Comparative Financial and Environmental Life Cycle Assessment of three South African Pork Production Chains

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ABSTRACT

Intensive pork production systems have traditionally had a poor image with the public, because these production systems are associated with environmental pollution. While the world demand for meat, and especially pork, needs to be met, an increasing awareness exists among consumers, researchers and producers about the environmental impacts associated with producing meat. Notwithstanding this, environmental impacts are not captured in the price of meat. This study determines the energy balance and emissions of three case studies, and compares these results with their financial performance using the Life cycle assessment (LCA) method. The case studies were three typical South African pig production facilities, selected by the South African pork producer's organisation (SAPPO). The production inputs, from feed acquisition to the delivery of one kg of pig at the farm gate, were included. The three farms are located in different areas of South Africa, namely KwaZulu-Natal province (Case study 1), North-West province (Case study 2) and the Western Cape province (Case study 3). The functional unit (FU) for this study is defined as 1 kg of South African pig (live-weight) at the farm gate. The major activities that predominantly contributed to the environmental impact categories were the slurry management activity, followed by electricity usage. Because the financial and environmental performance comparison showed deviations, it is recommended that environmental and financial performance measurements be made. This will provide a true reflection of the impacts. The potential for improvement in financial and environmental performance proved to be significant in the productivity of the sow herd, as well as in the management of the piglets. The location of the production facility does not seem to have significant environmental or financial implications. Management of the emissions produced by piggeries can offset the impact of the piggery's location.

Keywords: Environmental impact; life cycle assessment; pork production; global warming potential; eutrophication potential; acidification potential

1. Introduction

The world demand for meat consumption has led to its intensive production. Consumption of pork in South Africa has increased by 53 % over the past decade. However, the intensive, concentrated meat production practices place a heavy strain on the environment. Furthermore, intensive pork production systems traditionally have a poor image with the public because they are associated with environmental pollution (Basset-Mens & Van der Werf, 2005:140). The location of the intensive pork production unit requires that production inputs need to be transported to the plant, and the outputs produced at the unit need to be transported to the market place. The location of the pork production unit therefore plays an important role in terms of the environmental impacts generated throughout the production chain. The comparison of the three selected piggeries in terms of environmental, financial and economic

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performance should provide useful information with regard to the impact of the location of the piggery relative to input sources, pork markets and the impact of location relative to other infrastructure.

Life cycle assessment (LCA) can assist in quantifying environmental impacts and increasing awareness of the resultant impacts caused by producing products and delivering services (ISO 14040, 2006). The entire life cycle of a product includes raw material extraction, manufacture, distribution, transportation, maintenance, recycling, emissions and final disposal. LCA induces more informed decision-making. It can be used also for marketing advantages based on environmental performance. Additionally, LCA can be used to compare products, processes or services.

2. Methods and Data

Data for the three pig-farming practices was collected during field trips. This data was used to model and to evaluate the environmental performance of the case studies. The three case studies are of farrow-to-finish production farms. This means that the weaners are born and raised on the farm until they reach their slaughter weight. Some weaners are retained to replace sows that are slaughtered. This study had a gate-to-gate system boundary. The system boundary did not include the environmental impacts pertaining to the production of the feed and fertiliser, the distribution of the final product and its recycling. The slaughterhouse activity and its inputs, as well as the distribution of the final product were also excluded. Therefore, if comparisons of results are to be made with previous studies, one must compare the segments in their production chain that included similar inputs and processes studied. The three case studies were evaluated and compared based on the following environmental impact categories; global warming potential (GWP), eutrophication potential (EP), acidification potential (AP) and energy use (EU).

3. Results

For all three case studies, the factor that contributes the most to GWP was slurry management. It contributed 89 %, 79 % and 69 % to GWP for Case studies 1, 2 and 3 respectively. In Figures 1, 2 and 3, the relative contribution of each activity to GWP can be seen. The feed acquisition activity's relative contribution to GWP for Case studies 1, 2 and 3 was 0.80 %, 0.75 % and 3.43 % respectively. This was smaller than initially envisaged. Case study 3 had a higher GWP for feed acquisition. This was mainly due to maize being transported approximately 1 250 km by road to the farm. In Case study 3, 11 % less maize was used than for Case study 1, and 14 % less than for Case study 2, when their feed rations were compared. A higher percentage of wheat, sunflower, oats, lucerne, canola and lupines was used in Case study 3, because these feed components were produced closer to the piggery than the maize component. This was done to offset some of the transportation distance of the maize component. For Case study 3, the farm adapted to some extent to the unavailability of resources in its region.

