Environmental impacts of extensive outdoor pig production systems in Corsica

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ABSTRACT

The extensive outdoor pig production systems in Corsica are quite different from the conventional production of Europe. Because of the longer lifetime of pigs and the lower technical performance of animals, the environmental impacts of a kilogram of pig until it leaves the farm gates could be expected to be greater. The diets of pig have to be considered because the animals are fed partly with natural feed like acorns and chestnuts. The hypothesis is made that those feedstuffs which grow naturally without any human mediation do not have any environmental impact. Three Corsican systems with an increasing amount of natural feed in the diet were assessed using Life Cycle Assessment (LCA). The results per kg of pig indicate a decrease of 62-81% for selected impacts from the system with the least amount of natural feeding to the more extensive system. By comparison, the conventional production systems of Europe previously assessed by Dourmad et al. (2012) have intermediate results.

Keywords: outdoor pig production, LCA, natural feed

1. Introduction

The extensive outdoor pig production systems in Corsica are quite different from the standard production systems of Europe which have been described and assessed by Dourmad et al. (2012). The animals are raised outdoors, on extensive areas and partially fed with chestnuts and acorns that have fallen directly from trees. Animals can also be left free in the mountain for a transhumance period. Compared to standard production, the technical performance of the pigs is lower, and their lifetime (18-24 months) longer. Therefore, the Corsican pigs are expected to have a higher environmental impact per kilogram of pig, despite an improved quality (Edward 2005).Their natural feed could partially reduce the environmental impact. It is not cultivated or transported by humans. The chestnuts and acorns grow naturally on trees, with no maintenance.

This study performed an environmental assessment by Life Cycle Assessment (LCA) of three outdoor pig production systems in Corsica. The objectives were to quantify the environmental gain on the kilogram of pig produced, reached by the use of natural feed, and also to identify the specific data to collect on such systems to be able to make an evaluation (Webb et al. 2014).

2. Methods

2.1. Description of the three Corsican pig systems

Three extensive outdoor pig production systems in Corsica were investigated (Table 1) and compared to the average conventional system in Europe (Dourmad et al. 2012). The technical data of husbandry methods was collected from farms. Two systems (Farm1 and Farm2) keep the animals on extensive areas where produced feedstuffs are regularly provided to the pigs by the farmer. The pigs supplement their diet by taking acorns and chestnuts from the ground. In a third system (Farm3) a part of the fattening pigs (64%) goes into the mountains for a transhumance period of 135 days per year. During this period, the pigs are not fed at all by the farmer and are dependent on natural feed found in the mountains.

Animal products sold by the Corsican farms are diverse: fattened pigs, piglets and maiden sows. The systems were compared on their common product with results expressed for fattened pigs and sows.

The systems differed by the type and the proportion of produced feedstuffs in the pig diets: grains from crops cultivated in Corsica (maize, barley …), feeds produced in Corsica with Corsican feedstuffs, and feeds coming from metropolitan France. Their amounts and characteristics were considered to estimate the ingestion by the pigs of purchased feeds (Table 2). The Corsican feeds given to the pigs are specific to extensive diets. It is elaborated to complement the seasonal starchy diets with chestnuts and acorns. It takes into consideration the growing characteristics of the pigs and their energy needs. For this reason, the crude protein content of the feeds is higher than in standard production (average content of 13.4% given by Dourmad et al. 2012).

Per sow and compared to Farm1, the amount of produced feedstuffs given to the pigs is respectively lower by half for Farm3 and higher by 18% for Farm 2 (Figure 1). The main difference between Farm1 and Farm2 is the type of diet and its protein content. Farm1 gives mainly concentrated feeds to sows with less quantity of feed and more protein content than in Farm2. Farm 2 gives grains (barley, maize) which correspond to higher quantities of feed with less protein content. For the three systems, the amount of feedstuffs and protein is largely below the amount given in the conventional system of Dourmad et al. (2012) (1330 kg of feed /sow/year and 28 kg N/sow/year). This could be partly explained by the fact that the pigs also ingested natural feed (chestnuts and acorns) which was not considered. But the total protein amount ingested by sows (even with the natural feed included) is known to be less than in standard conditions.

