Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 121 No. 1 (2020) 43–55

https://doi:10.17170/kobra-202002281033 ISSN: 2363-6033 (online); 1612-9830 (print) – website: www.jarts.info

Does backyard-keeping of native sows by smallholders in Quezon, Philippines, offer sustainability benefits compared to more intensive management of exotic sow breeds?

Philipp C. Muth [a], Inga K. Pöhlmann [a], Sangeun Bae [a], Christoph Reiber [a,*], Orville L. Bondoc [b], Anne Valle Zárate [a]

[a] *Animal Husbandry and Breeding in the Tropics and Subtropics, Hans-Ruthenberg-Institute of Agricultural Sciences in the Tropics, University of Hohenheim, 70593 Stuttgart, Germany*

[b] *Institute of Animal Science, College of Agriculture and Food Science, University of the Philippines Los Baños, College, Laguna 4031 Philippines*

Abstract

The present study in Quezon, Philippines, assessed the sustainability of small-scale production systems, based either on native or on exotic sow breeds, using different survey tools in a socio-economic approach. In two research periods, data sets with 49 and 68 households, respectively, all smallholder farmers keeping ≤ 5 sows, were compiled. In 2016, four municipalities were purposively selected, each representing one of Quezon's four districts. In 2017, two municipalities, both with larger populations of native pigs, were re-visited in order to review and supplement the previously obtained information.

Small-scale pig production based on native sow breeds could result in less local environmental load than that based on exotic sows, as indicated by a significantly closer approximation to organic standards, and a reduced public health impact. However, native sows were less productive than exotic sows, thus allowing only a reduced live weight offtake per household and year (274 vs. 607 kg). Regarding economic viability, both pig production systems were equally cost-effective and required similar weekly labour hours. The advantage of basing production on exotic sows was the possibility to make larger investments, a financial function that could not be met by native sows. The revenues from marketing piglets and porkers from native sows were low, preventing a better outcome. Conversion to organic production and certification could represent one strategy for development given that increasing the value added is putatively the only way to improve the cost-effectiveness of the production from native pigs in Quezon.

Keywords: Antibiotic, local breeds, organic farming, pig

1 Introduction

In recent years, the growing demand for pork in Southeast Asia has not only been met by expanding pig populations but mainly by increasing yields. In fact, traditional pig farming, originally small-scale, extensive and free-roaming, is being replaced by systems of varying scales and degrees of intensification which allow higher yields. Intensified pig production is characterised by the confinement of pigs and the use of external inputs in terms of feed, pharmaceutical drugs and genetics. A high-energy and balanced diet is required to meet the nutrient requirements of the high-performing exotic pig breeds in intensive production systems. The term "exotic" refers to pig breeds that are not native to the region in question but are imported (FAO, 2001). Depending on the country, small farms account for a different share of total production, representing as much as 70 % in some Southeast Asian countries (Huynh *et al.*, 2006). Those small farmers who operate semi-intensive to intensive pig production are often located in proximity to urban centres where demand for pork is highest (*ibid.*). Regarding economic development, small-scale pig producers could benefit from intensification. On the other hand, intensive livestock production is associated with environmental problems such as green-

* Corresponding author – c_reiber@uni-hohenheim.de
Phone: +4971145923175

Published online: 3 April 2020 – Received: 27 April 2019 – Accepted: 19 March 2020

house gas emissions, eutrophication, acidification and deforestation, especially in pig and poultry production where the production of feed and animal production are increasingly becoming decoupled (Steinfeld *et al.*, 2006). This also means that feed production competes with food production for arable land. But other external effects of pig production could also affect sustainability. For example, the overdose or improper use of antibiotics and other allopathic medicines in livestock production gives rise to the resistance of pathogens, potentially endangering human and animal health (Landers *et al.*, 2012). Finally, animal welfare could be impaired, for instance, where confined animals are not able to satisfy their behavioural needs.

Against this backdrop, public authorities and non-governmental organisations are looking for strategies to promote sustainable pig farming practices in the smallholder sector that are economically successful but at the same time ecologically and socially sound. In the Philippines, where about 35 % of pork production takes place in backyard systems (Smith, 2017), the National Swine and Poultry Research Development Centre (NSPRDC) pursues sustainability objectives in smallholder pig farming by promoting organic or organic-alike agriculture based on native, otherwise known as, locally adapted pig breeds (FAO, 2001). The NSPRDC's approach is to distribute native sows to smallholder farmers and provide a variety of advisory services that address various aspects of pig farming, in particular, the optimal use of local and low-cost feed resources. However, it is not known whether environmental and social benefits can be realised by pig production based on native breeds and whether it is economically competitive in small-scale production systems compared to more intensive production of exotic (non-native) sow breeds.

This case study, conducted in the Philippine province of Quezon, therefore focused on assessing the sustainability components of animal performance, economics, and the environmental and social impact of native and exotic sow-based small-scale production systems using different survey tools in a socio-economic research approach. Farmers' views on the challenges they face in their respective production systems were also examined.

2 Materials and methods

2.1 Study site and sample selection

The study was conducted in the Philippine province of Quezon in the Calabarzon region (region IV-A). The northern provinces of Calabarzon benefit from the proximity to the Manila metropolitan area in terms of investment and employment opportunities. Economic growth in the agricultural sector is primarily driven by pig and poultry production, boosted by demand (NEDA, 2017). In contrast to Calabarzon's urbanised and economically vibrant provinces, Quezon has areas classified as geographically isolated and disadvantaged (NEDA, 2016). In 2015, the poverty incidence of Quezon was 22.7 %, while the regional average of Calabarzon was 9.1 % (PSA, 2015). Calabarzon has about 1.5 million pigs, with approximately 400,000 pigs kept in backyards, and produces 365,056 t of swine per year (PSA, 2017), of which Quezon accounts for about 13 %.