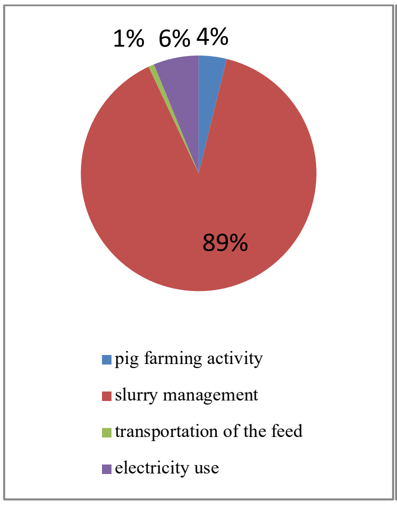

Figure 1: GWP results for the LCA activities of Case study 1

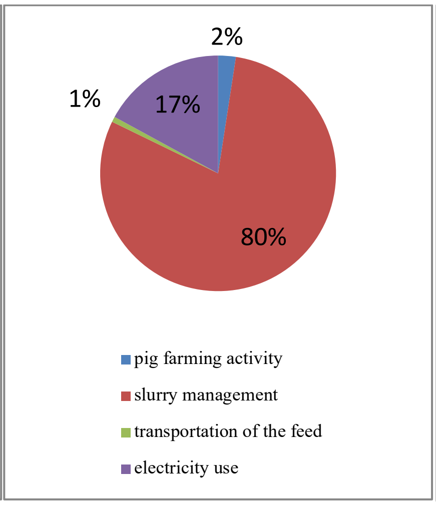

Figure 2: GWP results for the LCA activities of Case study 2

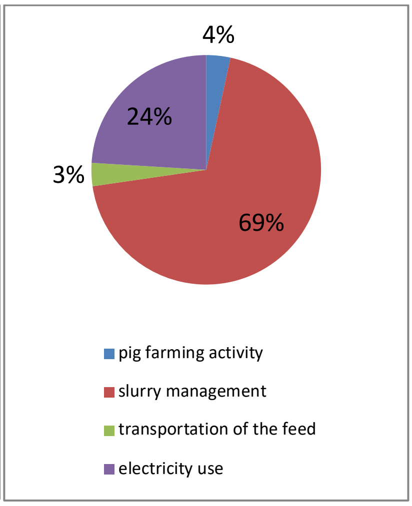

Figure 3:GWP results for the LCA activities of Case study 3

The main factor contributing to the EP for all three case studies was slurry management. Slurry management accounted for 95 %, 94 % and 91 % of the contributions to EP for Case studies 1, 2 and 3 respectively. Devers, et al. (2012) found that slurry management contributed 85 % of the total EP in a cradle-to-gate LCA in South Africa, and 58 % for one in Flanders. These two figures are lower than for this study because the production of raw materials was included in the study by Devers et al. The results are similar, but the way in which the two studies accounted for the impacts of the slurry differs. The results for the total EP in Case studies 1, 2 and 3 were 0.00343, 0.00323 and 0.00308 kg of PO_4-eq/FU respectively, in one year. The EP for Case study 1 was 6% higher than for Case study 2, and 10 % higher than for Case study 3. A previous LCA study of pork production in South Africa found that the leaching of nitrogen from the slurry and the production of feed were the major contributors to EP: slurry management was responsible for 90 % of the EP (Devers et al., 2012:55). The contribution of the slurry management activity to EP in this gate-to-gate LCA was high because another large contributor to EP, namely the production of feed, was outside the system boundaries. The pig-farming and feed-mixing and transportation activities were minor contributors to EP for a South African Case study. In this study, these two activities accounted for only 0.2 and 0.7 % respectively. The pig farming activity included neither the enteric emissions nor emissions from managing the slurry. The slurry management was done separately, and accounted for 0.0289 kg of PO_4eq/FU (Devers et al., 2012:55). The transportation of feed did not contribute significantly to the EP in that cradle-to-grave LCA.

The reason for the lower impacts in EP for this study can be explained by the following: 1) different methods of accounting for environmental impacts, 2) smaller system boundaries, and 3) a different FU. When looking at the results, it is clear that the case study that produces the least slurry per FU will have the lowest EP. The FU is also heavily affected by the FCR. The production chain for Case study 3 needed less feed than for those of the other two case studies to convert it to the FU. For Case study 2, more piglets were weaned in a year than for the other two case studies. The farm for Case study 1 produced the most slurry per FU, and needed more feed and water to produce one FU. For Case study 1, also fewer piglets per sow per year were weaned. The farm for Case study 1 had a high percentage of pre-weaning (9.9 %) and post-weaning mortality (3 %) compared with those of the other two case studies. The farm in Case study 1 housed more sows per year per FU. This implies that the farm of Case study 1 would have a higher feed usage per FU, produce more slurry per FU and have a higher EP than for those of the other two case studies. The EP results of the three case studies did not provide useful information regarding an optimal environmentally friendly region for the production of pork. The higher EP for Case study 1 could also be the result of different structuring in the pig's pen. Weaker genetics could also result in a higher pre- and post-weaning mortality. The EP results show that the management of the pork production chain holds major environmental impact mitigation opportunities.

