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Herd dynamics reflect constraints for pig production and farmer attitudes in smallholder systems in Lao PDR

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Abstract. A field intervention and 17 months' monitoring of pig herd dynamics in seven villages in Northern Laos was conducted. The collected data show for the first time herd dynamics based on quantitative data. They show that dynamics follow a regular cyclic pattern based on the general farm management approach applied by farmers, which lacks a specific pig management focus. Interventions aimed at improving animal management and nutrition were far less successful than envisioned but revealed major conflicts in perception between implementers and farmers. Farmers did not shift their focus to pig production as major income-generating activity as envisioned by implementers. Nevertheless, despite only partially improved systems, farrowing and animal growth rates were increased among committed farmers, whereas death rates have decreased. However, our quantitative data show a significant number of constraints reflected in the way how animals enter, pass through and leave smallholder production systems. Disease and disease prevention, as well as animal feeding are the two dominant hindrances to improved production. Both these obstacles are rather related to a lack of focus on animal production and therefore animal requirements than to an inherent lack of understanding. To increase interest though, poor income opportunities due to lacking market opportunities will have to be tackled. However, even with an incomplete transition from a traditional to an improved system, overall production increased by 600% in committed farmers with an about equivalent increase in income from this activity, showing that current systems leave massive scope for improvement if perceptions and other external obstacles such as access to inputs and markets can be overcome.

Additional keywords: animal husbandry, animal production, farmer adoption, forage, population dynamics.

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Introduction

Lao PDR is bordered by five countries in the Mekong region and is an importer and significant 'transit country' for livestock, in particular cattle, buffalo and pigs. Pig production has increased significantly in Laos over the past years, but a strong imbalance exists between commercial production close to urban centres and border crossings to Thailand such as Xayaboury, Vientiane and Savannakhet provinces (FAO ADB, OIE SEAFMD 2009) and smallholder production in more remote or less well connected areas. Pigs are present on most smallholder farms and play an important role as cash reserve, ceremonial offering or protein source for subsistence. In these systems pigs are generally sold at local wet markets if proximity allows this, or to local traders who pound all villages in an area regularly for tradeable livestock. These traders move pigs then either within Laos to areas of low supply or follow strong market-pulls from neighbouring Vietnam and China where skyrocketing demand provides good opportunities for pig producers and middlemen.

The importance of local indigenous pig breeds as assets for farmers and a means of generating income has been shown in many contexts for similar systems (Drucker and Anderson 2004; Dietze 2011) as well as for Laos (Phengsavanh 2013). There is some evidence indicating that indigenous pigs are well adapted to tropical production conditions and might be less susceptible to diseases and parasites (Zanga *et al*. 2003; FAO 2007) but production is nevertheless generally severely constrained by lethal diseases and poor management practices. Nevertheless, unlike improved exotic genotypes, local breeds are thought to be less reliant on external inputs, generally more hardy and able to survive and reproduce on less and lower quality feed (Holness 1991; FAO 2007). Despite or due to these characteristics, farmers rarely change their approach towards a more market oriented production, and put little effort into improving their pig management. As a consequence markets do also not develop much in rural areas leading to reduced opportunities for smallholders.

Although some information regarding nutritional constraints of Laotian smallholder systems has been produced so far, the dynamics of pig production on community or household level have, to the knowledge of the authors, not been described so far. Available information (e.g. Chittavong *et al*. 2012; Phengsavanh 2013) is largely based on on-station trials and farmer surveys but longitudinal studies monitoring pig production systems over a continuous period are missing. Understanding such dynamics provides insights as to (i) the extent to which different constraints hamper pig production, (ii) the current use of pigs as commodity, (iii) disease dynamics in the pig and livestock sector in Laos if combined with additional data, and (iv) the contribution of local pigs to smallholder household income. As the assessment of such dynamics in smallholder systems is resource intensive and requires active participation of farmers, the present study is one first attempt to get a detailed understanding of pig herd dynamics and their implications while offering some thoughts on improved management options.

Materials and methods

Study area

Data collection and interventions were carried out in Laos, Phongsali province, Mai district and Sayabouli province, Sayabouli district, which encloses the provincial capital of the province with the same name. The latter borders north with Hongsa district, in the south with Phiang and Pak Lai districts, in the east with Vientiane province and in the west with northern Thailand. It encompasses 77 villages and is home to 70 362 people (Lao Statistics Bureau 2014).

Mai district is located in the south-east of Phongsaly sharing borders with Khua district to the south-west, Ngoy distric in Huaphan province to the south, Samphan district to the north-west and Dien Bien Province in Vietnam to the north and east. According to the Lao Statistics Bureau (2014), 88 villages are located in the district, half of which are accessible by road. The total population is 25 448 dispersed over 4365 households.

The climate in Mai district is tropical. The average annual temperature is 23.6°C with 1721 mm of annual precipitation in a unimodal distribution from May to September (6 mm, 18.5°C in January, 431 mm, 26.3°C in July). Sayabouli district also has a tropical climate with an average annual temperature of 24.7°C and precipitation averaging 1277 mm, equally with a unimodal distribution (January: 12 mm, 20.3°C, August: 261 mm, 26.5°C).