Table 1. Description of the three Corsican pig production systems assessed and comparison with the average conventional system of Europe described by Dourmad et al. (2012)

Units	**Description data**	**Farm 1**	**Farm 2**	**Farm 3**	***Conventional system of Europe (Dourmad et al. 2012)***
Pig unit	Products				
	- **Finished pigs (nb/year – *kg LW*)**	**104 – *120 kg***	**65 – *140 kg***	**204 – *120 kg***	***4910 - 113 kg***
	- Primary sows (nb/year – *LW kg*)	10 – *65 kg*	15 – *65 kg*	16 – *85 kg*	
	- Culled sows (nb/year – *LW kg)*	5 – *155 kg*	5 – *170 kg*	16 – *170 kg*	
	- Piglets (nb/year – *LW kg*)	70 – *8 kg*	338 – *20 kg*		
	- Boar (nb/year – *LW kg*)	1 – *176 kg*		0.5 – *176 kg*	
	Pig areas (ha)	170	219	220	*0*
Farrowing unit	Number of sows (nb)	21	30	40	*395*
	Housing	Outdoor / sheds	Outdoor / sheds	Outdoor / sheds	*Building - slatted floor*
	Piglets per sow per year (nb)	5.7	14.1	5.8	
	Produced feed per sow* (kg/year)	546	645	278	*1330*
	Produced feed intake (%):				
	- Growing diet	66%			
	- Finishing diet	23%		93%	
	- Corsican maize	11%	42%		
	- Corsican triticale		7%		
	- Corsican barley			7%	
	- Corsican diet 80-20		51%		
Fattening unit	Housing	Outdoor	Outdoor	Outdoor + transhumance	*Building - slatted floor*
	Age at slaughter of fattening pigs (d)	540	503-720	549	
	Live weight of fattening pigs at slaughter (kg LW)	120	140	120	*113*
	Produced feed conversion ratio[a] (kg/kg)	4.1	7.3	1.4	*2.5*
	Produced feed intake (kg/year) :				
	- Growing diet	61%	2%	15%	
	- Finishing diet	21%	2%	69%	
	- Corsican maize	18%	30%		
	- Corsican triticale		0.4%		
	- Corsican barley			9%	
	- Birth diet		1%	7%	
	- Corsican diet 80-20		37%		
	- Corsican diet 60-20-20		28%		

[a] without natural feed which corresponds to a part of the diet for the Corsican pigs

For the fattening pigs, from weaning to selling, Farm3 is still the most extensive system with lower quantities of produced feedstuffs and nitrogen given to pigs. Farm1 and Farm2 give a close amount of nitrogen coming from the produced feedstuffs, but with half as many feedstuffs for Farm1. This is due to the type of feedstuffs provided with mainly concentrated feeds in Farm1 and with grains in Farm2. The comparison with the European standard production of Dourmad et al. (2012) (267 kg of feed/pig and 6.8 kg N/pig) shows higher amounts of feedstuffs and nitrogen given to the pigs for Farm1 and Farm2 (Figure 1). This is due to the lifetime of the pigs which is three times longer (18-24 months) than in standard production. The amount of feed could also be explained by lower technical performances and a lower adaptation of the feeds to the physiological needs of the animals. However, Corsican pigs also eat natural feed which is not presented on figure 1. By considering it, the difference with conventional production would be greater. Farm3 has lower amounts of feed and nitrogen per pig compared to conventional system because the proportion of natural feed is greater.

Table 2. Characteristics of the produced feedstuffs given to the pigs in the three Corsican farms