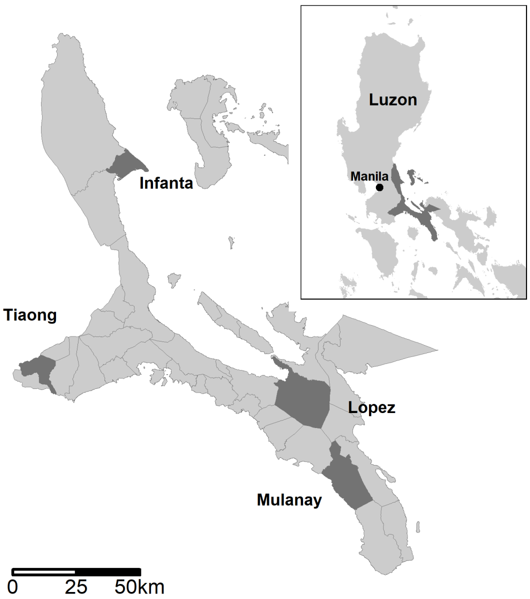

Fig. 1: *Location of the province of Quezon (small picture), and of the municipalities of Infanta, Tiaong, Lopez and Mulanay (data from gadm.org, last accessed 18.07.2019).*

For Quezon, no comprehensive list of small pig farmers was available, therefore all municipalities with native and exotic pig populations were considered for selection. In order to reduce the bias of selecting locations that are particularly suitable or unsuitable for native or exotic sow-based pig production, the municipalities should be geographically separated. Therefore, in the first step, one municipality each (Infanta, Lopez, Mulanay, Tiaong; Fig. 1), from the four districts of Quezon was purposively selected to collect data set 1 (Pöhlmann, 2016). The acreage and cropping patterns of households differed for the different municipalities, as did the contribution of pig production to total household income (Table 1). To limit the sample to the predominant smallholders, the maximum number of sows per household was set at five. In the second step, data collection within a municipality was initiated as a convenience sample from a list of pig farmers compiled by the local authorities and exten-

Table 1: *Municipality characteristics (data set 1).*

Trait	*Parameter*	*Municipality* Infanta	*Lopez*	*Mulanay*	*Tiaong*
Households	N	11	13	14	11
Household size in N	Median	4	4	5	4
Farm area in ha	Median	0.50	1.50	0.75	1.50
Main crops					
Most common crop	(% of households)	rice (73)	coconut (77)	coconut (71)	eggplant (36) corn (36)
Second most common crop	(% of households)	coconut (55)	banana (69)	banana (64)	legumes (27)
Household revenue in PHP*	Median	196,700	209,000	141,700	330,500
Percentage of pig revenue	Median	74	61	20	16

* PHP = Philippine Peso

ded by snowball sampling by asking farmers and Barangay Captains for additional contacts and by random walk. Data set 1 consisted of 25 households keeping native sows and 24 households keeping exotic sows. In 2017, the municipalities of Infanta and Tiaong, both with larger populations of native pigs but representing different farming systems and socio-economic environments, were re-visited to collect data set 2 (Bae, 2017). The sample from Infanta and Tiaong were expanded using snowball sampling and by random walk as described above. During the second research period, the previously obtained information was validated and deepened. Data set 2 had 34 households each for those keeping native and exotic sows.

2.2 *Definition of sustainability, survey tools and implementation of the survey*

In both research periods, the data were collected in face-to-face interviews using questionnaires structured around a mixed set of open and closed questions. The questionnaires were then used to derive farm-level sustainability indicators. According to Lebacq *et al.* (2013), sustainable livestock production systems are environmentally friendly, economically viable for farmers and socially acceptable. Following this definition, indicators of animal performance (productivity) and profitability of the pig production unit were used to characterise the economic viability of households keeping native and exotic sows. A global index (Organic Livestock Proximity Index, OLPI) was used to assess the approximation of pig farming practices to organic production standards, enabling farm-level quantification of nutrient cycling and/or animal welfare promoting agricultural practices (Mena *et al.*, 2012). The preventive use of allopathic medicines was considered as an additional indicator of social sustainability due to its public health impact (van Wagenberg *et al.*, 2017). Other indicators included were linked to several sustainability issues (Lebacq *et al.*, 2013): The origin of feedstuffs was used as an indicator to describe the nutrient influx, which not only is associated with the environmental sustainability of the farms but also the farms' economic autonomy. Working hours was used to evaluate the profitability of livestock production systems, as well as to describe the quality of life of farmers and thus its social sustainability.

Data on animal performance and economics were collected retrospectively using the 12-month recall method (Ieda *et al.*, 2015). The questionnaire used to collect data set 1 addressed socio-economic characteristics of the households, animal performance, costs and revenues of pig production and husbandry practices. The calculation of the OLPI was based on the standards of the Organic Certification Centre of the Philippines for organic farming (OCCP, 2003), which are strongly aligned with international organic standards (IFOAM, 2014). Fifteen specifications for organic pig farming practices in the Philippines were included in the questionnaire to calculate the OLPI score (Table 2). The questionnaire used for the collection of data set 2 contained fundamental questions from the questionnaire for data set 1 but was supplemented and deepened with questions on the use of allopathic medicines and/or ethno-veterinary plants for the prevention and treatment of diseases. During this second research period, farmers were also asked to rate different aspects of production (feed cost, availability of labour, disease, lack of investment capability, market instability) on an ordinal scale, according to the perceived level of challenge each posed to their production system. The questionnaires were translated into Tagalog, pre-tested and adapted before the interviews were conducted. Both questionnaires are available upon request from the corresponding author.

2.3 *Statistical analysis*

All statistical calculations were conducted with the R software version 3.4.3 (R Core Team, 2017). The socio-

Table 2: *Specifications for the calculation of the Organic Livestock Proximity Index (OLPI) and the proportion of pig production units (n=49) that met the respective requirement (data set 1).*

Specification	*OCCP requirement**	*Percentage of compliance*
Native pig breeds are preserved and promoted.	5.2.1	53.1
No mutilations (e.g. tail docking, teeth clipping) except for the castration of males are performed.	5.3.1	100.0
Feeding is provided in a form that the expression of natural feeding behaviour is possible.	5.4.4	20.4
The diet provided includes roughage.	5.4.5	53.1
At least 50 % of the feed is produced on-farm or by regional farms.	5.4.6	30.6
No feed ingredients prohibited according to the OCCP regulations (e.g. genetically engineered organisms or products thereof) are used.	5.4.7	32.7
No prophylactic use of allopathic drugs.	5.6.3	28.6
No use of hormones or of other products that influence fertility.	5.6.4	95.9
Vaccinations are used only within disease control schemes.	5.6.5	100.0
Information (e.g. on veterinary treatments) is recorded.	5.6.6	53.1
The stocking density does not exceed the limit of 170 kg N from manure per ha of agricultural land and year†.	5.11	46.9
The animals are protected from the weather and the stables are clean and ventilated.	5.12.1/5.12.2	85.7
The minimum indoor area according to the OCCP regulations is provided.	5.12.3	40.8
The minimum outdoor area according to the OCCP regulations is provided.	5.12.3	49.0
Piglets are provided adequate substrates for rooting.	5.12.4.f	20.4

* The requirements are set out in the following document: Organic Certification Centre of the Philippines, Inc. (OCCP) (2003) OCCP Standards for Organic Agriculture and Processing. OCCP, Pasay City, Philippines.
† The stocking density was calculated from the number of heads of a certain pig class; different body weights were not considered.

demographic household data and the inventory data on the pig herd were analysed descriptively with appropriate measures of central tendency and variation. For categorical data, frequencies are reported.