Specifically seven villages were selected with diversity in ethnic composition (Table 1). The criteria for choosing these sites were: high poverty (at least in pockets), high ethnic diversity, overall high pig numbers in the district, pigs playing an important role for smallholder farmers in the villages, different market chains being in place or evolving, and accessibility throughout the year. These factors were determined through visits and consultation with farmers, District and Provincial Agricultural and Forestry Office (DAFO and PAFO) staff, and expert advice from other projects.

Table 1. Village data for the target sites

Villages	Represented ethnicities	Number of people in village
	Sayabouli	
Houay Loun	Khmu/Lao	1115
Houay Keng	Khmu/Hmong	905
Nong Nong	Hmong	275
	Phongsaly	
Om Pha Long	Tai Dam	372
Phung Khao	Khmu	147
Sop Houn	Tai Dang/Khmu/Tai Dam/Lao	528
Om Ka Neng	Khmu/Tai Dam	247

Project interventions and design

The aim of the overall project was to improve pig production through improved feeding, and health management. For this end, farmers were exposed to improved management approaches, including (1) improved feeding using *Stylosanthes guianensis* and commercially available soy bean meal or complete feed as protein sources; (2) improved housing allowing for better hygiene, isolation of animals to avoid the spread of diseases and better care for piglets; (3) improved animal health management including vaccination, deworming and the provision of iron and vitamins. In each village farmers were grouped in three categories: (a) farmers with high commitment and interest (Champions); (b) farmers with interest but limited commitment or hesitation to get fully engaged (Improved); (c) farmers who were not interested in getting involved with project activities and can be considered a control group representing the traditional system (Outsiders).

The project strategy on training farmers was a two-track approach, including regular follow-ups with farmers (every 4 weeks) and group trainings on specific topics (such as animal diseases, feeding and feed quality, water, hygiene and management) once or twice a year, with field visits to successful Champion farmers. Although all Improved and Champion farmers participated in the group trainings, the regular follow up depended on farmer engagement, and interaction and feedback here was generally stronger with Champions than with Improved farmers.

Soybean meal and complete feed were purchased at local markets. Commercial complete feeds of Thai origin contained 22–14% protein and 3–8% fibre, recommended for different age groups of pigs respectively and were used as recommended by the producer.

Specific attention was given to the question what herd dynamics would look like in smallholder pig systems and how they would be affected by project interventions reflecting potential changes in livestock-related practices. So far no quantitative data are available as to how smallholder farmers in Northern Laos manage and use their pigs and in how far this information has to be taken into consideration for development interventions.

Data collection and determination of herd dynamics

The project had been active in the target sites from 2011 to 2015 with several interventions and training activities as well as data collection on animal health, nutrition and livestock markets. An initial baseline survey was used to collect general data regarding farming systems and income sources used to describe the systems (Okello *et al.* 2017).

Lacking a culturally embedded habit of record keeping, data collection in Laos can be challenging. Attempts to get animal management parameters recorded by farmers themselves or district extension staff, as was attempted in 2012–2013, was not successful. Based on these experiences, we carried out the collection of the here relevant data ourselves from August 2013 to December 2014. The data collection was conducted once per month by visiting 54 farmers in seven villages with a total of 1379 pigs (throughout the duration of the monitoring). Most pigs were ear tagged for proper identification, only in few cases farmers interested in project activities opposed to tagging, which resulted in us either abandoning the inclusion of these households or, if circumstances allowed for it, finding other ways of identifying the existing animals, such as using individual descriptions for animals (e.g. white feet, blaze, short ears) or photos. Data on animal management were collected using a questionnaire type list of topics to be assessed on-farm, either by asking farmers or by assessment by sight, whereas animal weight gain data were measured each time, weighing animals up to 40 kg on mechanical spring scales. Aspects captured included animal feed resources, approximate quantity on feed provided, feeding frequency, quality of housing including pen structure, cleanliness and design, quantity of water supply, herd size and structure, reason for animals leaving (or entering) the herd, litter sizes and date of farrowing as well as basic economic data. The selection of farmers was done with the assistance of local extension workers but was mainly based on the willingness of farmers to collaborate. In consequence group sizes between Champion, Improved and Outsider farmers were different and understandably especially outsider farmers showed little interest in supporting a monthly data collection. All pigs were recorded as belonging to the farmer who took care of them, no matter if they were exchanges, gifts or entrusted animals. Animals were classified by their weight into the following categories: piglets (<7 kg), weaners (7–20 kg), growers (>20 kg) and mature pigs (>40 kg). Mature pigs thus include breeding stock as well as fattened pigs too heavy to be weighed under field conditions. Sexual maturity was not taken into account.

Feed quality was assessed by estimating feed composition based on available analyses. Collected data comprised approximate ratios of used feedstuffs in the diet mixtures and total weight of provided feed. An approximate DM and crude protein (CP) value were allocated to each feed, based on an average of former analyses in the region. From these values the approximate CP content of the total diet was calculated. Although these values present therefore only a rough approximation they still allow comparisons between different farmers and farmer groups within this experimental setting.

For each farmer type, pig production potential (PPP) was calculated, as described by Amanor (1995). The PPP, defined as the proportion of mature and grower pigs to the total herd size, was calculated as: PPP = N/H; where

PPP – production potential;
N – number of mature pigs + grower pigs;
H – herd size.