		Corsican growing diet Farm 1	**Corsican finishing diet Farm 1**	**Corsican birth diet Farms 2 & 3**	**Corsican growing diet Farm 2**	**Corsican finishing diet Farm 2**	**Corsican growing diet Farm 3**	**Corsican finishing diet Farm 3**	**Corsican diet 80-20**	**Corsican diet 60-20-20**	**Corsican barley**	**Corsican maize**	**Corsican triticale**
Ingredients (kg/ton of feed)	Wheat	+	++	+++	+		+++	+					
	Wheat middlings			+				++					
	Bran				++	++							
	Barley	+++	+++	++	++	+++	+	+++					
	Maize	++		+	++	++	+						
	Pea	++	++		++	+		++					
	Rapeseed meal			+	++		+						
	Soybean meal	+	.	+			++						
	Cane molasses					.	.	.					
	Salt	.	.	.	.	.	.	.					
	Amino acids	.	.	.	.	.	.	.					
	Calcium carbonate	.	.	.	.	.	.	.					
	Phosphate	.	.	.	.	.	.	.					
	Corsican Maize								200	200		1000	
	Corsican Barley								800	600	1000		
	Corsican Triticale									200			1000
	Total	*1000*	*1000*	*1000*	*1000*	*1000*	*1000*	*1000*	*1000*	*1000*	*1000*	*1000*	*1000*
Nutritional characteristics	Crude protein (%)	25.5	20.8	27.3	24.6	17.7	28.6	19.2	9.7	9.7	10.2	8.1	9.6
	Phosphorous (%)	0.47	0.45	0.51	0.65	0.52	0.54	0.49	0.32	0.32	0.34	0.26	0.35
	Gross Energy (MJ/kg)	25.0	24.7	25.2	25.2	24.8	25.2	24.6	16.0	16.0	16.0	16.2	15.7
	Digestibility of the feed (%)	84	83	82	77	79	83	81	84	85	82	90	88
	Ash of the feed (% MS)	5.0	5.0	6.5	5.0	5.0	5.0	5.0	2.0	1.9	2.2	1.2	1.9

+++ amount > 300 kg / t of feed ; ++ 150<amount<300 kg ; + 50<amount<150kg ; . amount<50 kg

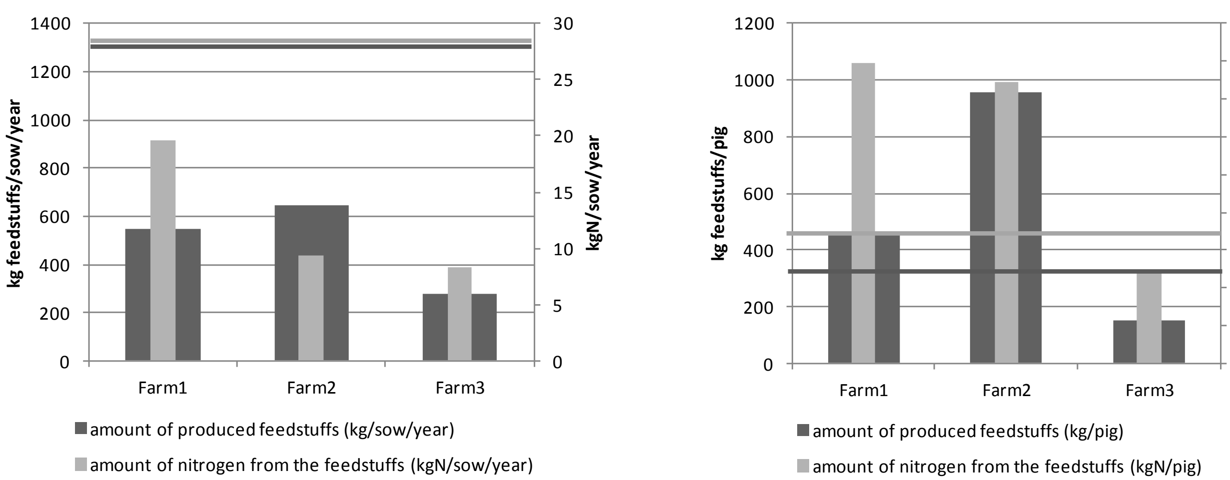

Figure 1. Produced feedstuffs in the diet of sows and fattening pigs of the Corsican systems compared to the standard production of Dourmad et al. (2012)

2.2. LCA assessment

The three extensive outdoor pig production systems in Corsica are assessed, using Life Cycle Assessment (LCA) for the impacts: climate change (kg CO_2eq), acidification (kg SO_2eq), eutrophication (kg PO_4^{3-}eq), energy consumption (MJ) and land occupation ($m^2.year^{-1}$). The environmental impacts are calculated at farm gate, including the production and supply of inputs (feedstuffs, sheds, primary sows, and boars) (Figure 2). The results are expressed per kg of live weight of the two co-products (sows and fattening pigs). At the farrowing unit, an allocation was made between culled sows and piglets and corresponded to the energetic valorization of the feed (Gac et al. 2014): 60% for the culled sows and 40% to the piglets.

The ingestion of natural feeds (chestnuts, acorns) is not considered in the Life cycle perimeter because the fluxes linked to their production are natural (not linked to human activities) and those due to their degradation (NH_3, N_2O and CH_4 gaseous emissions, NO_3- and P losses) would occur without the presence of the pigs.

