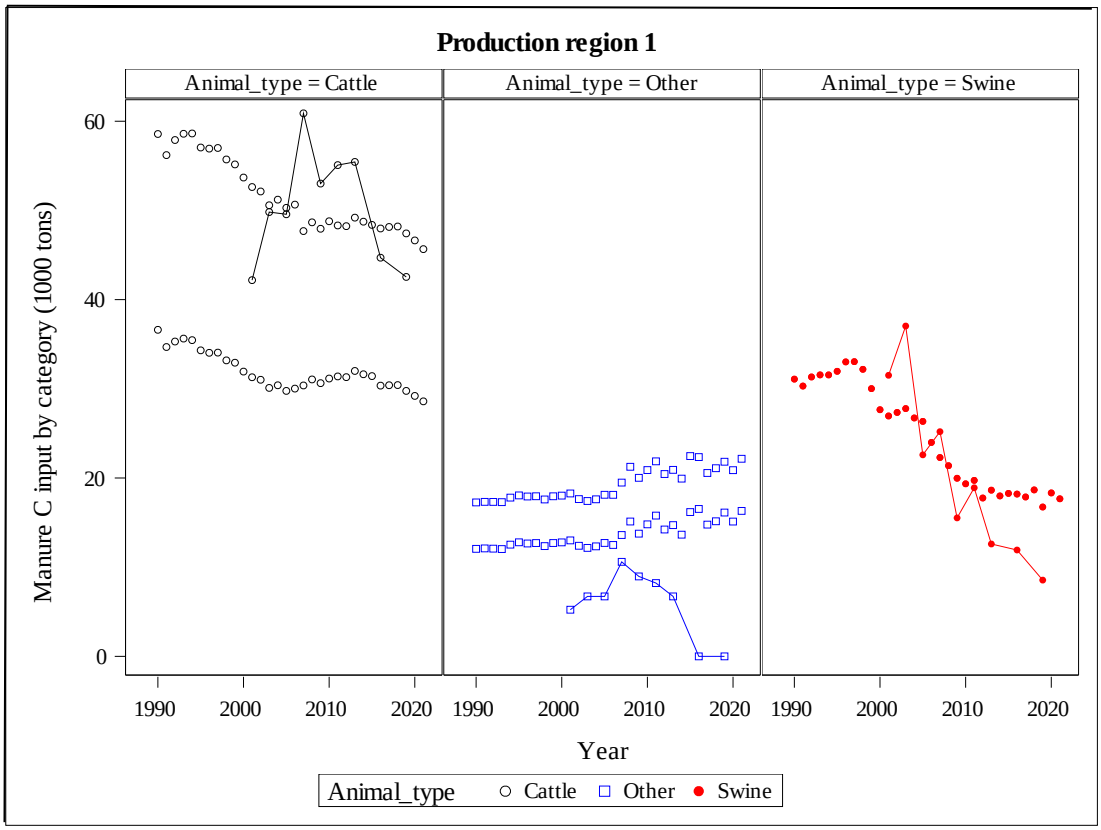

Production region 6
Total manure C input (1000 tons)
70
60
50
40
1990
2000
2010
2020
Year
SumTotC_PO6k
SumAkerC_PO6k
TotsumC_PO6k
TotsumC_PO6k