All persons gave their informed consent before their inclusion in the study and no humans and animals have been subjected to unethical treatment in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. This manuscript does not contain clinical studies or patient data.

Statistical analyses and data presentation

The repeated-measures under General Linear Model of SPSS (SPSS Statistics 17.0, 2008) was used in a mixed ANOVA with time as within-subjects factor and management issues as between-subjects factor (e.g. number of feeding time per day). Missing values (4.3% of total values) were replaced by the last recorded value to allow for inclusion of all cases.

To assess differences in PPP, a univariate analysis under General Linear Model in SPSS was performed.

To analyse feed quality data were organised by pig age. Thus, independent of the date the animal entered the system, the first value represents the first month of a pig in the monitored farming system. Pigs remained in the system for periods of less than 1 and up to 14 months. For CP comparison a pairwise *t*-test was conducted due to extremely unequal sample sizes per month, resulting from less and less pigs remaining in the system over time. Correlation between average daily gain (ADG) and CP was determined by regression analysis in SPSS.

Despite the differences between both provinces in terms of climate and ethnic composition we found the similarities in pig systems sufficient to pool the results for most of our findings. By doing so we tried to even out differences in project interventions between different communities, due to differences in the commitment of government extension services between districts and over time. As these factors could not be quantified we hope to reduce the risk of erroneous conclusions based on differences of external, project related conditions. Where clear differences between groups existed, they are mentioned and discussed.

Results

In the 57 monitored households, heads of households were with four exceptions all male. An initial survey in the project areas indicated that the average upland area managed per household is 3.5 ha (±3.29) and that 49% of households own additional paddy fields of an average size of 0.37 ha (±0.50). Pigs were the most dominant livestock in the target sites, both in biomass and income generation, followed by poultry. The average animal composition per month and over a period of 17 months is shown in Table 2. The difference between numbers in weaners and growers in Table 2 is a result of having started monitoring an existing but changing system mid-cycle. When comparing the number of weaners and growers in Fig. 2, the number of growers exceeds that of weaners at the beginning of the monitoring period while later the two dynamics start to follow more similar patterns.

Although women are in general terms the main care takers of pigs, it is common that men do manage the system or contribute to it. All households raised initially local breed genotypes (Moo Lath) but many changed during the duration of the project to cross breed animals, local × exotic breed (e.g. Duroc, Large

Table 2. Animals per household per month and per total observation time, maximum number per household (minimum number is 0) and total animal count adding all monthly counts

	Piglet	Weaner	Grower	Mature
Average number/farmer per month	3.8 ± 3.4	4.1 ± 3.5	3.7 ± 2.9	2.3 ± 1.5
Average number/farmer in 17 months	15.1	5.2	7.7	2.4
Maximal number in 17 months	68	20	31	9
Total animal counts	739	219	315	116

White). Traditionally, pigs were kept in a low input, extensive free range system with supplementary feeding especially during the wet season when animals have to remain confined to avoid crop damage. Supplementary feeding is diverse and consisted mostly of rice bran, papaya and pumpkin, taro root and banana stems, as well as maize and cassava especially in Sayabouli. Kitchen waste, distiller's waste, and a variety of local leaves and roots also make up a minor faction of the diet. Feed was either cooked into a stew like mash or fed uncooked but coarsely chopped with water 1–2 times a day. Feed selection was based on availability rather than nutritive value or animal requirements and would accordingly vary from month to month and farmer to farmer. Nevertheless, most farmers would not be able to provide sufficient feed especially during the late dry season (March–April) and animals would lose up to 30% of their bodyweight or, in the case of younger animals, show signs of severe stunting.

Before the project, only three farmers had tried commercial feed and recognised its effectiveness but had, due to a lack of strategic feeding and economic considerations gotten very minor profits out of this attempt and abandoned the approach. Disease and inadequate feed resources were generally perceived by farmers as the most important constraints to pig production.

Although Improved as well as Champion farmers were all encouraged to adopt improved housing, feeding and health approaches for their pigs, actual adoption depended on individual willingness to change. Although Champion farmers generally tried to improve in all three categories, improved feeding got adopted slowest and with most deficiencies while vaccination and deworming as well as improved housing were faster to be implemented. For Improved farmers adoption was overall less focussed and many farmers adopted only what fitted easily in their farm management routine. This led in several cases to a discontinuation of certain improvements made during one period of the year while temporarily adopting other suggestions, leading overall to less visible improvements.

Farrowing incidence

Farrowing occurred year round with a regular cyclic production low every year from September to December (Fig. 1). This coincides with the mating time from May to August, which is the main cropping season. During this period farmers are generally very engaged with field work and have little time for other activities. It is therefore likely, that the production low is a direct result of farmer schedule and focus. The total number of sows farrowing per month varied between 1 and 18. Peaks occurred mainly due to high farrowing rates among Outsider and Improved farmers, whereas Champion farmers had a more continuous production with lower variation and a higher total number of farrowings (1.43 farrowings per sow throughout the observation time versus 1.32 and 1.29 in Outsider and Improved farmers).

