MODELLING OF FAM-GATE NITROGEN BALANCE IN PIG PRODUCTION – CASE STUDY OF LATVIA

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Abstract. The 150 million pigs reared across EU represent the largest livestock category before that of bovines. In Latvia in 2021 the number of pigs reached 327.0 thousand. The European Green Deal is aimed at transforming EU into an equitable and prosperous society, with a modern, competitive and efficient economy in the use of resources, in which there are no net emissions of greenhouse gases. The EU taxonomy for sustainable activities stipulates that economic activity can qualify as environmentally sustainable only if it substantially contributes to one or more environmental objectives. In case of agriculture, there are limited options how to contribute substantially. One of these options is ensuring sustainable farm-gate nitrogen balance. Moreover, in pig production this option is almost the only real option, especially for landless pig farms. The Platform on Sustainable Finance has proposed several indicators how to measure the farm-gate nitrogen balance, e.g. nitrogen use efficiency (NUE). There is a lack of systematic knowledge about the fam-gate nitrogen balance in Latvia's pig farming. Therefore, the aim of the study was to model the farm-gate nitrogen balance and examine NUE for both conventional and organic pig production. The input data for modelling were derived from two comparable models of pig production (conventional and organic, 1 000 sows, full production cycle). The criterion of minimum NUE (40%) proposed by the platform was applied to assess the results of the modelling. Results of the study reveal that possibility to meet the minimum NUE of 40% depends on NUE of feed. NUE of feed should be higher than 50% in order to reach the minimum NUE of 40%: at least 58% (conventional production) and 66% (organic production). Thus, ensuring NUE of pig production at least 40% could be challenging for pig farms that purchase feed with unknown NUE or low NUE.

Keywords: nitrogen balance, nitrogen use efficiency, pig production, modelling, EU Taxonomy.

Introduction

The global nitrogen cycle plays a central role in the biogeochemistry of the Earth with large natural flows of nitrogen from the atmosphere into terrestrial and marine ecosystems through biological nitrogen fixation (BNF), in which the largely un-reactive molecular nitrogen is reduced to ammonium compounds. The fixed nitrogen is subsequently transformed into a wide range of amino acids and oxidized compounds by micro-organisms, and finally returns to the atmosphere as molecular nitrogen through microbial denitrification in soils, fresh and marine waters and sediments [1]. Nitrogen (N) is essential for life and plays a key role in food production, being among the most important crop yield-limiting factors in the world, together with water [2]. However, N losses contribute to climate change and lead to pollution of the environment, which is harmful for the functioning of ecosystems and human health [**Error! Reference source not found.**; **Error! Reference source not found.**]. Recent studies ha ve suggested that current N losses from agriculture to the environment are too high for a 'safe operating space for humanity' [4]. Continuing population and consumption growth during the coming decades will further increase the demand for N fertiliser and may increase N losses and aggravate the trespassing of the 'safe operating space' unless significant improvements are made in the whole food production–consumption chain [5]. Pig and poultry production systems have reached high-performance levels over the last few decades. Together, these sectors provide a large amount of affordable and nutritious food, especially high-quality protein, contributing to food security worldwide. However, there is still room for improvement when it comes to their environmental sustainability. Feeding pigs and poultry requires tremendous amounts of feed resources, with several studies indicating it as an important source of environmental impact [6]. The 150 million pigs reared across EU represent the largest livestock category before that of bovines, and the EU pig meat sector alone accounts for nearly half of total EU meat production [7]. The pig production plays significant role in Latvia's livestock farming as well. According to the provisional data of the Central Statistical Bureau, in 2021 the number of pigs reached 327.0 thousand [8]. Nitrogen efficiency in pork production has improved through the application of scientific knowledge gained since the 1980s; further improvements can be expected by implementing recent knowledge [9].

The European Green Deal is aimed at transforming the European Union into an equitable and prosperous society, with a modern, competitive and efficient economy in the use of resources, in which there are no net emissions of greenhouse gases [10]. The EU taxonomy for sustainable activities stipulates that economic activity can qualify as environmentally sustainable only if it substantially contributes to one or more environmental objectives [11]: (i) climate change mitigation, (ii) climate change adaptation, (iii) sustainable use and protection of water and marine resources, (iv) transition to a circular economy, (v) pollution prevention and control, and (vi) protection and restoration of biodiversity and ecosystems. In case of agriculture, technical screening criteria have not been adopted yet. Nevertheless, the proposals by the Platform on Sustainable Finance allow concluding that there will be limited options how to contribute substantially. Actually, there will be three general options – substantial contribution to climate change mitigation, climate change adaptation or protection and restoration of biodiversity and ecosystems (B&E).