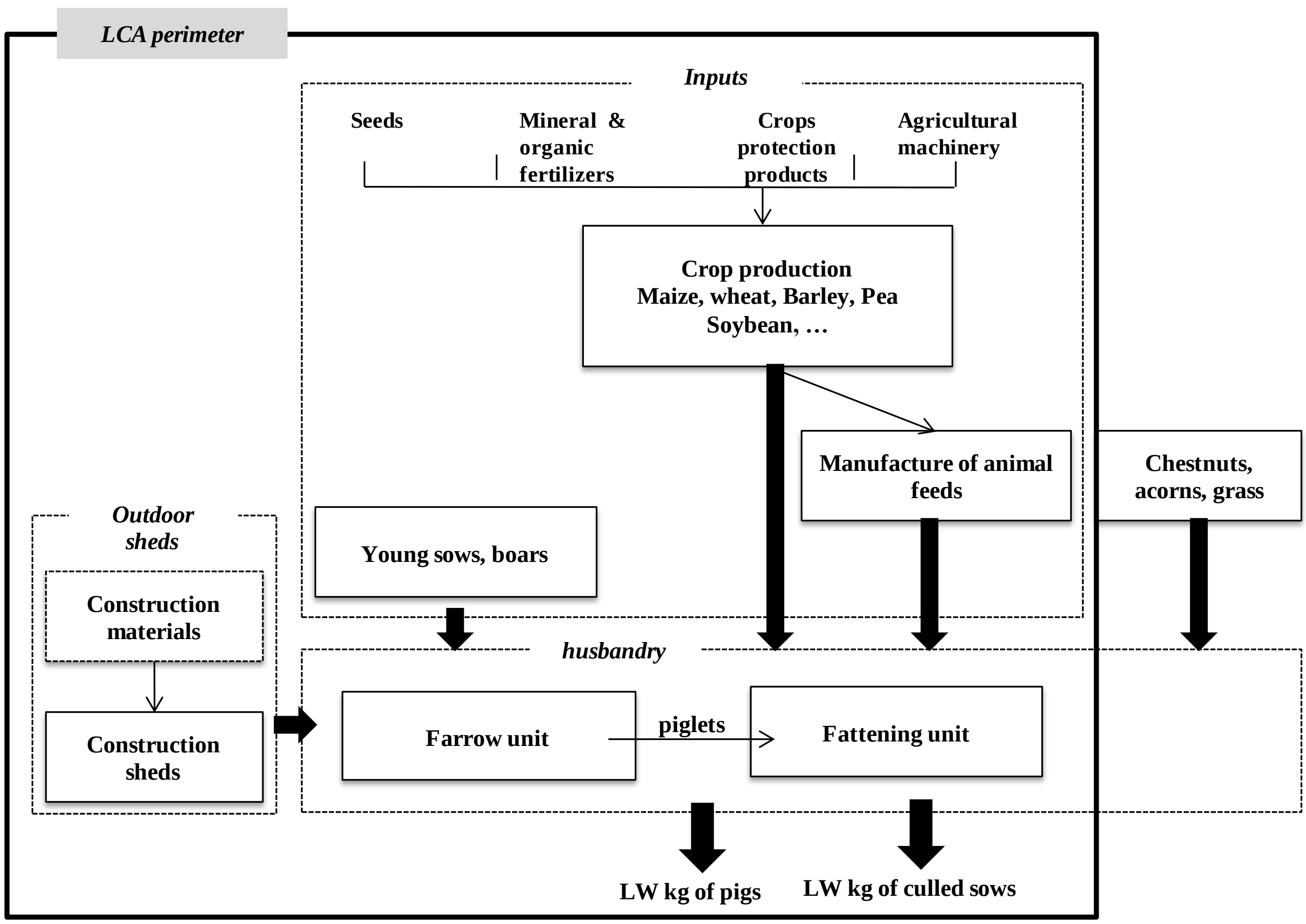

Figure 2. LCA perimeter

Details of the amount and characteristics of the feedstuffs given to the pigs were collected at the farm, and provided by the farmers. The LCA data of metropolitan ingredients of the diet were chosen from a national database (Bouter et al. 2012) and LCA was performed for Corsican barley and maize considering the key data presented in Table 3. For the barley, the straw in Corsica is sold as the grain. An economic allocation was made to consider this specificity: 60% for the grain and 40% for the straw. For the other crops, all the impacts were allocated to the grain.