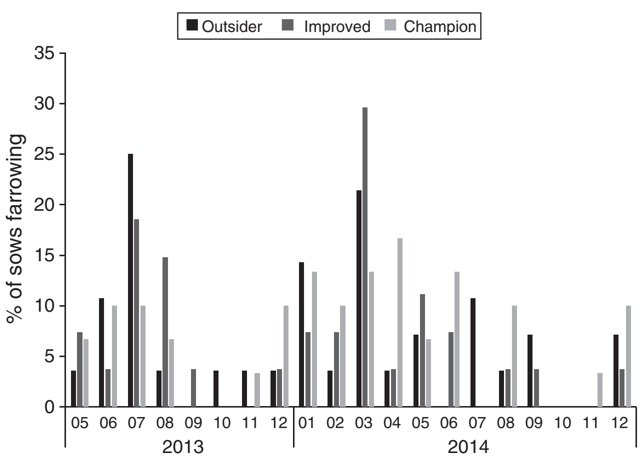

Fig. 1. Monthly incidence of farrowing from May 2013 to December 2014 disaggregated by group.

Pig herd dynamics

The total number of animals monitored was 620 for Champion farmers, 380 for Improved farmers and 379 for Outsider farmers. The monthly changes in different pig classes throughout the year are shown in Fig. 2. It shows the number of all animals monitored per months separated by classes and their aggregated total in Fig. 2*a*, whereas Fig. 2*b*–*d* depict the monthly animal numbers for weaners, growers and mature animals, respectively, disaggregated by farmer type. Piglet numbers were not depicted separately as they did not vary much between farmer types and their average shown in Fig. 2*a* reflects their dynamics reasonably well. The development of total animal numbers mirrors largely the cyclic pattern described above, with all pig classes following a similar pattern based on piglet numbers (Fig. 2*a*). Due to large variations in management and pig performance though, a clear correlation between different pig classes is not visible. The effect of introducing commercial feeds to farmers, though, shows in the piglet peaks in August 2013 compared with March 2014. In 2013 the transition from piglets to weaners and especially to growers is much delayed with feed based on locally available sources and *Stylosanthes guianensis.* In 2014 then, after the introduction of commercial feed, these shifted dynamics match much closer, indicating a faster, more concerted development of young animals.

Piglets amount to 53% of the total number of animals recorded whereas mature animals comprised only 8.4%. Only 3.6% of the total number of recorded animals was breeding stock and especially the number of reproductive males was generally very low with some villages having only one or temporarily even no boar at all. Additionally, the number of mature animals was slightly declining over the period of measurement, but was still higher for Champion farmers than for Outsider and Improved farmers (Fig. 2*b*). Despite not following a very regular pattern there is a significant change of numbers of piglets and thus total animal numbers per month ($P < 0.05$). Weaner and grower pig trends are on average lower for Outsider farmers than for the other two groups (Fig. 2*c*, *d*) with higher losses during the production process manifesting in their herd dynamics.

The reasons for exiting the herd population can be divided in four major categories being: (i) exit due to death, which was the single most common reason at the early project period and decreased significantly during the advancement of the project; (ii) sale, which became a stronger exit factor over time as a result of project interventions especially for Champion farmers; (iii) used for other purposes, mostly given away as a token, or present,