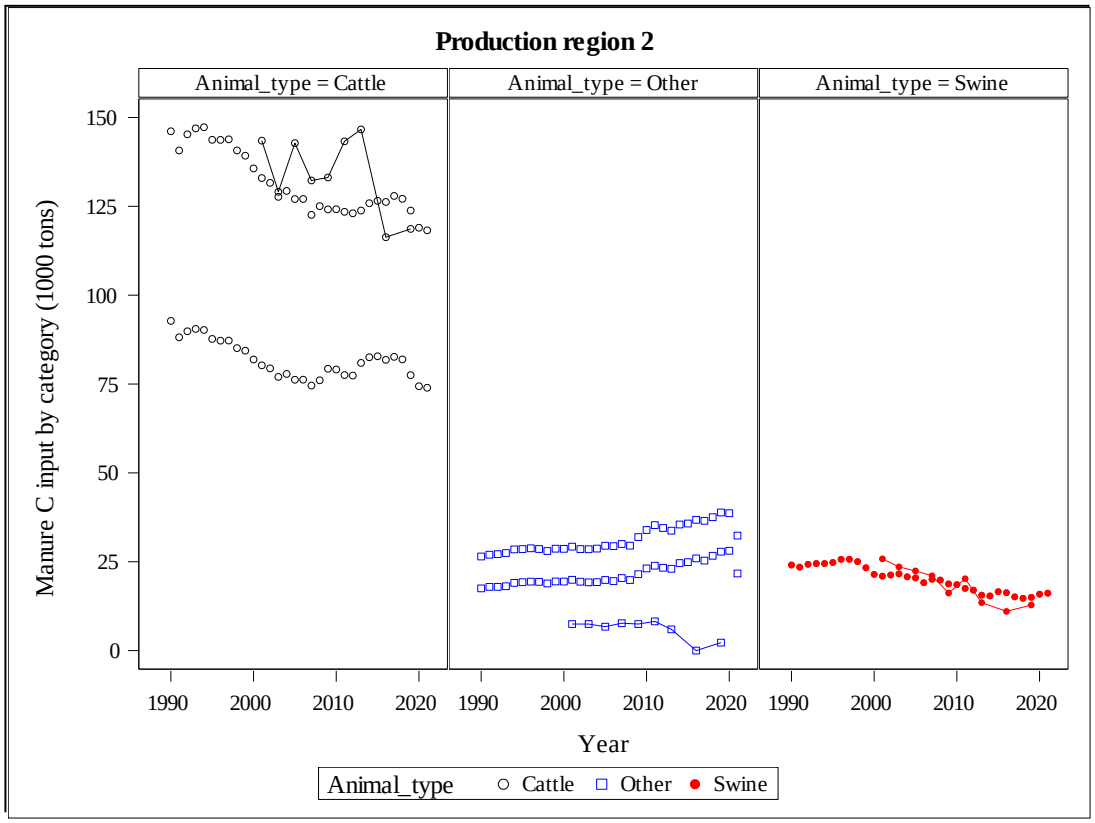

Production region 7
Total manure C input (1000 tons)
80
70
60
50
40
1990
2000
2010
2020
Year
SumTotC_PO7k
SumAkerC_PO7k
TotsumC_PO7k
TotsumC_PO7k