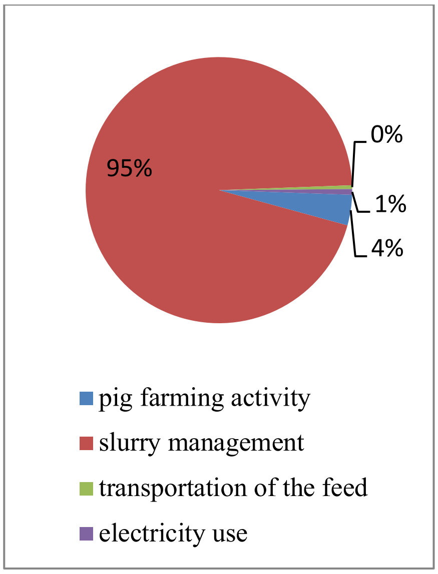

Figure 41: EP results for the LCA activities of Case study 1

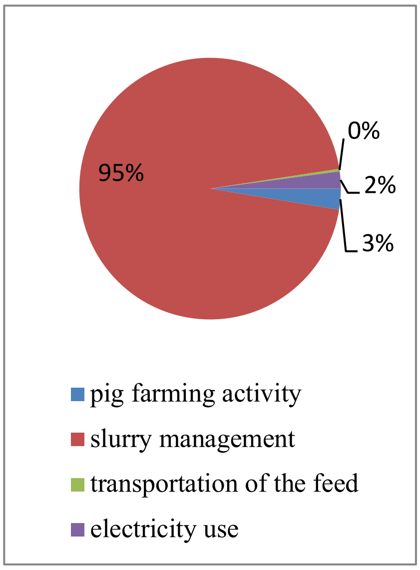

Figure 52: EP results for the LCA activities of Case study 2

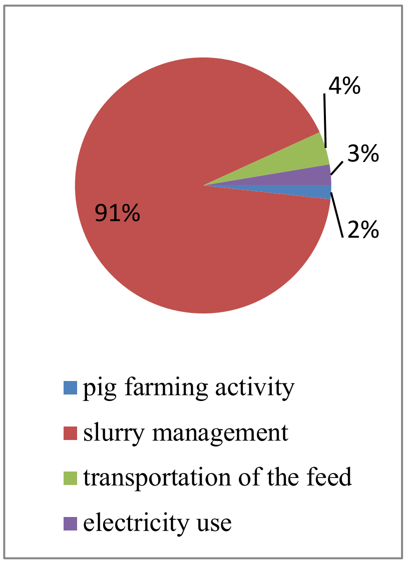

Figure 6: EP results for the LCA activities of Case study 3

In this study, AP was also caused mainly by the slurry management, and accounted for 95 %, 93 % and 85 % of the AP for the three case studies respectively. Case study 1 produced the highest amount of slurry per FU, and had the highest AP per FU.