The reproductive performance of the 105 sows in data set 1 was averaged for each of the 49 households, and the average weight gain of fattening pigs and the annual live weight extraction per household were calculated from sales data for piglets, *lechon*-piglets and fattening pigs. Live weight extraction were log-transformed for the analysis because of heteroscedastic residuals and subsequently back-transformed.

For the economic evaluation, the variable costs and revenues from pig production per household and year were calculated and used to determine the return on investment (ROI) as a measure of cost-effectiveness. Variable costs and revenues were log-transformed for the analysis because of heteroscedastic residuals. The ROI was calculated by dividing the net returns from pig production by the variable costs; fixed costs were not considered. In addition, the weekly working hours required for pig production were calculated.

For assessing the approximation of the pig production system to organic livestock production, variables indicating conformity with OCCP standards (2003) were defined and coded with 0 and 1, where 1 indicates a positive reply (Mena *et al.*, 2012). The OLPI was defined by the number of positive replies divided by the number of variables (n=15) multiplied by 100. No weighting factors were applied.

Animal performance and economic traits as well as the OLPI were analysed using a general linear model that considered the effects of breed group (native, exotic), municipality (Infanta, Lopez, Mulanay, Tiaong) and their interaction. Tests for the significance of effects were calculated according to the principle of marginality. Least-squares means were compared pairwise where the municipality effect was significant. Differences were considered significant at $P < 0.05$.

The frequencies for the preventive use of antibiotics and anthelmintics were calculated for both breed groups within the two municipalities considered for the collection of data set 2. Differences were checked by either chi-squared test or Fisher's exact test and considered significant at $P < 0.05$.

For the analysis of perceived challenges of pig production, a cumulative link model with a logit link using the clm function from the "ordinal" package (Christensen, 2018) was fitted for each ordinal response variable. The breed group (nat-

Table 3: *Socio-demographic characteristics on small farms with native and exotic sows (data set 1).*

	Breed group							
	Native (n=25)				*Exotic (n=24)*			
Trait	x̄	sd	Median	P25-P75	x̄	sd	Median	P25-P75
Household size (n)	5.2	1.8	6.0	4.0-7.0	4.1	1.9	4.0	3.0-5.0
Children (n)	2.8	1.7	2.0	2.0-4.0	1.9	1.7	1.5	1.0-2.3
Land (ha)	1.7	2.1	1.5	0.4-2.0	1.7	4.2	0.5	0.0-2.0
Revenue (PHP 1,000 hh^{-1} a^{-1})	195.5	183.4	132.2	63.2-330.5	316.2	254.7	256.0	164.0-305.2
Revenue (PHP 1,000 $head^{-1}$ a^{-1})	38.3	33.7	17.3	13.5-67.2	87.7	57.7	75.5	46.8-136.8
Off farm revenue (%)	33.1	36.3	25.7	0.0-70.6	36.9	34.2	28.9	0.0-65.6
Cropping revenue (%)	19.5	20.2	15.2	2.4-34.7	14.7	20.2	3.9	0.0-22.3
Livestock revenue (%)	6.0	14.0	0.0	0.0-4.0	0.8	2.5	0.0	0.0-0.0
Pig revenue (%)	38.7	33.8	25.6	7.3-65.3	47.6	32.5	48.3	17.5-72.4

PHP = Philippine Peso, hh = household, x̄ = arithmetic mean, sd = standard deviation

ive, exotic) and municipality (Infanta, Tiaong) were combined into one effect with four levels and the significance of this effect calculated by the likelihood ratio test. Where the effect was significant, the odds ratios and its 95 % confidence intervals were computed.

3 Results

3.1 Household characterisation and pig herd demographics

The socio-demographic parameters differed slightly between households keeping native sows and those keeping exotic sows (Table 3). The farms in data set 1 were family-owned and households keeping native and exotic sows had an average of 6.0 (2.0 of them children) and 4.0 (1.5 of them children) household members, respectively (numbers are medians). Most households cultivated 2 ha or less, with majority of farmers keeping exotic sows owning less than 0.5 ha (Fig. 2). Pigs were the main livestock species. Households keeping native and exotic sows earned an average of 25.6 % and 48.3 %, respectively, of their annual revenues from pig production (numbers are medians) but showed a high kurtosis distribution for both groups (Fig. 2). In addition to agricultural activities, off-farm activities often made a relevant contribution to the annual revenues of households. Sixty percent and 72 % of farmers who raised native and exotic sows, respectively, received income from off-farm activities. On average, households keeping native sows were characterised by a higher number of persons and a lower total annual income compared to exotic sow-keeping households. As a result, the latter generated higher revenues per person and year with 37.5 % of households earning revenues of more than PHP 100,000 per person and year (Fig. 2).

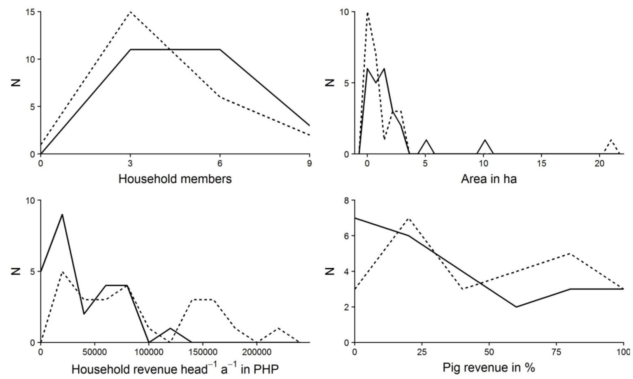

Fig. 2: *Frequency polygons for selected socio-economic parameters for households keeping native sows (solid line, n = 25) and exotic sows (dashed line, n = 24) (data set 1).*

The herd inventory was similar for both breed groups (Table 4). Six (24 %) of the farmers who kept native sows, and three (13 %) of the farmers who kept exotic sows had one or more boars. Most farmers kept one to three sows. The type of native breed kept differed depending on the municipality. Farmers in Tiaong mainly raised Black-Tiaong sows while those in Infanta kept the Quezon breed. Farmers who kept exotic sows preferred the Large White breed. During the collection of data set 1, there were about 3.0 and 4.5 piglets (numbers are medians) on farms keeping native and exotic sows, respectively. On average, only two fattening pigs were kept (number is median), because offspring were partially sold already at weaning. In total, three sale strategies were identified: the sale of all piglets at weaning, the fattening of all piglets to sell them for slaughter and a mixture of both strategies. In wean-to-finish operations, those farms that kept native and exotic sows had 5.0 and 8.0 fatteners (numbers are medians), respectively.

