Wheeler, D.M., Barugh, I.W., Morel, P.H.C. 2016. Description of an outdoor pig module for OVERSEER. In: *Integrated nutrient and water management for sustainable farming*. (Eds L.D. Currie and R.Singh). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 29. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 9 pages.

DESCRIPTION OF AN OUTDOOR PIG MODULE FOR OVERSEER

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Abstract. A model has been developed to provide estimates of nutrient flows within an outdoor pig farm that is consistent with the scope of OVERSEER® Nutrient Budgets (OVERSEER). The primary focus was on nitrogen (N). The model uses standard industry information as inputs to define the number of animals for different classes and their performance. The amount of feed brought in to the farm system and its quality is user defined or based on default values. Feed utilisation (including bird loss) is defined by the feeding method. The outdoor pig unit is divided into management areas (areas for lactating, mating, and growers and finishers, and an acclimatisation area for replacements). Sows use huts, and can be placed in village's pre or post farrowing, and any pig class can be placed in sheds or barns as a means to reduce excreta deposition on the block. The model includes waste management options for the bedding and excreta from each form of housing. The nutrient flow and excreta deposited in each management area is estimated. For N, leaching losses were highly dependent on the stock density (the amount of feed intake) and the amount of pasture cover. Pasture cover was dependent on management (for example, stock density, placement and movement of troughs and huts, nose ringing) and hence pasture cover for each management area is an input.

Introduction

To provide an estimate of nutrient flows within an outdoor pig farm, an outdoor pig sub-model has been developed that is consistent with the scope of OVERSEER® Nutrient Budgets (OVERSEER). Initial analysis indicated that the features of outdoor pig units that the model should capture included:

- Different classes of animals have a defined areas within an outdoor pig block
- A high proportion of the diet is from feed brought in.
- To maintain production, the feed composition for a class is relatively constant but the amount fed varies with time, e.g. sows may be fed more in winter as it is colder.
- Feed utilisation varies with the feeding method used.
- Bird loss of feed can occur.
- The animals are on pasture, and consume pasture.
- The amount of pasture present is highly variable between seasons and between blocks.
- Pasture cover is dependent on management (for example, stock density, placement and movement of troughs and huts, nose ringing) and hence pasture cover for each management area is an input.
- Outdoor pig farms run a constant number system – the number of animals on farm at a given time (referred to as on hand) is constant.

- Outdoor pig blocks can have significant infrastructure, such as fencing, laneways, and housing. Outdoor pig blocks are typically used for 2 to 5 years, and on larger farms rotate around the farm. The infrastructure is removed at the end of the rotation. Typically, outdoor pig blocks exclusively have pigs on them.
- Animals are housed in huts. Straw is used in the huts as bedding material.
- Sometime farrowing 'villages' are used, and sheds or barns may be used as a mitigation strategy to reduce nutrient loading to soil.
- Replacement animals are assumed to be brought on, and are held in a separate area to acclimatise to the farm conditions.
- On blocks used for outdoor pigs, no fertiliser, irrigation, or effluent is applied.
- Blocks used for outdoor pigs are sometimes subsequently used for cropping, where there is sufficient nutrient accumulation to crop a successful crop with limited fertiliser input for at least a year.

In developing the outdoor pig model, the aim was to provide a model that could be integrated into the existing OVERSEER model, to use components already in OVERSEER as an aid to reduce resource and to maintain relativity between different land uses, and to take account of the observed characteristics of outdoor pig farms. To achieve this, a development version of OVERSEER version 6.2.1 model was used. Inputs were split into farm scale (animal enterprise based inputs, including numbers and production) and block scale (block characteristics) as already occurs with other animal enterprises in OVERSEER. This construct allowed an outdoor pig unit to be part of a pastoral or arable farm, and crops from a cropping block can be fed to outdoor pigs. However, pigs were restricted to be only present on an outdoor pig block, not on pastoral or cropping blocks.

Preliminary analysis was undertaken to determine the best way of estimating feed intake. For the ruminants modelled in OVERSEER, pasture dry matter intake is estimated from animal ME requirements, after removing energy supplied by supplements and crops. Most systems are pasture dominant, and there have been problems allocating fed that is consistent with animal energy requirements without generating error conditions when the diet comprises pre dominantly crops and supplements. Pigs, being monogastrics, have a different metabolism to the ruminants modelled in OVERSEER. The concepts for protein (Morel *et al*., 2014) are that 1) Protein content per se is not relevant, 2) Amino acid contents in feed should be described in terms of ileal amino acid content; 3) The ileal digested essential amino acids should be in a specific proportion to each other (ideal amino balance concept); 4) Protein utilisation is dependent on the amino acid profile of the incoming feed and the amino acid requirements of the animal; and 5) Protein requirements for different metabolic processes have a different specific amino acid profile. Hence the growth rate, body composition, and the distribution of excreta N between dung and urine are dependent on the amino acid composition of the feed. This is recognised in the formulation of feed for pigs as feed quantity and quality, including mineral nutrient contents and amino acid composition, is critical for production, and this results in feeding regimes across farms being highly controlled. A model to estimate grass intake and nutrient partitioning within the animal using a metabolic energy requirement model was developed (Morel *et al*., 2014, Morel and Morel, 2016) that required amino acid profile of each feed.