Table 3. Characteristics of Corsican barley and maize (collected at farm)

Description data	**Corsican barley**	**Corsican maize**
N mineral (kg/ha)	40	253
P_2O_5 (triple superphosphate) (kg/ha)	100	139
K_2O (potassium oxide) (kg/ha)	100	
Seed for sowing (kg/ha)	175	26.2
Pesticide (active ingredient) (kg/ha)	0.9	1.23
Diesel (l/ha)	40	91.6
Irrigation water (m^3/ha)	31	2900
Electricity consumption (kWh/ha)		1131
Yield (q/ha)	45	127
Straw (kg/ha)	60	

Sheds were considered for the sows and piglets of the farrowing units with 160 kg of galvanized steel sheets and 0.5 m^3 of concrete per shed. No other infrastructure is used in the three farms. No direct energy consumption is needed for the pig units.

The environmental emissions linked to the excretions of the pigs were assessed with emission factors applied only on the part of the excretion due to purchased feed. The excretion due to natural feed was not considered. The ammonia emissions were calculated with the emission factors of the EMEP/EEA Tier 2 (2009) (eq.1). The method of IPCC Tier 1 (2006) was used to assess, the nitrous oxide emissions (eq. 3.), the methane emissions from enteric fermentation (eq 4.) and the nitrogen leaching (eq. 2.). The IPCC tier 2 (2006) method was used for the methane emissions from the manure management (eq.5). The equation of Nemecek and Kägi (2007) estimated the phosphorous losses.

$$NH_3 = N\ excreted_{\ produced\ feed} \times 0.7 \times EFNH_3 \times 17/14 \qquad eq.1$$
$$NO_3 = N\ excreted_{\ produced\ feed} \times EFNO_3 \times 62/14 \qquad eq.2$$
$$N_2O = (N\ excreted_{\ produced\ feed} \times EFN_2O + NH_3 \times 14/17 \times 0.1\% + NO_3 \times 0.1\%) \times 44/28 \qquad eq.3$$
$$CH_4\ enteric = EFCH_4\ enteric \times AAP \qquad eq.4$$
$$CH_4\ manure = VS_{\ produced\ feed} \times 0.65 \times 0.67 \times EFCH_4\ outdoor \qquad eq.5$$

Where
NH_3 emitted = annual ammonia emitted, kg NH_3
NO_3 leached = annual nitrate leached, kg NO_3
N_2O emitted = annual nitrous oxide emitted, kg N_2O
N excreted $_{produced\ feed}$ = annual nitrogen excreted by the pigs coming from produced feed ingested, kg N
0.7 = kg TAN $_{produced\ feed}$ /kg N excreted $_{produced\ feed}$
$EFNH_3$ = emission factor of NH_3, 25%
$EFNO_3$ = emission factor of NO_3^-, 30%
EFN_2O = emission factor of N_2O, 2%
$EFCH_4$ enteric = emission factor of CH_4 enteric, 1.5 kg CH_4/pig /year
$EFCH_4$ outdoor =emission factor of CH_4 from manure, 1%
AAP = Annual Animal Production
VS $_{produced\ feed}$ = volatile solid excreted by pigs coming from produced feed ingested, kg dry matter
0.65 = maximum methane-producing capacity for manure produced by livestock category T, m^3 CH_4 kg^{-1}
0.67 = conversion factor of m^3 CH_4 to kilograms CH_4

The N and P excretions of the pigs were calculated by a mass balance approach considering the nutritional characteristics of the produced feed and the animal performances. The excretion is the difference between the ingestion of produced feedstuffs (the natural feed is not considered) and the body retention of the produced feedstuffs (eq.6 and eq.7 for respectively N and P, Corpen (2003)).

$$N\ Body\ (kg) = e^{(-0.9385 - 0.0145\ Lean\%)} \times (0.915BW^{1.009})^{(0.7364 + 0.0044\ Lean\%)} / 6.25 \qquad eq.6$$
$$P\ Body\ (kg) = 5.3\ BW \qquad eq.7$$

Where BW = body weight, kg

3. Results

3.1. Life cycle inventories

The environmental fluxes are given in Table 4.

The N fluxes (ammonia, nitrous oxide and nitrates) are correlated to the N excretion which is correlated to the N ingestion. Because of this, the relative ranking of the three farms is the same as for the N ingestion (Figure 1).