Table 4: *Pig herd inventory on small farms with native and exotic sows (data set 1).*

	Breed group							
	Native (n=25)				*Exotic (n=24)*			
Pig class	%*	x̄	Median	P25-P75	%*	x̄	Median	P25-P75
Boar	24	0.4	0.0	0.0-0.0	13	0.2	0.0	0.0-0.0
Sow	100	2.2	2.0	1.0-3.0	100	2.5	2.0	1.0-3.0
Piglet	56	3.2	3.0	0.0-6.0	58	5.5	4.5	0.0-9.3
Fattener	60	4.9	2.0	0.0-6.0	54	4.7	2.0	0.0-8.5

* proportion of farms keeping the respective pig class.

Table 5: *Results of general linear model analysis of the performance of pigs on small farms with native and exotic sows (data set 1).*

	Breed group		*Municipality*				*Significance*		
Trait	*Native*	*Exotic*	*Infanta*	*Lopez*	*Mulanay*	*Tiaong*	*Breed group*	*Mun.*	*BG x Mun.*
n	25	24	11	13	14	11			
Sow weight (kg)	77 ± 6	148 ± 7	111 ± 9	119 ± 9	104 ± 8	116 ± 10	< 0.001	0.627	0.977
Farrowing interval (d)	182 ± 9	179 ± 9	176 ± 13^{ab}	169 ± 12^{a}	155 ± 12^{a}	222 ± 13^{b}	0.771	0.004	0.885
Litter size at birth (n)	8.5 ± 0.3	10.7 ± 0.4	9.0 ± 0.5	10.2 ± 0.5	9.4 ± 0.5	9.8 ± 0.5	< 0.001	0.353	0.043
Litter size at weaning (n)	7.6 ± 0.4	10.0 ± 0.4	8.2 ± 0.5	9.1 ± 0.5	8.9 ± 0.5	9.0 ± 0.5	< 0.001	0.591	0.017
Daily weight gain (g)	391 ± 60	861 ± 66	526 ± 82^{b}	913 ± 78^{a}	481 ± 89^{b}	585 ± 105^{ab}	< 0.001	0.005	0.070
Offtake (kg hh^{-1} a^{-1})*	274	607	475^{ab}	800^{a}	208^{b}	349^{ab}	0.015	0.017	0.036

hh = household; Mun. = Municipality; BG = Breed group. * back-transformed.
Within municipality, least-squares means with common small-case superscript letters do not differ significantly ($p \geq 0.05$).

3.2 Productivity and economic viability

Data from data set 1 showed no difference in the fertility of the sows of both breed groups, but the body weight, prolificacy and especially the growth performance of the offspring differed significantly (Table 5). Sows of the native group weighed on average 71 kg less than those in the exotic sow group. The breed group had no influence on the farrowing interval of about 180 days, but municipality significantly influenced the farrowing interval. Sows in the exotic group farrowed and weaned significantly larger litters, resulting in an average of 2.2 and 2.4 more piglets per litter at farrowing and weaning, respectively, compared to the sows in the native group. The interaction term was significant for both prolificacy traits. The daily weight gain during fattening was influenced by both main effects, with the fattening pigs in the exotic sow group gaining more than twice as much weight per day as the pigs in the native sow group. Farmers who raised exotic sows achieved a significantly higher annual live weight offtake in the form of piglets, *lechon*-piglets and porkers compared to households with native sows. The interaction term was also significant for this parameter.

The economic parameters are shown in Table 6. The cost and revenue structure was significantly influenced by breed group. The variable costs required for pig production were significantly lower for farmers who raised native sows than for those who raised exotic sows, with municipality having a significant effect on annual variable costs. On average, farmers who kept native sows spent PHP 30,000 less per household and year for pig production than farmers who kept exotic sows. Pig feed constituted 91 % and 92 % to the variable costs in the native and exotic group, respectively, followed by expenditures on veterinary medicines and services (1 vs. 5 % of variable costs in the native and exotic group, respectively) and breeding fees (8 vs. 3 % of the variable costs in the native and exotic group, respectively). Farmers who kept exotic sows achieved significantly higher revenues and fetched an average of PHP 41,200 more per household and year compared to farmers who kept native sows. Revenue earnings were also influenced by the municipality and the interaction effect. The ROI averaged around 1.0 and did not differ between the breed groups and the municipalities and was not affected by their interaction. The work that the farmers of both breed groups invested weekly in pig production differed in terms of feeding (65 vs. 39 % of total time in the native and exotic group, respectively) and cleaning (35 vs. 61 % of the total time in the native and exotic group, re-

Table 6: *Results of general linear model analysis of the economic success and labour requirement of pig production on small farms with native and exotic sows (data set 1).*

	Breed group		*Municipality*				*Significance*		
Trait	*Native*	*Exotic*	*Infanta*	*Lopez*	*Mulanay*	*Tiaong*	*Breed group*	*Mun.*	*BG x Mun.*
n	25	24	11	13	14	11			
Variable costs (PHP 1,000)*	18.6	48.6	54.7^{a}	45.5^{a}	14.4^{b}	22.9^{ab}	0.004	0.008	0.809
Revenue (PHP 1,000)*	27.6	68.8	49.6^{ab}	89.2^{a}	21.3^{b}	38.3^{ab}	0.003	0.006	0.017
Return on investment	1.1 ± 0.4	1.0 ± 0.4	0.5 ± 0.6	1.6 ± 0.5	1.0 ± 0.5	1.0 ± 0.6	0.748	0.614	0.627
Labour (h $week^{-1}$)	12.8 ± 1.4	12.4 ± 1.5	14.0 ± 2.1	13.8 ± 1.9	14.2 ± 1.9	8.5 ± 2.2	0.755	0.135	0.833

* back-transformed; PHP = Philippine Peso; Mun. = Municipality; BG = Breed group.
Within municipality, least-squares means with common small-case superscript letters do not differ significantly ($p \geq 0.05$).

Table 7: *Results of general linear model analysis of the Organic Livestock Proximity Index (OLPI) on small farms with native and exotic sows (data set 1).*

	Breed group		*Municipality*				*Significance*		
Trait	*Native*	*Exotic*	*Infanta*	*Lopez*	*Mulanay*	*Tiaong*	*Breed group*	*Mun.*	*BG x Mun.*
n	25	24	11	13	14	11			
OLPI (%)	67.7 ± 2.6	39.9 ± 2.7	53.0 ± 3.9^{ab}	44.1 ± 3.5^{b}	58.6 ± 3.4^{a}	58.1 ± 4.0^{a}	< 0.001	0.021	0.111

Mun. = Municipality; BG = Breed group.
Within municipality, least-squares means with common small-case superscript letters do not differ significantly ($p \geq 0.05$).

spectively), but overall there were no differences in working hours between breed groups and municipalities.