The platform has developed several proposals on the technical screening criteria for the substantial contribution to B&E, but the proposed technical criteria for the substantial contribution to climate objectives have been recalled and are being revised now. The available information on forthcoming technical screening criteria indicates that ensuring sustainable farm-gate nitrogen balance will probably be the most realistic option for pig production, especially for landless pig farms. Up to date, hardly any study has looked specifically at farm-gate nitrogen balance in Latvia’s sector of pig production. Thus, there is a lack of systematic knowledge about fam-gate nitrogen balance in Latvia’s pig farming. Moreover, it is possible that nitrogen balance (including nitrogen use efficiency) of pig farms will affect the access of pig farms to finance [12]. Therefore, the aim of the study was to model the farm-gate nitrogen balance and examine nitrogen use efficiency for both conventional and organic pig production. The scope of this study is solely pig production. Feed (feed crop) production and utilisation of manure are not within the scope of this article. Consequently, the farm-gate nitrogen balance has been modelled for a landless farm.

Materials and methods

The main data sources for the study are information and empirical data obtained within the research project “Assessment of impact of EU framework promoting sustainable finance on agriculture” (2021-2022) and the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) project “Sustainable development of pig breeding based on organic farming and free from antibiotics” (2019-2022). The models of conventional and organic pig production developed within the EIP-AGRI project have been used as the basis for modelling of fam-gate nitrogen balance.

Table 1

Key assumptions of models of conventional and organic pig production in Latvia

Parameters	Convectional production	Organic production
Size of herd, number of breeding sows	1 000	1 000
Exported animals (in year)		
Sold fattening pigs, kg live weight	2 778 236	2 307 960
Excluded* fattening pigs and gilts (30-85 kg), kg live weight	15 372	11 182
Excluded* gilts (85-120 kg), kg live weigh	6 852	8 097
Excluded* gilts (120-150 kg), kg live weigh	5 157	5 157
Excluded* breeding sows, kg live weight	67 500	67 500
Feed consumption		
Breeding sows, t per year	1 100.0	1 100.0
Piglets (till weaning), t per year	48	224.2
Weaners (up to 30 t), t per year	988.9	916.6
Gilts (30-120 t), t per year	119.6	108.0
Fattening pigs, t per year	5 673.1	4 722.3
Gilts (120-150 t), t per year	51.6	51.6
Straw consumption, t per year	50.0	780.0

*sold because of excluding from the herd

Source: the study by Auzins, Leimane and Krievina [13]

These models of conventional and organic pig production are full production cycle models (involve the herd from piglets to breeding sows), and they are comparable to each other. The assumptions and principles of these models are laid out within the study by Auzins, Leimane and Krievina [13]. The key assumptions of these models are presented in Table 1.

The methodology proposed by the platform [**Error! Reference source not found.**; **Error! Re ference source not found.**] has been used to assess and model the fam-gate nitrogen balance of pig production. As mentioned above, the assessment of nitrogen balance has been conducted without considering feed production and utilisation of manure. Thus, all feed (also straw as bedding) is regarded as imported feed, an all manure is regarded as exported manure. According to this methodology, feed and straw have been considered as N inputs, and exported animals and manure – as N outputs. All sold animals (both finished flattening pigs and excluded pigs) have been regarded as exported animals. However, fallen animals have not been regarded as exported animals and included as N outputs.

The N input from feed is assessed according to the crude protein content. The standard nitrogen to protein conversion factor (Kjeldahl method) 6.25 specified by ISO 20483:2013(E) [16] is used to calculate N content from crude protein content. The assumptions about crude protein contents and the calculated N contents are presented in Table 2.

Table 2

Assumptions about crude protein content of feed and calculated N content

Feed	Crude protein content, kg per t product	N content, kg per t product
Feed for lactating sows	160	25.6
Feed for gestating sows	140	22.4
Milk replacer*	260	41.6
Prestarter	220	35.2
Starter**	190	30.4
Link	190	30.4
Grower	160	25.6
Finisher	150	24.0
Feed for gilts (120-150 kg)	150	24.0

*used only in conventional pig production

** used only in organic pig production

Source: the authors' assessment (project "Sustainable development of pig breeding based on organic farming and free from antibiotics")

The N content of winter wheat straw (most common cereal crop in Latvia) is used to assess the N input from straw. According to Karklins and Ruza, the N content of winter straw is assumed 4.6 kg per t straw [17].