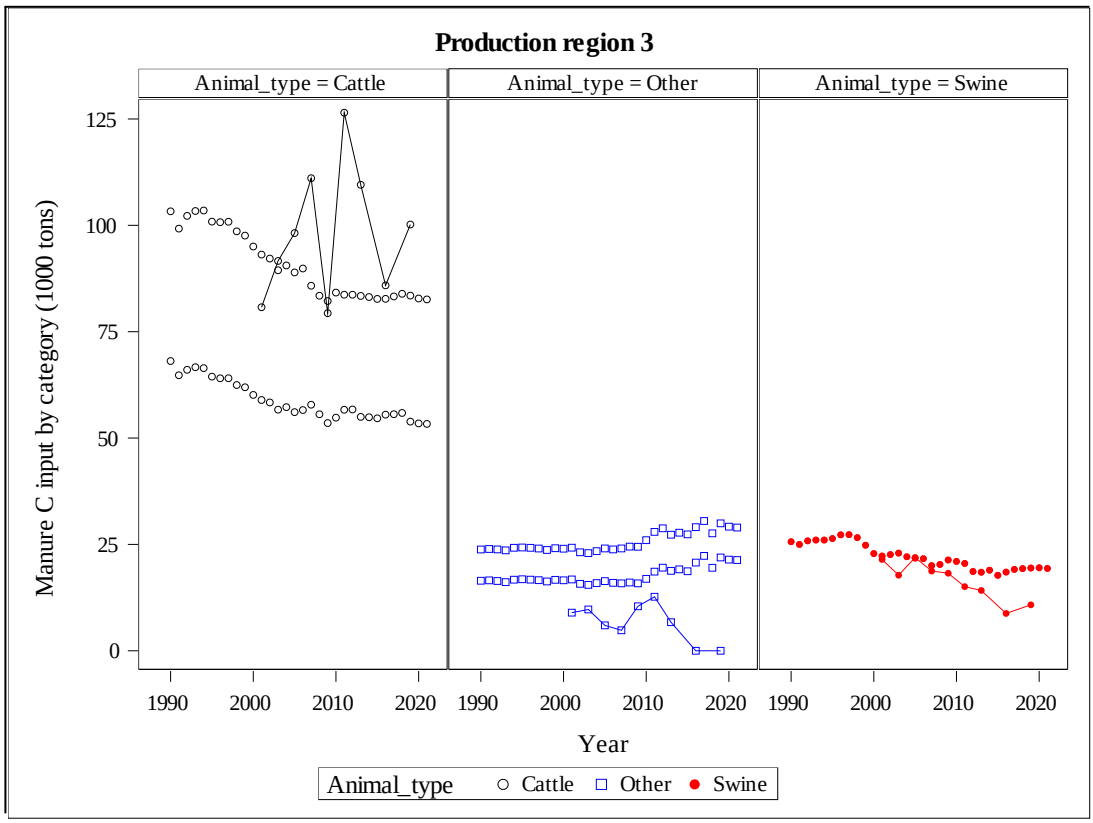

Production region 8
Total manure C input (1000 tons)
60
50
40
30
1990
2000
2010
2020
Year
SumTotC_PO8k
SumAkerC_PO8k
TotsumC_PO8k
TotsumC_PO8k