3.3 Environmental and social impact

The approximation of the pig production units to organic standards was evaluated using data from data set 1 (Table 7). The OLPI was used to assess the extent to which agricultural practices that promote nutrient cycling, resource use and animal welfare were applied. Farms keeping the native breeds achieved a significantly higher OLPI score compared to the system based on exotic sows. On average, the OLPI score of farms keeping native sows was 27.8 percentage points higher than the OLPI score reached by farms keeping exotic sows. The municipality also influenced the approximation to organic standards. In addition to the “preservation and promotion of indigenous breeds”, which was automatically fulfilled or not fulfilled due to the sample selection, the breed groups differed mainly for the following OLPI variables: Farmers of the native sow group offered roughage more frequently (80 vs. 25 %, X^2 (1, n = 49) = 12.746, $p < 0.001$), produced the majority of feed more frequently by themselves (48 vs. 13 %, n = 49, $p < 0.001$, Fisher’s exact test), used allopathic drugs less frequently for prophylaxis (44 vs. 13 %, n=49, $p = 0.025$, Fisher’s exact test) and offered more frequently access to (sufficient) outdoor area (76 vs. 21 %, X^2 (1, n = 49) = 12.787, $p < 0.001$).

Table 8: *Frequency of preventive treatment of pigs on small farms with native and exotic sows (data set 2).*

Drug type / subset	*n*	*% use* *Native*	*Exotic*	*P value*	*Odds ratio 95 % CI*
Antibiotic					
Tiaong	31	7.1	52.9	0.009	13.4 (1.4-686.1)
Infanta	37	15.0	88.2	< 0.001	35.9 (5.0-485.1)
Anthelmintic					
Tiaong	31	14.3	88.2	< 0.001	36.3 (4.3-596.6)
Infanta	37	45.0	100.0	< 0.001	–

95 % CI = 95 % confidence interval.

Analysis of feed data collected from the two municipalities visited in the second survey period revealed the type and origin of feed (data set 2). The data showed that farmers keeping native sows from Tiaong used a wide range of feed, most often copra meal (67 % of farmers fed this product), followed by vegetable leftovers and rice bran (each fed by 57 % of farmers). In Infanta, all farmers who kept native sows fed their pigs with rice bran (100 %), and most of them also fed taro leaves (85 %). None of the other items were used by more than 50 % of the farmers keeping native sows.

Table 9: *Results of cumulative logit link model analysis of the assessment of the challenges in pig production by smallholder farmers (data set 2).*

Challenge / Municipality	*Breed group*	*n*	*mean score**	*Model parameters* est. (β)	SE	z-value	P-value
Feed cost							
Tiaong	native	11	1.7	0.0			
	exotic	14	2.5	1.281	0.842	1.522	0.128
Infanta	native	20	2.1	0.841	0.794	1.059	0.289
	exotic	17	3.6	2.578	0.832	3.100	0.002
Disease							
Tiaong	native	11	1.5	0.0			
	exotic	14	3.1	2.274	0.898	2.533	0.011
Infanta	native	20	2.5	1.516	0.896	1.692	0.091
	exotic	17	3.3	2.567	0.912	2.815	0.005
Lack of investment capability							
Tiaong	native	11	1.4	0.0			
	exotic	14	2.1	1.216	0.928	1.310	0.190
Infanta	native	20	2.6	1.725	0.888	1.944	0.052
	exotic	17	3.3	2.523	0.894	2.823	0.005
Market instability							
Tiaong	native	11	1.4	0.0			
	exotic	14	2.3	2.301	1.155	1.992	0.046
Infanta	native	20	2.7	2.631	1.135	2.319	0.020
	exotic	17	3.3	3.281	1.159	2.831	0.005

* 1 = of no challenge at all, 2 = of very little challenge, 3 = of a moderate challenge, 4 = of quite a challenge, 5 = of a huge challenge.
est. = estimate; SE = standard error

Where the production was based on exotic sows, farmers generally purchased commercial feed according to the needs of their pigs (compound feed for piglets, fatteners and pregnant or lactating sows) regardless of the municipality. In addition, 57 % of the farmers in Tiaong fed copra meal and 59 % of the farmers in Infanta fed rice bran to their pigs.

Data from data set 2 showed that farmers from Tiaong and Infanta who raised exotic sows used antibiotics and anthelmintics more frequently to prevent disease than those who raised native sows (Table 8). Antibiotics were mostly administered in the form of oral powder; intravenous solutions were the second most common route of administration. The most used antibiotics were doxycycline (38 %) and penicillin-streptomycin (24 %). Antibiotics administered by veterinarians could not be identified. When administered to the sows, the main purpose of antibiotic treatment was to prevent post-farrow infections, while the use in piglets was aimed at the prevention of respiratory and gastrointestinal infections. When farmers were asked if they knew of ethnoveterinary plants for preventing and treating swine diseases, 62 % of farmers who kept native sows mentioned at least one plant, while 26 % of farmers who kept exotic sows could mention at least one natural remedy. The plants named by the farmers, the plant parts used, the field of application and the method of preparation, if available, are listed in online Supplementary Material.

3.4 The perception of farmers regarding the challenges of pig production

To collect data set 2, farmers were asked to rate different aspects of pig production according to the level of challenge each posed to their production system. The breed group-municipality effect influenced farmers' evaluation of all aspects except the availability of labour (data not shown) significantly (Table 9). Forty-seven percent of farmers from Infanta who kept exotic sows rated feed costs as "of a huge challenge", while the majority of farmers of the remaining groups considered feed costs as "of no challenge at all". The likelihood of perceiving feed costs as a major challenge was significantly higher for farmers from Infanta who kept exotic sows than for farmers who kept native sows there and in Tiaong (OR: 5.7, 95 % CI 1.7–20.1 and OR: 13.2, 95 % CI

2.8–77.8, respectively). Sixty-five percent of farmers who kept native sows classified diseases as "of no challenge at all", while the majority of the owners of exotic sows from Infanta and Tiaong regarded diseases as "of a huge challenge" and "of a moderate challenge", respectively. The likelihood of considering diseases as a challenge was significantly higher for farmers who kept exotic sows in Tiaong and Infanta than for farmers who kept native sows in Tiaong (OR: 9.7, 95 % CI 1.9–74.9 and OR: 13.0, 95 % CI 2.5–102.6, respectively). Sixty-one percent of farmers who kept native sows rated the lack of investment capability as "of no challenge at all". Of the owners of exotic sows from Infanta, 29 % each rated this aspect as "of quite a challenge" and as "of a huge challenge". Farmers from Infanta who kept exotic sows rated the lack of investment capability as significantly more challenging compared to native sow farmers from Tiaong (OR: 12.5, 95 % CI 2.5–95.6). The majority of farmers from Tiaong who kept native pigs rated market instability as "of no challenge at all", while differences in perceptions for market volatility of the remaining groups were less conclusive. Farmers who kept exotic sows from Tiaong (OR: 10.0, 95 % CI 1.4-204.1) or from Infanta (OR: 26.6, 95 % CI 3.8-548.0) and farmers who kept native sows from Infanta (OR: 13.9, 95 % CI 2.1–278.1) rated market instability as significantly more challenging than the owners of native sows from Tiaong. Attention must be drawn to the very high confidence intervals for this aspect.