In order to avoid the biased assessment of nitrogen input for farms that import feed, the Platform proposes adjusting the nitrogen input from imported feed by applying the nitrogen unit efficiency of the feed production [**Error! Reference source not found.**; **Error! Reference source not found.**]. Th erefore, the authors have adjusted the N input from feed and straw. Two values of the nitrogen unit efficiency have been applied – 50% and 70%. The former corresponds to the nitrogen unit efficiency proposed by the platform if it is not known for imported feed [**Error! Reference source not found.**; REF _Ref129011135 \n \h * MERGEFORMAT **Error! Reference source not found.**]. The latter corresponds to the minimum nitrogen use efficiency (NUE) criteria for crop production (see below).

The N output from animals has been assessed by applying the N content of live weight (27.6 kg per t live weight) specified by Fernández, Poulsena, Boisena and Romb [18]. According to the platform's proposal of 2022, if a livestock farm has no or only little own utilized agricultural land, it must make a cooperation with a cropping farm and create a virtual farm gate balance [15]. Nevertheless, in this study exported manure is treated like exported animals and no adjustments of nitrogen unit efficiency applied to exported manure because this study solely focuses on pig production (see above). Although such an approach is a simplification, it complies with the platform's proposal of 2021 which considers all N outputs as just outputs (without additional adjustments) [14]. Thus, the N output from manure has been computed by multiplying the amount of manure produced in the farm and the N content. The data on the amount of the manure produced and the N content have been derived from the regulation of the

Cabinet of Ministers (Regulation No. 834, Annex 2) [19]. The estimated amount of manure and the N content are presented in Table 3.

The platform has proposed several indicators to measure farm-gate nitrogen balance (e.g. nitrogen surplus, NUE). However, the most appropriate indicator for this study is NUE. It is impossible to assess nitrogen surplus if the scope of the study is solely pig production and the farm-gate nitrogen balance is modelled for the landless farm.

Table 3

Estimated amount of manure and N content

Swine groups	Convectional production		Organic production	
	Amount of manure, t per year	N content, kg per t manure	Amount of manure, t per year	N content, kg per t manure
Breeding sows	2 500.0	5.25	1 500.00	8.40
Weaners (up to 30 kg) – for breeding	21.9	3.80	14.7	6.40
Weaners (up to 30 kg) – for fattening	1 216.7	3.80	572.7	6.40
Gilts (30-120 kg)	262.9	3.40	113.8	6.30
Fattening pigs (30-110/130 kg)	12 645.0	3.40	4 938.1	6.30
Gilts (120-150 kg)	11.6	3.40	6.6	6.30

Source: the authors' assessment

NUE is calculated as the ratio of nitrogen output to nitrogen input by applying the following formula:

$$NUE_i = \frac{Nanim_i + Nmanure_i}{Nfeed_i + Nstraw_i}, \quad (1)$$

where NUE_i – NUE for model scenario *i* (conventional or organic);
$Nfeed_i$ – nitrogen from feed for model scenario *i*, kg N;
$Nstraw_i$ – nitrogen from straw for model scenario *i*, kg N;
$Nanim_i$ – nitrogen from exported animals for model scenario *i*, kg N;
$Nmanure_i$ – nitrogen from exported manure for type *i*, kg N;

NUE_i is calculated by using both unadjusted and adjusted N inputs ($Nfeed_i$ and $Nstraw_i$). Although the platform proposes calculating *NUE* on a rolling three-year bases, the modelling is carried out on a year bases because the model assumes constant annual N inputs and outputs.

According to the platform proposals of 2021 and 2022, the minimum NUE is proposed 70% for crops, 40% for granivores and 30% for ruminants [**Error! Reference source not found.**; **Error! Reference source not found.**]. Thus, the value of 40% is used as a benchmark against which NUE_i is assessed.

Results and discussion

Based on the methodology, the data and the assumptions described above, the farm-gate nitrogen balance has been modelled for conventional and organic pig production. The assessed NUE (the results of modelling) is presented in

Table 4.