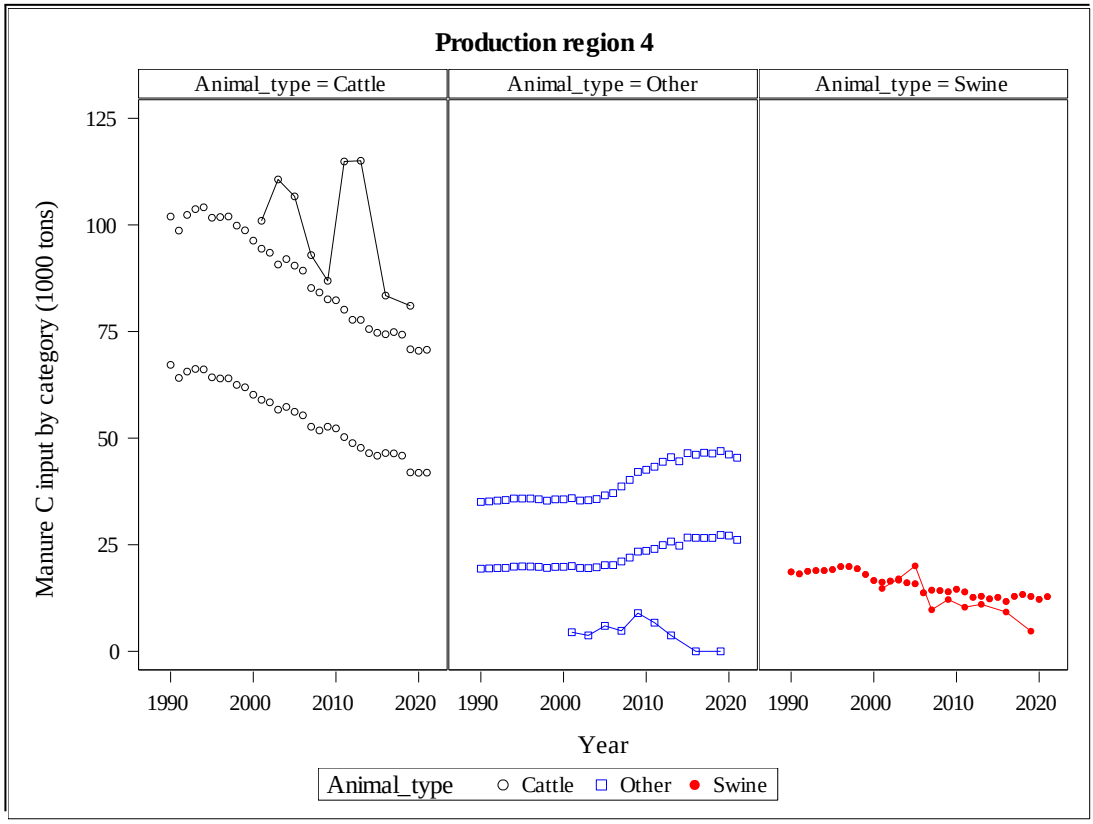
Appendix II

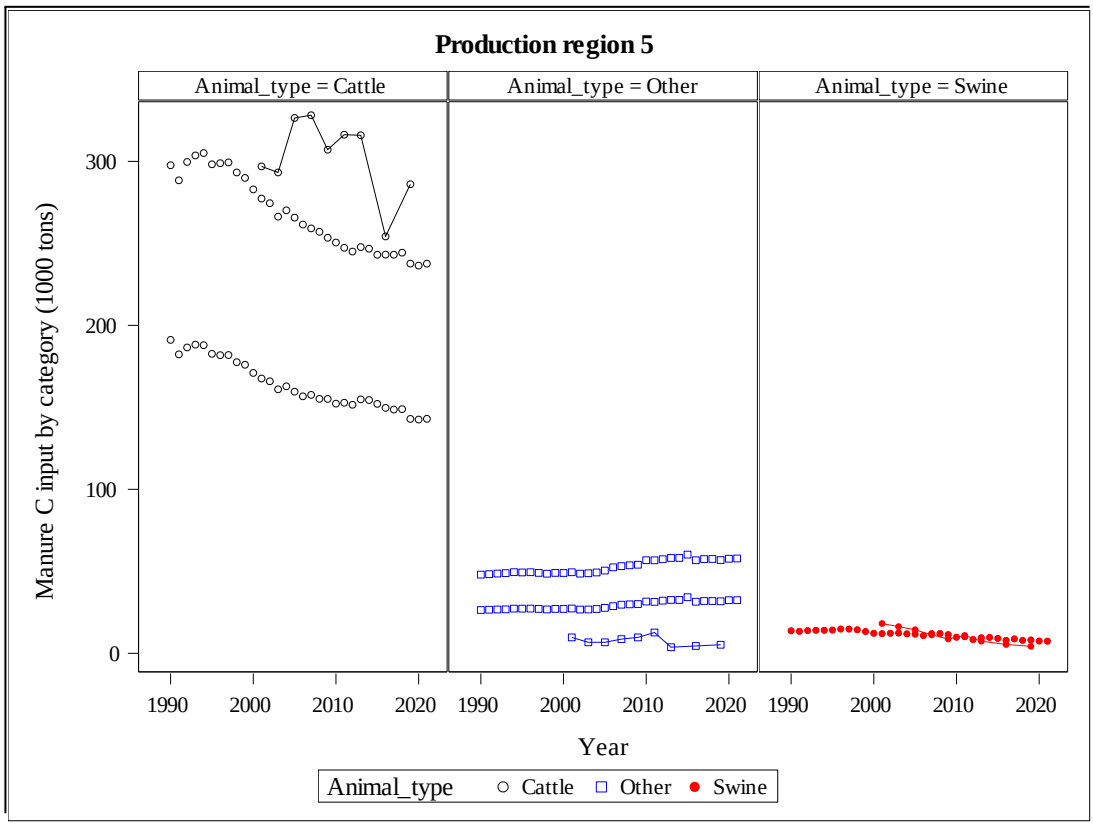
Figures: Total amount of carbon produced in manures for each agricultural production region (PO8) in Sweden from each of the livestock categories calculated with the animal number based (ANB) approach (upper circles) as well as the amount produced only during the period when the animals are in the stable by subtracting the grazing period (lower circles). The interpolated line is presenting total amount of carbon calculated with the *Gödselmedelsundersökningen* (GMU) approach using corrected dry matter contents for 2007 and onwards (as described in Fig. 2).