4 Discussion

In the present study, the sustainability of backyard-keeping of native sows in the smallholder sector of Quezon province, Philippines, was compared to more intensive management of exotic sows. In some municipalities of Quezon, small pig farms based on either native or exotic sows coexist. In contrast, the intensity of pig production in other regions often increases along a rural-urban gradient (Huynh *et al.*, 2006), which complicates the direct comparison. The coexistence of both systems and their commercial orientation made Quezon an ideal study site. In fact, the socio-economic environment of households and their income streams were comparable. The households in the sample mainly belonged to the lower income quartile. The income from off-farm activities of the households studied was often not sufficient to cover basic food and non-food needs (20,515 PHP per capita and year; PSA, 2015). In Calabarzon, employment is often irregular and/or does not fulfil economic needs. The rates of unemployment and underemployment are at 8.0 and 18.2 %, respectively (NEDA, 2017). Therefore, agricultural activities are important for households that are vulnerable to economic or natural shocks. Due to the small sample size of both data sets, this study still has the character of a pilot study, which makes it possible to reveal only large effect sizes with a reasonable statistical power.

Productivity and profitability are decisive for the contribution of pig production to farm income and thus to the economic pillar of sustainability. The biological parameters of pig production and the economic success of pig farming are closely linked. In Quezon, the combination of exotic genetics with nutrient-rich feeding resulted in better prolificacy (10.7±0.4 vs. 8.5±0.3 piglets per litter) of the sows and improved growth (861±66 vs. 391±60 g daily weight gain) of their progeny. Previous studies from the Philippine provinces of Benguet and Leyte reported similar reproductive performance in sows (Lañada *et al.*, 1999), but the growth rates of crossbred fattening pigs (160 g daily weight gain) were lower than in Quezon (Lee *et al.*, 2005). Due to the better performance of the sows and their offspring, households that kept exotic sows achieved a more than twice as high annual live weight offtake from pig production than those who kept native sows (607 vs. 274 kg per household and year). The annual live weight extraction from small-scale pig production in the present study was also slightly higher than that observed by Lemke *et al.* (2007) for pig production systems in Vietnam. Differences in pig performance between municipalities can be explained by differences in the availability and quality of inputs. In the present study, this related to the genetics (e.g. on breeds and lines within breed group) and to the farming system, which was defined by the feed basis and socio-economic environment. The latter for instance, was characterised by the level of advisory services provided by public and private stakeholders. In Tiaong for example, farmers who kept native sows experienced support from the NSPRDC. The NSPRDC bred gilts under organic management and distributed them to registered farms, provided training on housing and feeding, and access to veterinary services and artificial insemination. In addition, prior experience with exotic sows probably led to carry-over effects as some of the farmers from Infanta who started to keep native sows continued to use practices more akin to intensive pig production.

The strong effect of the breed group on live weight offtake indicated that the intensive management of exotic sows consistently enabled the maximisation of pork output per pig production unit, explaining the higher annual revenues from pig farming. Similarly, research in Vietnam showed that, in comparison to traditional management of native breeds, the semi-intensive management of exotic or crossbred sows led to significantly higher revenues but also higher costs of small-scale pig production (Lemke *et al.*, 2007). In that study, gross margins of semi-intensive pig producers were still higher than those of extensive pig farmers. In Quezon, variable costs and revenues also differed significantly between owners of native and exotic sows, but the ROI did not differ between both production systems. This means that both systems were equally cost effective and generated about 1 PHP per PHP invested. However, pig farmers from Quezon pursued different investment strategies by choosing to keep either native or exotic sows. In particular, production based on exotic sows is likely to fulfil important financial functions, e.g. regular cash income or emergency insurance, which are in agreement with other studies on pigs (Mbuthia *et al.*, 2015) and other livestock (Woldu *et al.*, 2016). It has recently been noted that access to financial services by marginalised sectors and rural communities in the region of Calabarzon is inadequate (NEDA, 2016), further corroborating this finding. The management of exotic sows allowed for high capital turnover, but volatile market prices for feed and pork create a financial risk which, in the worst case, could lead to the loss of investment. This was reflected in the assessment of pig production challenges by owners of exotic sows from an unfavourable environment, Infanta, where there were fewer alternatives to pig production due to less acreage and less attractive off-farm possibilities to obtain income. High feed costs and investment needs along with market instability were also seen by small-scale pig farmers in sub-Saharan Africa as production limiting factors (Mbuthia *et al.*, 2015), and reflect the problem that smallholders are not able to exploit economies of scale as efficiently as larger enterprises (Tarawali *et al.*, 2011). In Quezon, farmers who kept exotic sows relied largely on purchased compound feed, while the use of locally grown feed with only very limited use of premixed or concentrated feed was common in (semi-) intensive small-scale pig production in Vietnam (Muth *et al.*, 2017c). Using high-quality local feed and its supplementation with vitamins and minerals could reduce the need for compound feed and thereby reduce costs (Martens *et al.*, 2012). However, this would presumably only be accepted if the performance of the animals would not drop too sharply. For most of the farmers keeping native sows the aforementioned production aspects were not considered as a challenge. The management of native sows was far less expensive and thus financially less risky, allowing only the investment of relatively small amounts of money. The low revenue was a result of the low level of production and of low prices for niche products such as *lechon*-type pork. In fact, the prices paid per kg live weight were similar for offspring of native and exotic sows in 2016. Ineffective marketing could additionally have contributed to poor producer prices (Muth *et al.*, 2017b). In the Philippines first research on native *lechon*-type porkers has been carried out (Bondoc *et al.*, 2017) and provides a starting point to increase product information and develop marketing grids. This could stabilise markets and increase revenues from marketing of native pigs.