The second approach was to use an N balance approach, and to estimate grass intake independently. Given the problems associated with high supplement feed intake observed with pastoral based animals, and that grass amino acid composition was close to optimum for minimising the amount of urine excreta N (Morel, pers. comm.), and that grass is poorly digested by pigs, and that feeding regimes are highly managed, the N balance approach was initially adopted over estimating grass intake using a metabolic model.

This paper describes the developed outdoor pig model. It is based on the number of animals and performance using standard industry inputs. The amount of feed brought in and its quality can be user defined, or defaults are available. Feed utilisation (including bird loss) is defined by the feeding method. The outdoor pig unit is divided into management areas (areas for lactating, mating, and growers and finishers, and an acclimatisation area for replacements). Sows use huts, and can be placed in village's pre or post farrowing, and any pig class can be placed in sheds or barns as a means to reduce excreta deposition on the block. The model includes waste management options for the bedding and excreta from each form of housing. The nutrient flow and excreta deposited in each management area is estimated.

Pig classes

The pig classes considered in the model are described in Table 1. Feed intake and excreta distribution is estimated for each class.

Table 1. The inputs to determine numbers and production.

Class	Definition
Mating/dry sows	Sows post-weaning or being mated. Boars used for mating are also included.
Early gestating sows	Gestating sows for the first 40 days of gestation.
Mid gestating sows	Gestating sows between 40 and 90 days of gestation (50 day period).
Late gestating sows	Gestating sows for the last 25 days of gestation.
Lactating sows	Sows with piglets.
Piglets	Piglets less than weaning age still with the lactating sow.
Replacements	Replacement gilts and sows that are on the acclimatisation areas.
Weaners	Non-breeding pigs that are greater than the weaning age but less than 10 weeks (70 days).
Growers	Non-breeding pigs that are greater than 10 weeks (70 days) but less than 16 weeks (112 days)
Finishers	Non-breeding pigs that are greater than 16 weeks (112 days)

Block inputs

Outdoor pig blocks are typically divided into areas for acclimatisation, area for replacement gilts and boars, areas for mating, gestating and lactating sows (Barugh *et al*., 2016), and areas for finishing pigs if this occurs. There is also a portion of the block comprising lanes, tracks or other areas not housing pigs ('Other' area). To enable flexibility, such as including different soil types, multiple blocks can be defined such that each block can have a different combination of areas. For each area except other, the percentage green cover for spring, summer, autumn and winter are entered.

Pasture cover is dependent on management (for example, stock density, placement and movement of troughs and huts, nose ringing) and hence pasture cover is an input for each animal class within an outdoor pig block.

The other block scale data required to drive the outdoor pig model is climate, soil description and soil tests, as for pastoral blocks in OVERSEER.

Pig numbers and production

The model is based on the number of animals and performance using standard industry inputs. The inputs used to estimate numbers and production are shown in Table 2.

Table 2. The inputs to determine numbers and production.

Class	Definition
Sows	Number of sows and mated gilts
	Chopper (Carcass) weight of culled animals
	Replacement rates of sows
	Litters per year
	Average number weaned per litter
	Weaning age (days)
	Weaning live weight (kg)
Boars	Number of boars on hand
	Replacement rate
Unmated gilts	Number on hand
	Days spent growing gilts
Outdoor growers and finishers	Weaned from farm
	Brought in weaners
	Average live weight at purchase
	Average carcass weight on sale
	Average age at sale (days)

At any one time, the number of sows that are gestating, lactating or dry is estimated from the number of sows (Morel *et al.*, 2014) as the integer value of:

SowsGestating = 115 / CycleLength * NumberSows

SowsLactating = WeaningAge / CycleLength * NumberSows

where 115 is the gestation length of sows (days), NumberSows is the entered number of sows, WeaningAge is the entered weaning age (days), and the cycle length (days) is estimated from the number of litters per year as:

CycleLength = 365 / LittersPerYear

where LittersPerYear is the entered number of litters per year. The number of dry sows is the difference between the entered number of sows, less the estimated number of gestating and lactating sows.