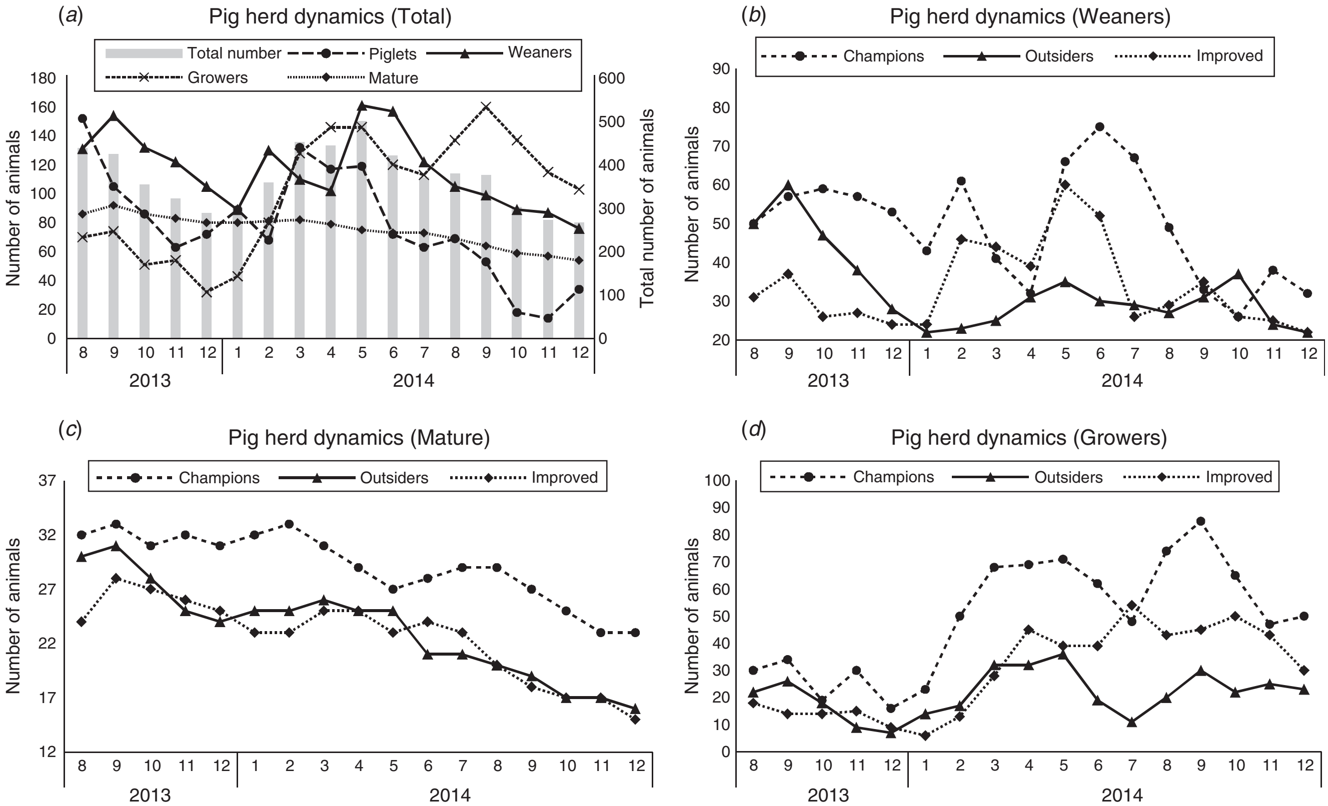

Fig. 2. Pig herd dynamics per month: (*a*) all animals disaggregated by age/weight groups; (*b–d*) mature animals, weaners and growers disaggregated by farmer type. Disaggregated data for piglets were not included as dynamics between farmer types did not vary strongly and the average given in (*a*) reflects the collected data sufficiently well.

sacrificed for religious reasons, consumed within the household or as part of a celebration, this factor is relatively constant; (iv) unclear exit, this category encompasses all those cases in which the whereabouts of pigs could not be tracked anymore. The substantial size of this last group is related to the common practice of moving animals to remote areas often many hours walk from the village to confined areas called Sanam. Here animals of several owners are left to scavenge freely in uncultivated areas and are often being looked after by only few people staying in the area. This practice is believed by farmers to reduce disease spreading and reduces the need for feeding the animals. It makes monitoring extremely difficult though.

The total number of pigs sold was 449 (32.3%), only 77 of them by Outsider farmers, whereas 329 died (23.7%) – 230 from disease as reported by farmers, 58 were stillborn, 12 were prematurely born and 29 died due to other reasons such as snake bites, poisoning and accidents –, 113 (8.1%) were directly consumed or given away and the fate of another 113 (8.1%) could not be retraced. The remaining animals were still in the system at the time of project closure. Pig mortality was significantly higher during the dry season than during the rainy season ($P < 0.05$) and higher in Outsider farmers than in Champion and Improved farmers. Sales peaked twice a year in May and November, at the beginning and end of the rainy season (Fig. 3). For Champion farmers pig mortality was higher during the dry season but significantly lower during the wet season ($P < 0.05$) compared with other farmers.

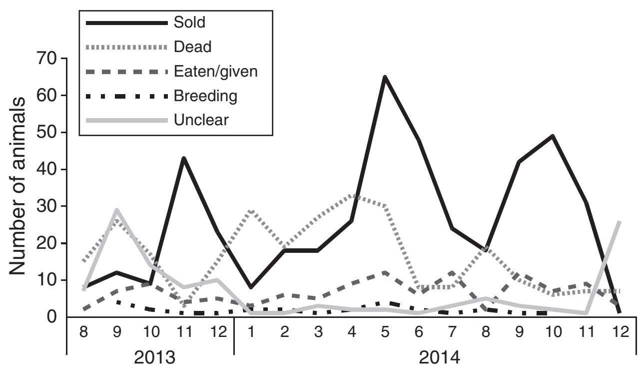

Fig. 3. Total pig exits per month disaggregated by exit reason.

Pig feeding and management

Animal feeding is reflecting in herd dynamics only indirectly and subliminal as it is only one factor influencing animal performance. Although initially all farmers fed their animals twice a day, some farmers started to adopt more frequent feeding but most animals (75%) remained at two feedings per day.

Farmers did not adopt smart-feeding approaches, adjusting the feed quality to animal requirements but rather used a one-feed-feeds-all approach, which was adjusted by each household for available resources and preferences. When comparing the average feed quality of all animals in the herd, the average CP content of diets fed to pigs in their first 3 months in the system was significantly higher ($P < 0.005$) than the CP content of diets for pigs which were 5 months or longer in the system. As these values are averages over all animals, this reflects that animals receiving better quality feed remained shorter in the farming system. The average CP values for the first 3 months of a pig's life varied between 68 and 64 g/kg DM, for month 4–8 they were between 56–51 g/kg DM, and for month 9–14 they dropped to CP values of 50–36 g/kg DM (Fig. 4). That pigs with higher CP nutrition indeed grow faster and thus leave the system faster than animals who receive lower quality feed also correlates well ($r = 0.829$, $P = 0.001$) with the calculated ADG from the measured life weights (Fig. 4). Due to the large variation in performance in all three farmer groups no significant differences could be determined for ADG or total weight gain means between groups. When cutting out the three lowest values of each group though, Champions reached an average weight gain of 19 kg per month, Improved farmers of 16 kg/month, and Outsiders of 13 kg/month.