In addition to their economic development it is also necessary to avoid environmental and social damage to ensure the sustainability of pig production systems, which is particularly emphasised in organic production. The OLPI reflected the level of compliance with the OCCP standards (2003) for organic livestock farming and clearly favoured the production system based on native sows (67.7±2.6 vs. 39.9±2.7 %). As the OCCP standards (2003) aim to ensure nutrient cycling (crop-livestock integration) and animal welfare, this finding suggests that farmers who kept native sows achieved higher levels of environmental soundness and animal welfare than the production system based on exotic sows. Because farmers who kept native sows mainly used locally grown by-products from crop production (e.g. copra meal and rice bran) as feed, little extra land and non-renewable energy was needed for feed production, and there was no competition with food production. If, in contrast, the feed chain requires a change in land use, the potential for global warming could be dramatically increased (Bava *et al.*, 2017). Feed production is a main contributor of greenhouse gas emissions, in particular of carbon dioxide, from livestock production and consumes large quantities of water (Sala *et al.*, 2017). However, environmental impacts at the local scale also need to be considered. If farmers produce feed by themselves, it is very likely that the manure will also be used to fertilise their plots. Improved crop-livestock integration has the potential to reduce both nutrient surpluses and the need for synthetic fertilisers (Bouwman *et al.*, 2011). This is in line with the regional authority's goal of promoting integrated nutrient management (NEDA, 2017). Conversely, purchasing compound feed, as was mostly the case with exotic sows, could increase the risk of local nutrient surpluses. Improper handling of manure could lead to greenhouse gas emissions, in particular of nitrous oxide, eutrophication, and acidification (Bava *et al.*, 2017). This is particularly relevant when farmers intensify pig production to compensate for lack of cropping area. It must be highlighted that, so far, the discussion on environmental impact referred to the unit of pig production. In contrast, most studies on life-cycle-assessment of livestock production use the unit of product as a baseline (Sala *et al.*, 2017; van Wagenberg *et al.*, 2017). Taking the unit of product as a reference could reverse the present evaluation, given that the live weight output of the system based on exotic sows was clearly increased. This also implies that increasing the productivity of native sow-based pig production could improve its environmental sustainability, as demonstrated in a study of intensive pig production systems in Italy (Bava *et al.*, 2017). For the purpose of this study it was more relevant to refer to the production unit in order to consider possible local-scale impacts, e.g. the deterioration of freshwater resources, which are given priority by Calabarzon's authority (NEDA, 2016).

The social pillar of sustainability was examined from two perspectives: animal welfare and public health. In terms of animal welfare, which is gaining importance in urbanised and wealthier societies (Tarawali *et al.*, 2011), it was found that farmers who had native pigs more often kept sows outdoors in their backyard. While providing outdoor access was positively taken into account, the sows were often tethered which clearly limited their ability to express natural behaviour. Thus, a fundamental assumption for animal welfare in favour of production based on native sows could not be made. Reducing the use of allopathic drugs in animal production has crucial implications for public health and therefore contributes to the social sustainability of animal production systems. Indiscriminate use could increase the risk of residues in food and the risk of developing anthelmintic and antimicrobial resistance. Farmers who kept exotic sows were more likely to use allopathic medicines for preventive treatment, possibly made easy by the availability of over-the-counter antibiotics in stores. It was found that doxycycline and penicillin-streptomycin, rated as "critically important" and as "highly important" respectively for risk management of antimicrobial resistance due to non-human use (WHO, 2017), had the most widespread use. It is reported that the overuse of antibiotics has become a problem in smallholder pig production of several Asian countries, for instance Vietnam (Kim *et al.*, 2013), resulting in resistant bacterial strains. The significantly increased odds of preventive antibiotic treatment in farms keeping exotic sows could result from a higher susceptibility to diseases and from a fear of farmers to lose their investments due to disease. The latter is not unjustified, because even under the conditions of small-scale production the number of parities achieved by a sow has been shown to contribute significantly to its reproductive efficiency (Muth *et al.*, 2017a), and thus to its profitability. As observed for owners of exotic sows in Quezon, smallholders in sub-Saharan Africa also considered diseases as an important threat to their pig production system (Nantima *et al.*, 2015), indicating a shortage of veterinary services.

5 Conclusions and implications

In summary, results showed that smallholders keeping native sows used less external inputs in terms of compound feed and veterinary drugs, possibly resulting in less local environmental load and a reduced public health impact. In order to improve the understanding of the environmental impact beyond the application of practices considered as favourable, it is recommended to carry out a life-cycle-assessment (Sala *et al.*, 2017) and/or to directly measure effect-based indicators (e.g. nitrate concentrations in groundwater) (Lebacq *et al.*, 2013). Native sows were less productive, thus allowing only a reduced live weight offtake per household and year. However, both pig production systems were equally cost-effective and required similar weekly labour hours of the unpaid family members. The advantage of basing production on exotic sow breeds was the possibility to make larger investments, which could at least partially offset a lack of access to financial services. The financial function of exotic sows could be met only to a limited extent by native sows and their offspring due to the biological limitations of converting high quality feed (i.e. the investment) into growth. Therefore, the substitution of native sows for exotic sows seems rather unlikely under the current conditions and it is recommended that regulating access to allopathic drugs and ensuring access to veterinary services should receive a high priority due to the implications for public health. Managing nutrient surpluses in the form of pig manure is another key area that should receive attention in order to mitigate local environmental impact. Whereas practices of keeping native sows were relatively close to organic standards, the revenues from marketing porkers from native sows were low, preventing a better competitiveness. Conversion to organic pig production and certification could represent one strategy for development but only given that a market for organic pork products exists and premiums are being paid. Niche marketing of *lechon*-type piglets could also be an option. Since the expansion of production is limited by the availability of local feed resources, it is strongly recommended to increase the value added to improve the cost-effectiveness of the production from native pigs in Quezon.

Supplement

The supplement related to this article is available online on the same landing page at: https://doi:10.17170/kobra-202002281033 .

Acknowledgements

I.K. Pöhlmann and S. Bae were funded by a Dr. Hermann Eiselen scholarship from the fiat panis foundation. The logistical support from the staff of the National Swine and Poultry Research and Development Centre (NSPDRC) and the Municipal Agriculture Offices (MAO) is gratefully acknowledged. Sincere gratitude is expressed to all participating farmers from Quezon for their willingness to share information and sacrifice their precious time.

Conflict of interest

Authors state they have no conflict of interests.

References

Bae, S. (2017). *How can organic pig production with local breeds in the Philippines succeed in keeping morbidity and mortality low while avoiding anti-microbial use?* M.Sc. Thesis, University of Hohenheim, Stuttgart, Germany.

Bava, L., Zucali, M., Sandrucci, A. & Tamburini, A. (2017). Environmental impact of the typical heavy pig production in Italy. *Journal of Cleaner Production*, 140, 685–691.

Bondoc, O.L., Dominguez, J.M.D., Bueno, C.M. & Abanto, O.D. (2017). Evaluation of pre-slaughter and slaughter data from *lechon*-size Black Tiaong and Kalinga native pigs (organic farm) and Landrace, Large White and their F1 crosses (conventional farm). *Philippine Journal of Science*, 146, 411–423.

Bouwman, L., Goldewijk, K.K., Van Der Hoek, K.W., Beusen, A.H., Van Vuuren, D.P., Willems, J., Rufino, M.C. & Stehfest, E. (2013). Exploring global changes in nitrogen and phosphorus cycles in agriculture induced by livestock production over the 1900–2050 period. *Proceedings of the National Academy of Sciences*, 110, 20882–20887.

Christensen, R.H.B. (2018). ordinal - Regression Models for Ordinal Data. R package version 2018.4–19. Available at: https://CRAN.R-project.org/package=ordinal. Last accessed 26.04.2019.