The number of gilts on hand (NumberGilts) and the days taken to grow (DaysGiltsGrow) is estimated as the integer value of:

DaysGiltsGrow = (NumberGilts * 365) / (NumberSows * ReplacementRate/100)

where NumberGilts or DaysGiltsGrow is entered by the user, ReplacementRate is the entered replacement rate (%) and 365 is the number of days in the year.

The number of piglets on hand is estimated as the number of lactating sows multiplied by the average litter size.

The mature weight of sows is estimated from the entered chopper weight, assuming a dressing out rate of 60%. The mature weight of boars is assumed to be 20% larger than that of sows. The birth weight is based on the birth weight to sow weight for a limited range of data and is assumed to be 0.00615 the mature weight. Grower finishing live weight is based on entered average carcass weight on sale and a dressing out rate of 75%.

The amount of live weight (kg/year) brought, raised and sold is used to estimate product removal, and in the greenhouse gas reporting. The amount of live weight brought on to the farm is from weaners brought on, and replacement sows and boars brought in. The amount of live weight sold to the works is the weight of cull sows and boars, and grower/finishers sold off the farm. The amount of live weight sold store is the weight of piglets weaned but not kept on the farm.

The amount of live weight raised on the farm for the breeding herd includes live weight gain from replacement gilts and sows, and piglets up to weaning. The total amount of live weight raised on the farm is live weight raised for the breeding herd, plus live weight gain from raising weaners/growers/finishers from weaning weight to the sold weight.

Feeding

The model requires the amount of nutrient eaten by each class of animal. This is defined by amount and quality of feed brought in, which differs for different classes of pig, and the feeding system, which defines the utilisation of that feed. The characteristics of the feed that is fed to a given animal class is assumed to be constant each month, but feeding levels can be varied depending on seasonal requirements.

As a constant throughput system is used, the amount of feed is specified as an amount per day for the classes shown in Table 1. The feed composition is defined by the dry matter (DM) content, volatile solids, metabolisable energy (ME) content, crude protein, ileal digestible protein, digestible phosphorus (P), and nutrients (P, K, S, Ca, Mg, Na, Cl) that are fed to each class shown in Table 1 except that mating and dry sows and boars, early, mid gestation sows are assumed to be fed the same type of feed.

The amount of supplied feed consumed, along with nutrient intakes, is estimated for each pig class based on the number and feed characteristics (including amount of feed). The number of feeding days is estimated from the entered ages and the definitions of pig classes. If piglets are fed, then they are assumed to be fed creep feed for a maximum of 14 days.

Pasture production and pasture nutrient contents are based on the model described by Wheeler (2015). The monthly pasture production is adjusted for the amount of cover as entered by the user. It is assumed that pigs utilise 85% of the pasture grown.

Feed wastage and bird loss

Pig feed utilisation is the proportion of provided feed that is ingested by pigs. There are two components; 1) wastage; wastage, which is the amount of feed that falls to the ground, and 2) bird loss, the amount of feed eaten by birds and removed from the block. Feed wastage and bird loss is based on the feeding method and whether the feed is fed as meal or pellets, which can be selected for the pig classes of mating, gestating, lactating sows, replacements (gilts and boars) and growers and finishers, and whether bird loss is a problem.

The percentage wastage and bird loss for each feeding method are shown in Table 3. These values are based on an industry assessment of loss (supplied by I. Barugh, NZ Pork, 2015).

Table 3. Wastage (%) and bird loss (%) for meal or pelleted feed for each feeding method.

Method of feeding	Wastage		Bird loss	
	Meal	Pellets	Meal	Pellets
On ground	20	10	5	7
On a feed pad	12	5	5	7
Trough on pad	12	5	5	3
Trough on paddock	12	5	3	3
Ad lib feeder	10	5	3	3
Liquid feeder	5	5	0	1
Electronic sow feeder	2	2	0	0
Feeding balls	5	5	0	3

Excreta

The amount of N in dung from the supplied feed is estimated as the amount of non-digestible N (the difference between total crude protein and ileal protein) in the feed. Similarly, for P, the amount of P in dung is estimated as the difference between total P and digestible P. For other nutrients, a percentage digestibility is used as shown in Table 4. It is also assumed that 50% of nutrients in crops and pasture are not digested, and these are excreted as dung.

The amount of nutrient in urine is the difference between total diet nutrient (supplied feed, pasture and crops) less nutrients in dung and present in product. The product nutrient is live weight raised multiplied by the nutrient in live weight (Table 4). The concentrations in live weight are lower than those reported for other animal enterprises (Longhurst, 1995). Although Mahan and Shields (1998) showed that nutrient contents varied with weight, and the model of Morel *et al*. (2014) showed that nutrient content could vary with diet, a constant nutrient content has been used in the initial model.