The major constraint to proper animal performance was the amount of feed provided, which also explains the overall low ADG of not more than 120 g/day. Monthly sampling showed an average daily feed provision of 2–3 kg fresh matter with standard deviations of 60–120%. The estimated provided DM is only ~10–20% of this amount depending on the type of feed used and the amount of water added. This is in traditional systems partly compensated by free scavenging, which was not quantified but varies strongly in the amount of additional nutrients it can provide throughout the year, with starving animals at the end of the dry season.

Another effect on animal performance might have been water provision, which remained almost constant at ~2.5 L per day, mostly provided during feeding, despite attempts to introduce *ad-libitum* nipple systems.

Although the provided environment can influence herd dynamics in a significant way, 24 farmers improved pig housing during the monitoring period, including factors like overall hygiene, flooring and general state of the pen, whereas 29 did not. Hygiene posed a particular problem and only 10 farmers kept their animals in clean conditions, whereas 19 cleaned their pig pens only irregularly and 24 kept their animals in very dirty conditions. Similarly problematic was also the state of flooring and the overall appearance of the pen, often with rusty nails or sharp wire ends exposed in the inside area and wooden boards broken posing risk of injury.

Based on these observations only seven farmers were evaluated as taking adequately care of their animals, whereas 18 farmers showed persistent deficiencies in their management and 28 failed in providing appropriate environments. Also confinement practices changed little and only 13 farmers kept their animals constantly confined at the end of the intervention period, six kept them mostly confined and 33 did not confine (confinement here means the constant enclosure of animals in a specific area, be it a fenced area, shelter, or pen, with the aim to keep them in a somehow controlled environment). However, due to the lack of consistency and imperfections in farmer management, a direct correlation between improved environment and animal health or growth could not be established. Champion farmer who provided better environments, feeding and care than other farmers though, had significantly higher income gains.

Effect of interventions

Training farmers in improved pig management and feeding methods as well as building new market links increased pig sales 6-fold for Champion farmers and 2.5-fold for Improved farmers compared with Outsider farmers (Fig. 5). Income from pigs rose from 650 000 LAK (81 USD) to 4 251 000 LAK (531 USD) or by 654% for Champion farmers and 377% for Improved farmers. Although the time animals remained in the herd did not change significantly and remained between 145 and 150 days in all groups, the standard deviation differed significantly and was with 77.1 days much lower in Champions than in Improved (96.0 days) and Outsider farmers (115.9 days). At the same time animal weight increased by 17 ± 13.7 kg in Outsider farmers, 22 ± 14.2 kg in Improved and 24 ± 12.5 kg in Champion farmers.

Pig production potential

The distribution of immature and mature animals varied between district and farmer type but Champion farmers had a significantly increased ratio of mature animals compared with Outsider

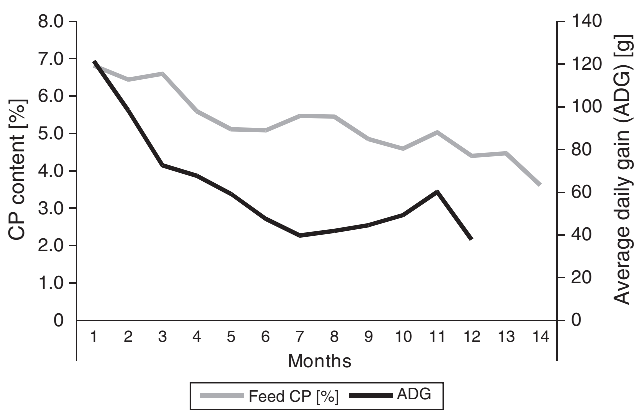

Fig. 4. Duration of animals being in the system relative to average crude protein (CP) contents in pig feed.

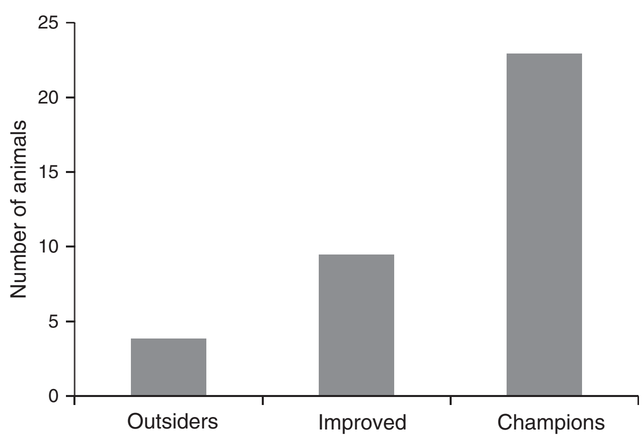

Fig. 5. Average number of pigs sold in 17 months per household, disaggregated by farmer type.

farmers ($P < 0.01$), whereas Improved farmers were not different from the other two groups. The PPP however did not show significant variation between districts (Sayabouli 0.48 ± 0.29, Phongsaly 0.51 ± 0.21) or farmer type (Champion 0.54 ± 0.26, Improved 0.54 ± 0.28, Outsider 0.45 ± 0.26).