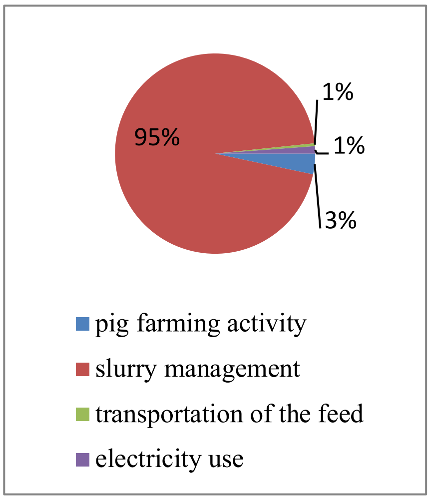

Figure 73: AP results for the LCA activities of Case study 1

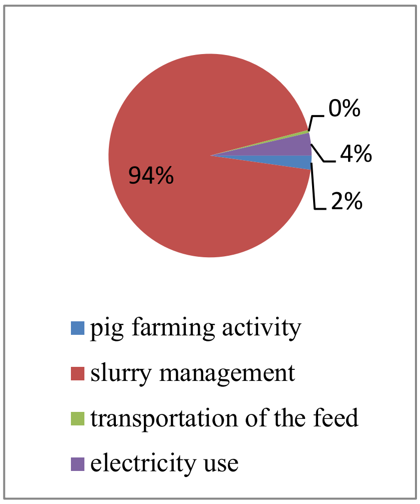

Figure 4: AP results for the LCA activities of Case study 2

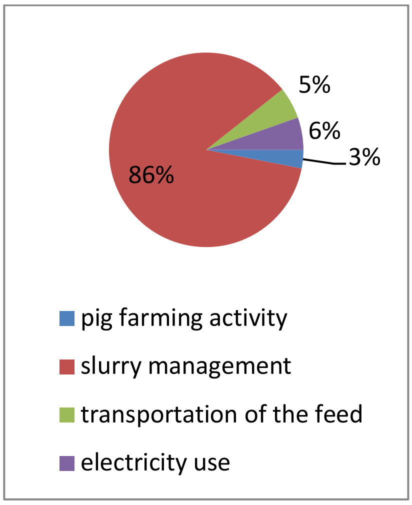

Figure 5: AP results for the LCA activities of Case study 3

The EU for Case studies 1 to 3 was 5.5, 8.4 and 11.7 of MJ/FU respectively. Electricity use and slurry management were the major contributors to the EU for the three case studies. The piggery of Case study 3 generated less slurry per FU but used far more electricity than those of the other two Case studies. The results for AP for Case studies 1, 2 and 3 were 0.0155, 0.0147 and 0.0146 kg of SO_2-eq/FU respectively. These results are shown in Figure 26. For Case study 1, a 6 % higher AP was generated than for Case study 2, and a 7 % higher AP than for Case study 3. The major activity that contributed to AP in all three case studies was the slurry management activity. This activity accounted for 95 %, 94 % and 86 % of the total AP for Case studies 1, 2 and 3 respectively.

The main contributor to AP in this study was the ammonia emitted from the slurry applied to the agricultural land. This process contributed 67 % of the total AP in a cradle-to-gate LCA. The feed production activity also contributed heavily to the AP (Fry & Kinston, 2009:14). A cradle-to-farm gate LCA in the USA found an AP of 0.025 kg of SO_2-eq per kg of live weight. This LCA study covered the slurry management activity, the feed production activity and the enteric emissions of the pig itself. The production of the feeds accounted for 45 % of the total AP, and slurry management accounted for 43 %. The AP for slurry management was 0.011 kg of SO_2-eq per kg of live-weight. The enteric emissions of the pig contributed 0.0027 kg of SO_2-eq to the total AP per kg of live weight. The enteric emissions contributed only 10 % of the total AP of the LCA (Stone et al., 2012:7). These results are similar to the findings in this study. The contribution to AP of the slurry management for Case studies 1, 2 and 3 was 0.0148, 0.0138 and 0.0125 kg of SO_2-eq/FU.

The AP in Case studies 1, 2 and 3 was highly affected by the slurry management activity. Slurry management and the production of feed were the highest contributors to this impact category, but only the slurry management was accounted for in this LCA. Feed production was outside of the system boundaries.

The farm in Case study 1 generated the most to AP per FU, followed by those of Case studies 2 and 3. The reason for this finding is that the subject of Case study 1 produced more slurry per FU than those of the other two case studies. This could have been related to the lower number of weaners that one sow produced per year in Case study 1. The subject of Case study 1 produced more piglets per sow per birth, but the pre- and post-weaning mortality rate resulted in fewer pigs being weaned per sow in one year. Therefore, the AP results could be related to the different infrastructure and management techniques in the production chain, and not to the specific region were the production of pork is located.