For the fattening unit, Farm3 which has the most extensive management has N fluxes lower by 86% for ammonia, nitrous oxide and nitrates compared to Farm1. Farm2 has higher nitrogen fluxes of 14% compared to Farm1.

The P fluxes are also reduced for Farm3 compared to Farm1 and Farm2. The methane fluxes are linked to the lifetime of pigs for the enteric component, and to the volatile solid excreted (which is a function of the gross energy intake) for the manure management component. The methane fluxes give less difference between farms than the other environmental fluxes because the methane fluxes are mainly due to enteric emissions (instead of emissions linked to the manure) and the lifetime of the pigs is very close between the three systems.

Table 4. Direct environmental fluxes of the pig units

	Farm1		**Farm2**		**Farm3**	
	Farrowing unit (/sow)	Fattening unit (/pig)	Farrowing unit (/sow)	Fattening unit (/pig)	Farrowing unit (/sow)	Fattening unit (/pig)
N excreted[a] (kg N)	18.4	13.4	6.4	11.5	5.3	2.1
P excreted[a] (kg P)	2.0	1.5	1.3	2.3	0.7	0.1
VS excreted[a] (kg VS)	118.2	98.0	86.2	100.8	79.2	50.3
Ammonia (kg NH_3)	3.6	2.8	1.4	2.5	1.0	0.5
Nitrous oxide (N_2O)	0.7	0.5	0.2	0.4	0.2	0.1
Methane (kg CH_4)	2.2	2.5	2.0	2.7	2.0	2.5
Nitrate (kg NO_3)	22.6	17.7	8.2	15.3	6.5	2.8
P losses (kg P)	0.3	0.3	0.3	0.5	0.3	0.1

[a] part of the excretion linked to the digestion of the produced feedstuffs (without natural feed)

3.2. Life cycle assessment

The LCA results per kilogram of live fattening pig and culled sow are given in Table 5.

Farm3 obtains lower impacts for all the indicators (per culled sow and fattening pig). Compared to Farm1, the result per kilogram of fattening pig are reduced by 64%, 81%, 77%, 62% and 67% for respectively the impacts of climate change, acidification, eutrophication, energy consumption and land occupation.

Farm2 compared to Farm1 has a reduction of impacts of 25%, 24% and 21% for respectively the impacts of climate change, acidification and eutrophication. The result is similar for eutrophication and higher for the land occupation impact.

Table 5. LCA results of the three Corsican farms and comparison with the average conventional system of Europe described by Dourmad et al. (2012)

	Farm1		**Farm2**		**Farm3**		***Conventional system of Europe***
	/kg culled sow	/kg fattening pig	/kg culled sow	/kg fattening pig	/kg culled sow	/kg fattening pig	*/kg fattening pig*
Climate change (kg CO_2eq)	6.9	4.09	6.1	3.03	2.11	1.47	*2.25*
Acidification (g SO_2eq)	87.0	51.5	67.2	38.7	17.0	9.7	*44*
Eutrophication (g PO_4eq)	91.0	53.8	98.9	53.3	25.4	12.3	*19*
Energy consumption (MJ)	35.5	20.2	32.1	15.8	12.4	7.7	*16.2*
Land occupation (m^2year)	11.35	6.43	15.17	7.83	3.78	2.14	*4.13*

For the impacts climate change, acidification and land occupation the respective importance of three main steps in pig production on the LCA result for a kilogram of fattening pig is presented in Figure 3 : the production of the piglets (piglets), the production of the feedstuffs (feedstuffs), the fattening of the pigs (fattening units). The production of piglets on the farrowing unit has a minor incidence on the results. For climate change the step of feedstuff production and the fattening unit have an equivalent impact on the results. This is due to nitrous oxide emissions during the feedstuff production and to both nitrous oxide and methane emissions on the fattening unit. For acidification, the impacts occur mainly on the fattening units with the ammonia emissions while for land occupation it is the feedstuff production which uses land.

For all the differences between systems, both the reduction and the increase occur during the two main steps: production of feedstuffs and the fattening units (Figure 3). It comes from the fact that the feeding strategies impact hugely the excretion from which the environmental fluxes and the impacts are calculated.