Food and Agriculture Organization of the United Nations (FAO) (2001). Annex 2 Working definitions for use in developing country reports and providing supporting data. In: Preparation of the First Report on the State of the World's Animal Genetic Resources. FAO, Rome, Italy.

Huynh, T.T.T., Aarnink, A.J.A., Drucker, A. & Verstegen, M.W.A. (2006). Pig production in Cambodia, Laos, Philippines, and Vietnam: A review. *Asian Journal of Agriculture and Development*, 4, 69–90.

Ieda, N., Bui, Q.V., Nguyen, N.T.D., Lapar, L. & Marshall, K. (2015). Characterization of smallholder pig breeding practices within a rural commune of North Central Vietnam. *Tropical Animal Health and Production*, 47, 1005–1016.

International Federation of Organic Agriculture Movements (IFOAM) (2014). The IFOAM Norms for Organic Production and Processing – Norms 2014, IFOAM, Bonn, Germany.

Kim, D.P., Saegerman, C., Douny, C., Dinh, T.V., Xuan, B.H., Vu, B.D., Hong, N.P. & Scippo, M.L. (2013). First survey on the use of antibiotics in pig and poultry production in the Red River Delta region of Vietnam. *Food and Public Health*, 3, 247–256.

Lañada, E.B., Lee, J.A.L.M., More, S.J., Cotiw-an, B.S. & Taveros, A.A. (1999). The reproductive performance of sows raised by smallholder farmers in the Philippines. *Preventive Veterinary Medicine*, 41, 171–186.

Landers, T.F., Cohen, B., Wittum, T.E. & Larson, E.L. (2012). A review of antibiotic use in food animals: perspective, policy, and potential. *Public Health Reports*, 127, 4–22.

Lebacq, T., Baret, P. & Stilmant, D. (2013). Sustainability indicators for livestock farming. A review. *Agronomy for Sustainable Development*, 33, 311–327.

Lee, J.A.L.M., Lañada, E.B., More, S.J., Cotiw-an, B.S. & Taveros, A.A. (2005). A longitudinal study of growing pigs raised by smallholder farmers in the Philippines. *Preventive Veterinary Medicine*, 70, 75–93.

Lemke, U., Kaufmann, B., Thuy, L.T., Emrich, K. & Valle Zárate, A. (2007). Evaluation of biological and economic efficiency of smallholder pig production systems in North Vietnam. *Tropical Animal Health and Production*, 39, 237–254.

Martens, S.D., Tiemann, T.T., Bindelle, J., Peters, M. & Lascano, C.E. (2012). Alternative plant protein sources for pigs and chickens in the tropics – nutritional value and constraints: a review. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 113, 101–123.

Mbuthia, J.M., Rewe, T.O. & Kahi, A.K. (2015). Evaluation of pig production practices, constraints and opportunities for improvement in smallholder production systems in Kenya. *Tropical Animal Health and Production*, 47, 369–376.

Mena, Y., Nahed, J., Ruiz, F., Sánchez-Muñoz, J., Ruiz-Rojas, J. & Castel, J. (2012). Evaluating mountain goat dairy systems for conversion to the organic model, using a multicriteria method. *Animal*, 6, 693–703.

Muth, P.C., Huyen, L.T.T. & Valle Zárate, A. (2017a). Sow efficiency and early piglet mortality in two local pig breeds on smallholder farms in northern Vietnam – a longitudinal study. *Tropical Animal Health and Production*, 49, 1227–1234.

Muth, P.C., Huyen, L.T.T., Markemann, A. & Valle Zárate, A. (2017b). Tailoring slaughter weight of indigenous Vietnamese Ban pigs for the requirements of urban high-end niche markets. *NJAS - Wageningen Journal of Life Sciences*, 80, 27–36.

Muth, P.C., Markemann, A., Huyen, L.T.T. & Valle Zárate, A. (2017c). Discriminating the quality of local pork from crossbred pork from extensive production of ethnic minorities in mountainous northern Vietnam. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 118, 45–57.

Nantima, N., Ocaido, M., Davies, J., Dione, M., Okoth, E., Mugisha, A. & Bishop, R. (2015). Characterization of smallholder pig production systems in four districts along the Uganda-Kenya border. *Livestock Research for Rural Development*, 27, 8.

National Economic and Development Authority Regional Office IV-A (NEDA) (2016). *2016 Calabarzon Regional Development Report.* NEDA, Laguna, Philippines.

National Economic and Development Authority Regional Office IV-A (NEDA) (2017). *Regional Development Plan 2017–2022.* NEDA, Laguna, Philippines.

Organic Certification Center of the Philippines, Inc. (OCCP) (2003). *OCCP Standards for Organic Agriculture and Processing.* OCCP, Pasay City, Philippines.

Philippine Statistics Authority (PSA) (2015). *2015 Full Year Official Poverty Statistics of the Philippines.* PSA, Quezon City, Philippines.

Philippine Statistics Authority (PSA) (2017). *Swine Situation Report – January–December 2016.* PSA, Quezon City, Philippines.

Pöhlmann, I.K. (2017). *How can food security and income diversity of smallholder farmers in the Philippines be improved by organic pig production?* M.Sc. Thesis, University of Hohenheim, Stuttgart, Germany.

R Core Team (2017). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing. Vienna, Austria.

Sala, S., Anton, A., McLaren, S.J., Notarnicola, B., Saouter, E., & Sonesson, U. (2017). In quest of reducing the environmental impacts of food production and consumption. *Journal of Cleaner Production*, 140, 387–398.

Smith, J. (2017). *Achieving Agenda 2030: Livestock research and the transformation of small-scale production.* International Livestock Research Institute (ILRI), Nairobi, Kenya.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. & de Haan, C. (2006). *Livestock's long shadow: environmental issues and options.* Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Tarawali, S., Herrero, M., Descheemaeker, K., Grings, E. & Blümmel, M. (2011). Pathways for sustainable development of mixed crop livestock systems: Taking a livestock and pro-poor approach. *Livestock Science*, 139, 11–21.

van Wagenberg, C.P.A., de Haas, Y., Hogeveen, H., van Krimpen, M.M., Meuwissen, M.P.M., van Middelaar, C.E. & Rodenburg, T.B. (2017). Animal Board Invited Review: Comparing conventional and organic livestock production systems on different aspects of sustainability. *Animal*, 11, 1839–1851.

Woldu, T., Markemann, A., Reiber, C., Muth, P.C. & Valle Zárate, A. (2016). Optimising contributions of goat farming to household economic success and food security in three production systems in Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 117, 73–85.

World Health Organization (WHO) (2017). *Critically important antimicrobials for human medicine – 5th revision.* WHO, Geneva, Switzerland.