The results of the study indicate that NUE of both conventional and organic production is below 40% if the nitrogen unit efficiency of feed and straw is assumed 50%. However, it exceeds the threshold of minimum NUE 40% if the nitrogen unit efficiency of feed and straw is assumed 70%. According to the additional analysis carried out by the authors, the nitrogen unit efficiency of feed and straw should be at least 58% and 66% receptively so that the NUE of conventional and organic production would reach 40%. Thus, the use of feed and straw with low or unknown nitrogen unit efficiency poses a significant challenge to pig farms, especially landless farms and farms that import (purchase) the considerable part of feed. This challenge of meeting the criteria of minimum NUE is probably not relevant to organic pig production because it is likely that certified organic farms will automatically qualify as making substantial contribution to the climate objectives [12].

Table 4

Assessment of farm-gate nitrogen balance for conventional and organic pig production

Indicators	Conventional*	Organic*
N input		
Feed, kg N	202 054	182 835
Straw, kg N	46	3 588
Total	**202 100**	**186 423**
Adjusted N input**		
If NUE of imported feed and straw 70%	**288 715**	**266 319**
If NUE of imported feed and straw 50%	**404 201**	**372 847**
N output		
Animals, kg N	79 298	66 237
Manure, kg N	61 756	48 225
Total	**141 054**	**114 462**
NUE		
Without adjustment	**69.8%**	**61.4%**
If NUE of imported feed and straw 70%	**48.9%**	**43.0%**
If NUE of imported feed and straw 50%	**34.9%**	**30.7%**

* refers to the model's scenario of either conventional pig production or organic pig production (see above)
Source: the authors' calculations

The findings of the study suggest that it could be challenging for Latvia's pig farms to ensure that their turnover is aligned with the taxonomy regulation. Thus, Latvia's conventional pig farms (especially landless farms) could face a considerable challenge to their access to finance in the future. Although the study deals with pig production in Latvia, the results of study generally outline NUE and probable challenges in pig production generally. Therefore, the findings of the study could also be relevant to pig farms in other countries, especially the countries of the Baltic Sea Region.

In order to achieve higher NUE, further research is required including research on the nitrogen unit efficiency of feed. The increase in the nitrogen unit efficiency of feed is probably the most reasonable option how to improve NUE in pig production. It should be noted that other research results suggest that it is possible to achieve higher NUE, e.g. Huthings *et al.* show maximum technical NUE of 71% for livestock that can be confined to livestock housing (in Northern Europe) [20].

Conclusions

1. The results of the study indicate that NUE (calculated on the basis of the farm-gate nitrogen balance) of the models of conventional and organic pig production in Latvia is about 70% and 61% respectively if no adjustments for the nitrogen unit efficiency of inputs (feed, straw) are made. These values exceed the minimum NUE limit for granivores (40%) proposed by the Platform on Sustainable Finance. If the N input from feed and straw is adjusted to the nutrient unit efficiency, the values of NUE are lower: 49% and 43% respectively (at the nitrogen unit efficiency 70%), and 35% and 31% respectively (at the nitrogen unit efficiency 50%).
2. According to the results of the study, the nitrogen unit efficiency of feed and straw should be at least 58% and 66% receptively so that NUE of conventional and organic production would reach 40%. These values are above the value which the platform proposes applying to imported feed with unknown nitrogen unit efficiency.
3. The results of the study also suggest that the use of feed and straw with low or unknown nitrogen unit efficiency poses a significant challenge to pig farms to meet the technical screening criteria of the EU Taxonomy. This challenge is particularly relevant to landless farms and farms that import (purchase) the considerable part of feed.

4. The findings of the study imply that Latvia's pig production (perhaps pig production in other countries as well) could face a considerable challenge to their access to finance in the future because ensuring sustainable farm-gate nitrogen balance will probably be the most realistic option for pig production. However, this challenge is probably not relevant to organic pig production because certified organic farms will likely qualify as making substantial contribution to the climate objectives automatically.
5. The increase in the nitrogen unit of efficiency of feed is likely the most reasonable option how to improve NUE in pig production. Nevertheless, future studies are required to explore possibilities how to improve the farm-gate nitrogen balance.

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Author contributions

Conceptualization, A.A.; methodology, A.A. and I.J.; validation, A.A. and I.J; investigation, A.A. and I.J.; data curation, A.A.; writing – original draft preparation, A.A.; writing – review and editing, A.A. and I.J.; project administration, A.A. All authors have read and agreed to the published version of the manuscript.

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