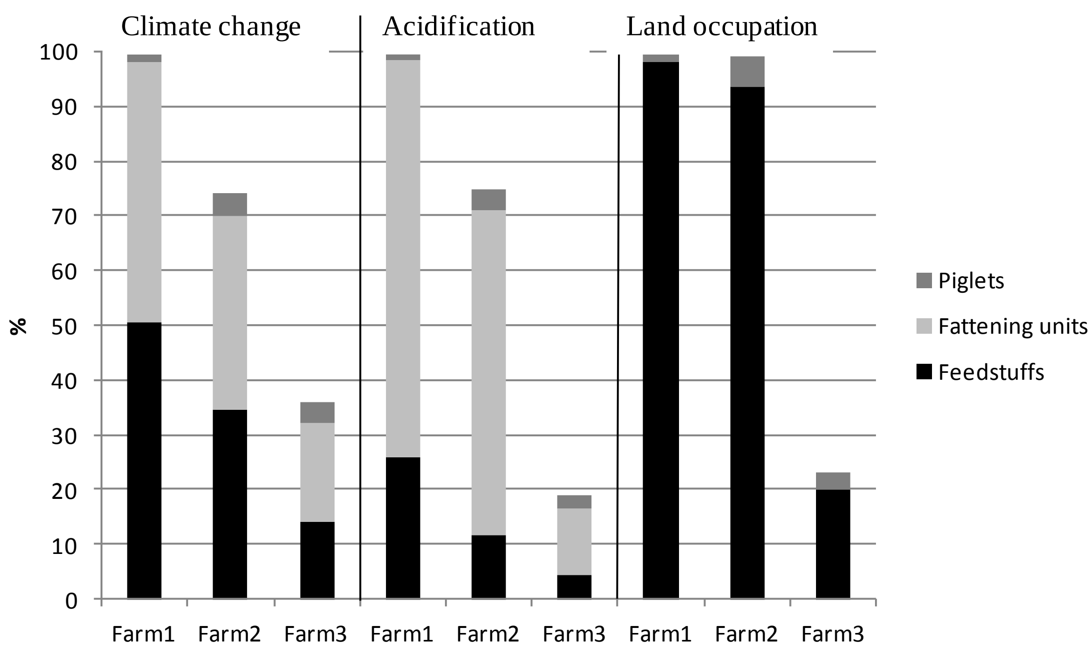

Figure 3. Contribution of the three main production stages to LCA results for a kilogram of fattening pig produced by the Corsican farms

4. Discussion

By comparing the LCA results of the Corsican kilograms of pig to conventional kilogram of pig (Dourmad et al. 2012), Farm3 obtained lower impacts, Farm1 had higher impacts and for Farm2 the results could be higher or lower depending on the impact. As expected, when the impacts for the farms are higher compared to the conventional system, this could be explained by the longer lifetime of the pigs and their lower technical performances. Dourmad et al. (2012) also obtained higher impacts for traditional systems of Europe compared to conventional ones: an increase of respectively 54, 79, 23, 50 and 156% for climate change, acidification, eutrophication, energy use and land occupation. The added value of this study is to have assessed three different extensive systems in which the proportion of natural feed varied. The result indicates that the increase in impact compared to conventional production could be compensated by the use of natural feed in the diet of the pigs.

This is due to the methodological choice of not considering the natural feed in the LCA perimeter. It was determinant in the results. It required being able to specify environmental fluxes without considering grazing and transhumance. The diets were detailed and the associated excretion estimated. The choice of the emission factors applied on the excretion was also a determining factor. Without information on the diets (amounts and composition), global emission factors (Tier1) would have been used, especially for ammonia and methane emissions from manure management. The environmental fluxes would have considered a global average diet without the possibility of extracting natural feeds from the assessment. The specification of the intake and excretion linked to manufactured feeds gave the information that made it possible to conclude on the specific impacts of extensive pig systems in Corsica. The more specific the system, the more detailed the information about the LCI should be, because average references are not valid.

5. Conclusion

This study shows the interest of natural feed in extensive pig systems. By not considering it in the LCA assessment, the environmental impacts of the kilogram of pig at farm gate are reduced and could reach a level below the impacts of conventional production. The results also underline a huge difference among the three systems studied which could change the conclusions of a comparison with conventional production. The sensitivity of the results to the diet of these systems is relevant because the importance of natural feed modifies all inventory data such as the amount of feed, the excretion and the associated environmental fluxes. To reach such a conclusion made it necessary to detail the diet without the natural feed and the associated excretion.

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