Discussion

In general, our observations correspond to those made by others in Laos (Millar and Connell 2010) and the animal management approaches and resulting systems performances found on smallholder farms in North Laos seem to be very similar to practices reported from smallholder farmers in other countries in South East Asia such as Philippines (Alawneh *et al.* 2014), North Thailand (Choocharoen *et al.* 2014), North Vietnam (Lemke and Valle Zarate. 2008) or West Papua (Iyai and Randa 2011) as well as smallholder systems in East Africa (Chiduwa *et al.* 2008).

As becomes clear from comparing average and maximal numbers in Table 2, differences between farmers were pronounced although average animal numbers at any given time were still low. We assume that the reason behind these generally low numbers and poor performances lies in the perception of pigs being a farm activity. Coming from a traditional self-sufficiency approach, covering the household food requirements for the whole year is the central focus of farmers in Lao PDR. Other farm enterprises present an added value and risk avoidance strategy and might fulfil other, often more social purposes of less essential nature. This lack of focus on one activity for the purpose of increased income generation is reflected in most problems observed in pig farming. For example, the quasi cyclic patterns found in herd dynamics must be attributed to general farm management practices, such as confining animals during the sensitive cropping season and releasing them at the end of the cropping season to roam (and mate) freely, rather than to a specific focus on animal management.

Unimproved systems show high fluctuations in piglet numbers especially due to disease, but even in improved systems piglet mortality is a serious constraint, resulting often in significant production potential losses. Death by disease is overall still the most dominant exit factor which has been described as common for smallholder systems (Huynh *et al.* 2006). It has to be taken into account, that death by disease is only based on farmer accounts and rarely otherwise confirmed as farmers did generally not keep dead animals for post-mortem. It is likely to include also reasons like hypothermia, crushing and the like. However, high disease incidence in the target sites, as published by Okello *et al*. (2017) and others, support the notion that many animals indeed die from diseases. Holt *et al*. (2016) conducted a cross-sectional study in the region, identifying prevalence and infection risk depending on pig management and homestead setup, which showed high risks of infection for humans and animals related to local practices and setups. We observed that pig mortality was higher in the dry than in the wet season which we relate to the traditional practice of leaving most animals roam freely during this time of year, facilitating the spreading of infections. We speculate that the increased pig losses of Champion farmers, (which generally kept their animals penned) during this time is related to the spread of disease via free roaming animals who get in contact with confined animals by approaching their free-standing pens. Due to the intensive contact inside the confinement, but also due to poor pen drainage, feed and water contamination and sometimes insufficient preventatives such as vaccination and deworming, infections spread quickly and have an even higher impact among the confined population. Although in the wet season when all animals are confined to protect crops, better management results in lower disease incidence in Champion systems. Death by disease had the strongest impact on animal production as a whole and presents the strongest impediment to profitable animal production for smallholders. A comprehensive solution though seems to be only possible through community regulations forcing the confinement of all animals to reduce the spreading of disease as also noticed by Phengsavanh *et al*. (2011). The transition from a traditional approach to an improved one however entails often unforeseen difficulties. The high rates of stillbirths and premature births observed in Champion systems might be management related, though no reasons could be identified.

The second major constraint is adequate feeding. Local Lao Moo Lath pigs have been shown to reach their maximal growth performance and efficiency at 11% CP in the DM (Phengsavanh 2013; pp. 44). Changes in feed quality and quantity were hard to measure and analyse due to many factors such as the general practice of feeding many pigs out of one trough, the availability of only estimated nutritional data, only estimated amounts of ingredients in mixed diets, varying amounts of water when cooking the feed and varying total amounts of feed provided. Despite all these factors leading to inaccuracies in our estimates it is safe to conclude that all monitored pigs received diets which did not meet their protein requirements and led to performances far below their genetic potential. Feedstuff higher in CP led to faster growth and therefore shorter production cycles. This confirms earlier observation (Phengsavanh *et al.* 2010; Chittavong *et al.* 2012) that low CP in pig diets is the most limiting feeding related factor to smallholder pig performance in Laos.

Alternative high quality feeding sources to improve protein supply for pigs in smallholder systems have been extensively discussed by Martens *et al*. (2012), and *Stylosanthes guianensis*, which had been tested as protein supplement for Moo Lath pigs earlier (Kaensombath *et al.* 2013) has been confirmed during this project to be a viable option for improved animal performance (T. T. Tiemann, A. Phengvilaysouk and S. Keonouchanh, unpubl. data). Stylo was grown by pig farmers, harvested and either given fresh or cooked with other feed stuff or processed into leave meal for storage. The percentage of inclusion in the diet varied between 10% and 70% but was mostly ~30–50% fresh matter. But although our results confirm Stylo's suitability from a physiological point of view, from a farming operations point, we found a very low uptake of this technology and despite much higher costs and consequently lower profits, farmers clearly preferred the use of commercial feeds. The reasons were practical: less work, as establishment, maintenance, harvesting and processing do not apply; less risk, as weather, pests or diseases do not affect the availability of animal feed; higher effectiveness, as soy bean and grain based commercial feeds are generally of higher digestibility and nutrient density than forage based feeds. The effect of introducing commercial feeds to farmers is visible in the piglet peaks in August 2013 and March 2014 as presented above. This observation gives reason to consider whether setting up viable commercial feed value chains in smallholder pig production projects should be a preferred approach to on-farm solutions for pig feed production. The latter seem to be more viable, were pig production is already a priority activity of farmers.