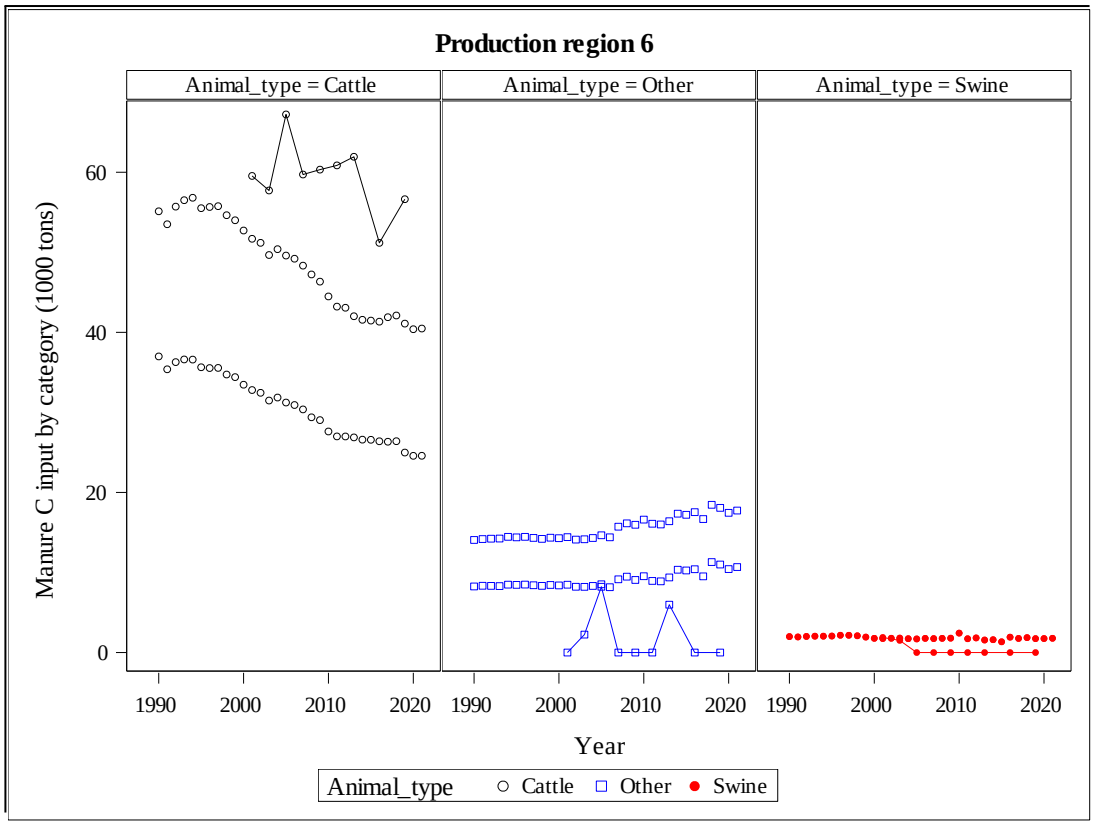

Production region 1
Animal_type = Cattle
Animal_type = Other
Animal_type = Swine
Manure C input by category (1000 tons)
0
20
40
60
1990
2000
2010
2020
Year
Animal_type
Cattle
Other
Swine