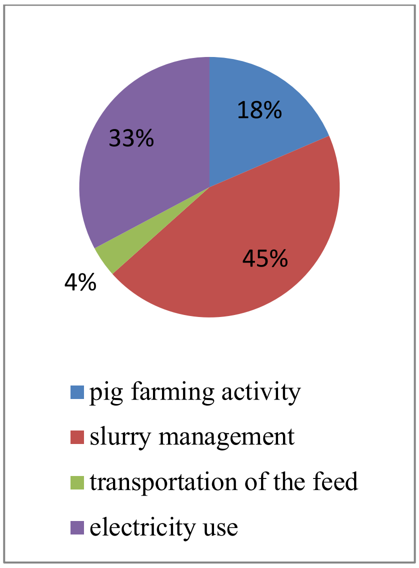

Figure 106: Energy use of the LCA activities of Case study 1

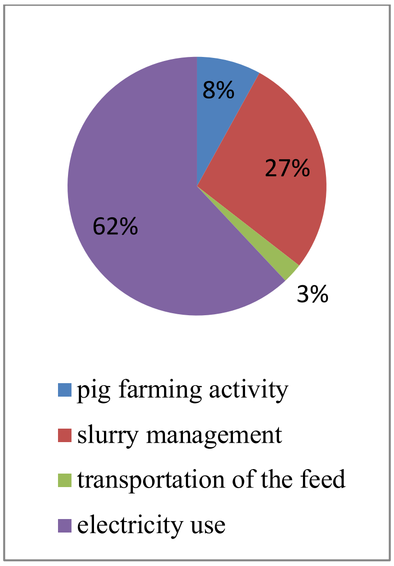

Figure 117: Energy use of the LCA activities of Case study 2

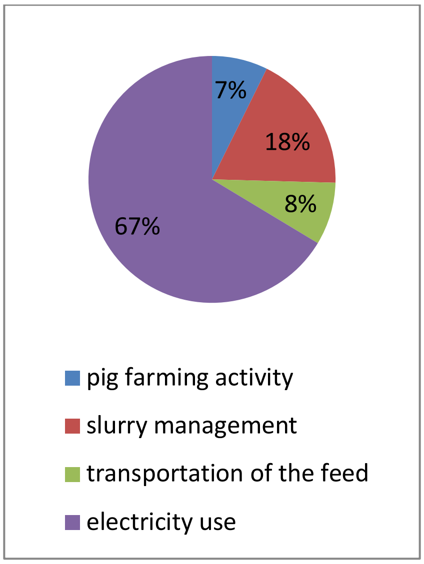

Figure 12: Energy use of the LCA activities of Case study 3

The energy use (EU) indicator was included as an impact category in this study to compare the efficiency of energy use among the three case studies. The total EU of the pork production chain is a way of measuring its efficiency in using renewable and non-renewable energy. The results are expressed in MJ equivalents. The EU results for Case studies 1, 2 and 3 are 5.6, 8.4 and 11.7 of MJ/FU respectively. Case study 3 had an EU of 52 % more than Case study 1, and 28 % more than Case study 2. The electricity use and slurry management activity contributed the most to EU/FU. Electricity use contributed more than 60 % to the EU/FU for Case studies 2 and 3, but only 33 % for Case study 1. Electricity use for Case study 2 per FU was more than double that of Case study 1. For Case study 2, an added heating source was provided in the pig's pen during the winter season, when the piglets were born. For Case study 1, an added heating source was not provided during winter, due to the higher average winter temperatures in this region.

Table 1: Summary of the impact category results for the three case studies

Impact category	**Case studies**		
	Case study 1 (KZN)	Case study 2 (NW)	Case study 3 (WC)
GWP (kg CO_2-eq per FU)	1.886	1.964	2.059
EP (kg PO_4-eq per FU)	0.00346	0.00323	0.00308
AP (kg SO_2-eq per FU)	0.0156	0.0147	0.0147
Energy use (MJ per FU)	5.55	8.44	11.66

4. Conclusion

After completing the gate-to-gate LCA for the three case studies, it became clear that transporting the main feed inputs over long distances did not have a significant environmental impact for the four impact categories reviewed. Strategically, it would place less strain on the environment if the piggery were located close to the production area of the main feed inputs. But transporting the feed accounted for only a minor portion of the environmental impacts in this gate-to-gate LCA. If the piggery is located close to other enterprises that can benefit from the fertilisation properties of the slurry, it will offset the environmental burden of acquiring the feed over a large distance.

From a tactical point of view, a piggery that is located in an area where the environmental impact of acquiring the feed is high could compensate by improving the herd performance with better genetics and by incorporating better technologies in its slurry management technique. From a financial perspective, it is better to locate the piggery closest to the market of the main input sources and closer to the offset point of the final product. In this way the transport costs are minimised.

5. Recommendations

A suggestion for avoiding the excess production of slurry is to lower the total usage of water by keeping the guttering in good repair. It is also recommended that for future LCA studies on the environmental impact of pork production, a more in-depth focus will be needed on slurry management techniques. The major activities that predominantly contributed to the environmental impact categories were the slurry management activity, followed by electricity usage. The financial and environmental performance comparison did show deviations. Therefore, it is recommended that environmental and financial performance measurements be made to create a true reflection of the impacts. The potential for improvement in financial and environmental performance proved to be significant in the productivity of the sow herd, as well as in the management of the piglets. The location of the production facility does not have significant environmental or financial implications. However, the management of the emissions produced by piggeries can offset the impact of the piggery's location.

6. References

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