The quality of feed aside, the amount of feed provided is a not less serious constraint to improved production as has been noticed also by Phengsavanh (2013; pp. 38). Although farmers simply do not provide enough DM, we also found a common approach trying to save high value resources, providing them sparsely to make them last longer. This stretching resulted in commercial complete feed supplementation of often only 5–10% in the total diet, resulting in no significant differences in growth performance while still costing farmers money. This approach was universal and hard to overcome and reflects strongly in the very low ADG and resulting long production cycles. By the end of the project period only few farmers fed acceptable amounts constantly.

More generally, the erratic production dynamics observed, with high standard deviations, within one farming system and big differences between farmers, concur with our observation of a lack of attention to animals and their needs in most farmers, often combined with convenient misconceptions about animal requirements. For example were, despite the provision of nipple water systems, the water containers rarely filled and pigs had to cover their water intake almost exclusively from water provided during feeding. A frequent answer provided was that pigs did not need water, having the surviving animals as proof. Ironically, a connection between insufficient water availability and low intake resulting in poor growth could not be made by farmers because insufficient feed provision did not lead to refusals. Also housing was in many cases improved at the beginning of the project but only in the case of some Champion farmers maintained in good conditions. Although pig behaviour and suitable pen designs are complex topics with many potential implications such as feed competition and resulting variable growth rates, but also poor mating, conception and born alive rates as well as direct piglet losses, general hygiene of animal environments – however achieved – can be considered without major doubt a relevant factor for animal health and wellbeing. The basic lack of understanding of germ theory and ethnic superstitions play a fundamental role here in farmer attitudes and behaviour. The general perception was that pigs did not require warm, dry or clean shelter and that even with improvements animals would still eventually get sick and die. This perception was often combined with the attitude that if an intervention could not solve a problem completely (e.g. vaccination should prevent animals from getting sick not only protecting it from one disease) it was not worth doing at all, slowing the progress of interventions substantially and leading to the described variations in production dynamics.

However, it is important to mention, that ethnic perceptions play an important role as to the extent animals are taken care of, making certain ethnic groups less likely to adopt more effective production approaches (such as confinement, cleanliness, sufficient high quality feed) than others. Although Hmong have a close relationship with their livestock, for example, Khmu people see themselves more as crop farmers and relate less to the needs of their livestock, which they see as secondary activity.

A big constraint to faster production cycles and healthy pig populations are very small breeding stocks often consisting of only one or two boars per village and on average only 2.3 sows per farmer. Also inbreeding is common and often young, not fully mature boars were used with gilts from the same mother sow or for direct mating with their own mother sow as already pointed out by others (Keonouchanh *et al.* 2011). This points to a general lack of capacity in management and planning or finding suitable solutions within the villages to improve production dynamics not only of individual farmers but of the village as a whole.

Our original plan to compare different sites had to be put aside as the overall conditions were not conducive to this approach. The differences found in farrowing dynamics between districts, for example, are likely to have been influenced by project interventions and multiple site specific factors. Project success is strongly related to the interaction between farmers and local extension services (Millar 2009) and building a personal relationship and trust are important factors. Due to personnel fluctuations in the involved government institutions though, personal exchange lacked continuity. Therefore the relationship and interaction with communities in different villages varied significantly which is likely to also have contributed to differences in impact on herd dynamics. It is therefore questionable if the differences between districts could be attributed to inherent disparities between sites or are rather a result of unequal project impact; which led us to change our focus.

Despite all these limitations and imperfections in production systems, the achieved small improvements led to a significant increase in production and income. During the intervention period, numbers of each, piglets, weaners and growers increased on average by ~1 per farmer between the end of 2013 and mid-2014. And, although overall only a slight increase in farrowings was recorded for Champion and Improved farmers, the most important change found was a more continuous production by Champion farmers. It indicates a moving away from a seasonal focus on pig production and sales towards a more market oriented, continuous output with a stronger interest in pig production throughout the year. Still, risk avoidance seems to prompt many farmers to sell pigs early, which is reflected in the peaks of weaner and grower numbers coinciding with sales numbers (Figs 2, 3) and was also communicated informally by farmers. This leads to only a small number of pigs reaching a weight of 40 kg or more before sale, keeping profits smaller than need to be while still bearing the highest risk of the early months of animal development. It also shows that reduced pig and especially piglet mortality was the main contributor to increased income in our case, followed by faster growth and higher weights, which is not surprising, considering the earlier observation of death by disease being the strongest impact on animal production as a whole. Lemke and Valle Zarate (2008) showed potential scenarios for very similar smallholder pig production systems in North Vietnam and their development over time and demonstrated the massive income potential for smallholders. The sustainability and further development of pig production at the intervention sites, though, is uncertain and will highly depend on political and market development in the region. A recent ban on meat exports until local demand is met by the central government might jeopardise the continuous development of the established value chain. In a stable value chain environment, a continuous evolution of production and management systems is likely, following similar trends observed in North Vietnam 10 years earlier (Rößler 2009). A recent follow up shows that farmers have kept engaging in pig production in both districts, the extent to which would have to be assessed though and remains unclear.

Conflicts of interest

None declared.

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