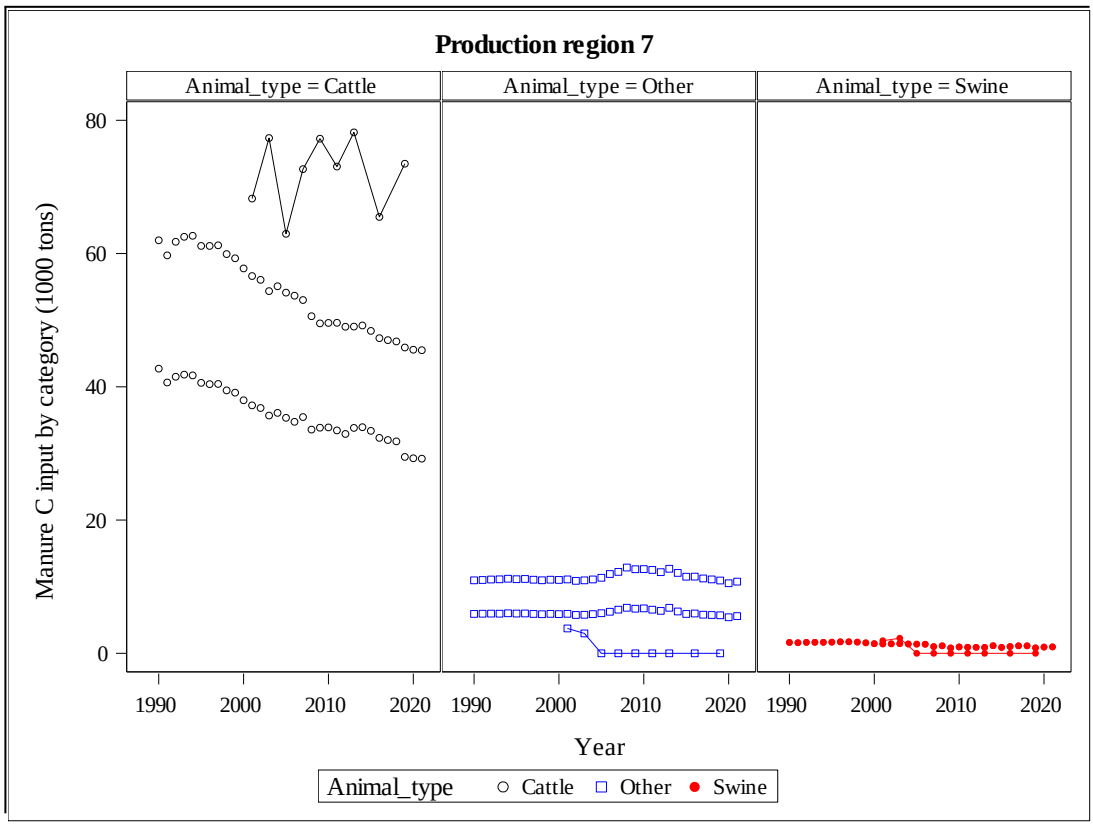

Production region 2
Animal_type = Cattle
Animal_type = Other
Animal_type = Swine
Manure C input by category (1000 tons)
0
25
50
75
100
125
150
1990
2000
2010
2020
Year
Animal_type
Cattle
Other
Swine