Table 4. For each nutrient, the digestibility (%) and live weight nutrient concentration (%).

Nutrient	Digestibility (%)	Live weight nutrient concentration (%)
N		2.2
P		0.43
K	82	0.09
S	80	0.10
Ca	51	0.74
Mg	28	0.02
Na	80	0.06

Excreta (dung and urine) is distributed to feeding structures based on the time pigs spend in each structure. It is assumed that little excreta is deposited on straw in huts, and hence this was ignored. Farrowing pigs can use villages pre and post farrowing. The inputs also allow mating, gestating or lactating sows, and unmated gilts to be placed in sheds or barns. The proportion of animals varies each month. This was primarily added as a mitigation option as few farms currently practice this. The remaining urine and dung is distributed to the blocks based on the area of each block occupied by a pig class.

Developing nutrient budgets and model outputs

The model uses the existing OVERSEER pastoral block procedures to estimate a nutrient budget and reports currently available in OVERSEER. N leaching is estimated using the background and urine patch models (Wheeler *et al*., 2011). The background and urine patch N leaching models include pasture intake as an input. When cover is zero, pasture production is zero and this results in increased N leaching from both background and urine patches. When estimating N leaching from urine, the sheep model was used. A preliminary investigation indicated that pig urine spot was more like a sheep spot than a dairy cow patch. However, the characteristics of the urine patch were not measured.

Within the cropping model, outdoor pigs can consume crops either in situ or cut and carry. The block pre–history has an outdoor pig option, which increases the initial accumulation of nutrients as a result of high feed inputs, although more research information is required to improve the available options.

Straw is supplied to huts, with a default rate of 140 kg/sow/year. Two straw management options can be used, with options of burnt, left is situ, spread on the block or exported. If barns are used, the straw and excreta in the straw can be composted or exported. Excreta deposited in villages is removed by hydraulic flushing, and the treatment options are the same as already present in OVERSEER. Effluent management is then modelled using the same procedures already in OVERSEER (Wheeler *et al*., 2012).

Greenhouse emissions (methane, nitrous oxide and embodied carbon dioxide emissions) were calculated using the same procedures that already existing in the model. Enteric methane emissions (kg methane per year) and methane emissions from dung (kg methane/year) are based on Hill (2012). It was assumed that dry and gestating sows had the same emission factors, and the amount of dung was based on the volatile solids component of the diet.

The average number weaned per week, is displayed with inputs as a check. It is estimated by multiplying the entered number of sows, the number of litters per year and the average litter size, and divided by 52. In addition, the model shows the estimated sow DM intake (tonnes DM/sow/year) and the efficiency of live weight gain in growers (kg DM intake per kg live weight gain), two key efficiency factors that growers use, and can indicate whether there have been any errors in the inputs.

Discussion and Conclusion

Pasture cover is difficult to assess or to write clear guidelines on how to assess it. However it is an important driver of N leaching and so additional work is required to refine the methods of assessment of pasture cover. The other major input is the feed amount and composition, although this is normally purchased from millers and hence good records normally exist. The production numbers and feed have a large effect on productivity and profitability, and hence this data is well known within the industry.

For P, the same procedures are used as for other animal enterprises. The lack of pasture cover probably increases P loss due to overland flow. This, and the extensive tracking observed on some feeding lanes means that P loss is probably underestimated in the model.

The output from the model are discuss in two case studies by Barugh *et al*. (2016). The output for the model, and the effect of mitigation options is consistent with published results (Stauffer and Menzi, 1999; Williams *et al*., 2000; Eriksen *et al*., 2002; Webb *et al*., 2013; Espagnol and Demartini, 2014). There was insufficient information from the published studies to undertake a full validation.

The main features of outputs from the study and published results for outdoor pig blocks are:

- The accumulation of nutrients due to high amount of feed brought in.
- N leaching losses were dependent on the stock density (the amount of feed intake) and the amount of pasture cover.
- Reducing feed N inputs or increasing productivity reduces N leaching.
- Placing animals in villages or barns reduces N leaching, with the size of the reduction dependent on the proportion of animals and the timing.

The model is being consider for inclusion in the full OVERSEER model in due course.

Acknowledgments

We wish to thank Overseer Management for making a development version of the model available. This work was funded by the New Zealand Pork Industry aided with a grant obtained from the Sustainable Farming Fund of the Ministry for Primary Industries (New Zealand) under the project *PigSeer-Integrating Outdoor Pigs into OVERSEER*. We also thank the outdoor pig growers that attended workshops to assist in development of this model.

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