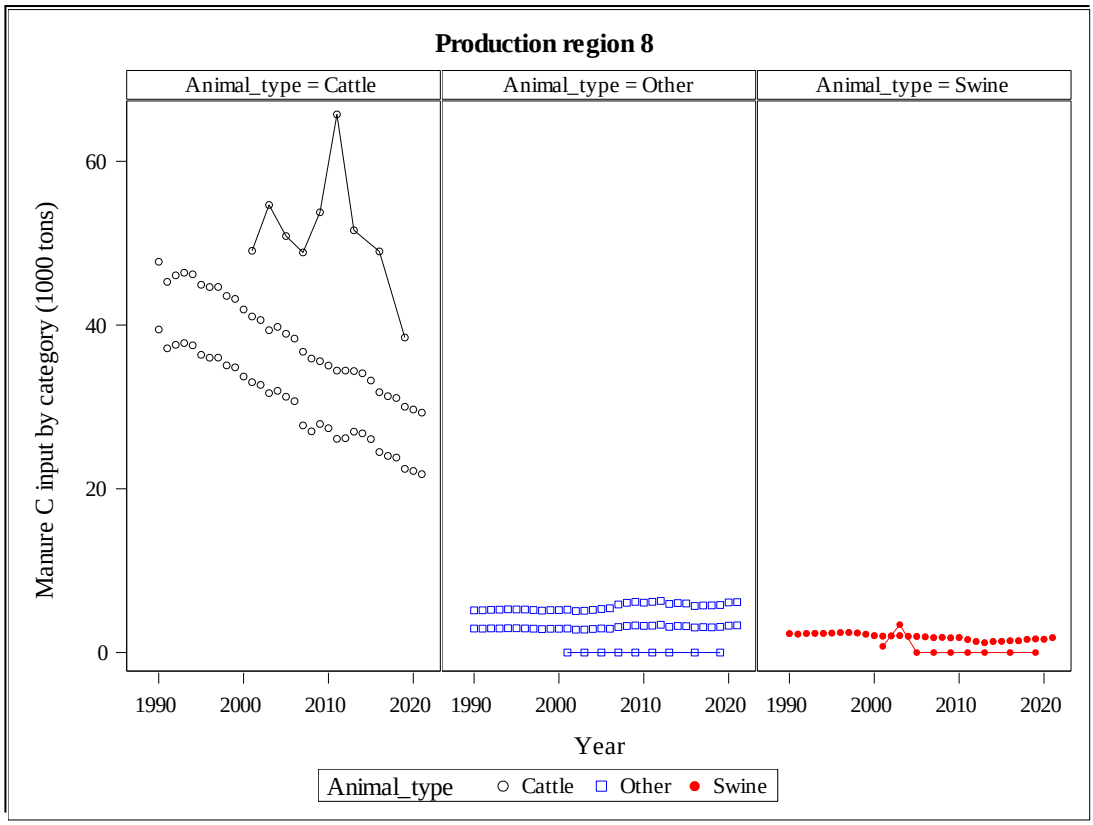

Production region 3
Animal_type = Cattle
Animal_type = Other
Animal_type = Swine
Manure C input by category (1000 tons)
125
100
75
50
25
0
1990
2000
2010
2020
Year
Animal_type
Cattle
Other
Swine


Production region 4
Animal_type = Cattle
Animal_type = Other
Animal_type = Swine
Manure C input by category (1000 tons)
125
100
75
50
25
0
1990
2000
2010
2020
Year
Animal_type
Cattle
Other
Swine


Production region 5
Animal_type = Cattle
Animal_type = Other
Animal_type = Swine
Manure C input by category (1000 tons)
300
200
100
0
1990
2000
2010
2020
Year
Animal_type
Cattle
Other
Swine


Production region 6
Animal_type = Cattle
Animal_type = Other
Animal_type = Swine
Manure C input by category (1000 tons)
60
40
20
0
1990
2000
2010
2020
Year
Animal_type
Cattle
Other
Swine


Production region 7
Animal_type = Cattle
Animal_type = Other
Animal_type = Swine
Manure C input by category (1000 tons)
0
20
40
60
80
1990
2000
2010
2020
Year
Animal_type
Cattle
Other
Swine


Production region 8
Animal_type = Cattle
Animal_type = Other
Animal_type = Swine
Manure C input by category (1000 tons)
0
20
40
60
1990
2000
2010
2020
Year
Animal_type
Cattle
Other
Swine