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REGULAR ARTICLES

Sow efficiency and early piglet mortality in two local pig breeds on smallholder farms in northern Vietnam—a longitudinal study

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Abstract In the recent past, pig performance and sow management on smallholder farms in the Southeast Asian Massif have been extensively researched. But the objective of this study was to investigate the lifetime efficiency of breeding sows of the local Vietnamese Ban (n = 89) and Mong Cai (n = 131) breeds in a production system context. The impact of sow longevity was considered in particular. In addition, predictors of early pre-weaning mortality in piglets were investigated. In total, nine villages of Son La province, situated in the uplands of north-western Vietnam, were selected, differing in access to markets, production intensity, and pig management level. Data was collected over a period of 10 years through an on-farm performance testing system. It was shown that sows of both breeds that achieved five or more parities farrowed and weaned significantly more piglets per life year compared to sows with only one or two parities. The conception rate (Spearman's *rho* = 0.374) and age at first farrowing (Spearman's *rho* = −0.424) were significantly correlated with the number of weaned piglets per life year of stayable (≥4 parities) Mong Cai sows. The risk of early pre-weaning death of piglets born to Mong Cai sows was affected more by litter size, while for piglets born to Ban sows, the risk was influenced more by the season. Therefore, interventions to improve the sow lifetime efficiency and piglet survivability must match the sow breed and management level.

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Introduction

The livelihoods of smallholders in the Southeast Asian Massif (SEAM) depend on rain fed crop-animal agriculture. Pigs constitute an important asset of these farming systems and are traditionally kept under extensive husbandry systems. Under resource-limited conditions, smallholders frequently draw on small-framed local breeds, such as the Ban breed in northern Vietnam, whereby typically one to two sows are kept (Chittavong et al. 2013; Riedel et al. 2014). Although representing an economic sideline activity, surpluses from pig production are readily sold. In contrast, pig keepers in the vicinity of the towns located at the foothills and in the valleys of the SEAM have gradually intensified and specialized their pig production (Lemke et al. 2006). In Vietnam, this development was accompanied by an influx of "exotic" germplasm and a loss in genetic diversity of local breeds (Berthouly-Salazar et al. 2012). The growing demand for pork by urban dwellers and improved access to inputs has driven the adoption of genetically improved breeds in crossbreeding schemes. In northern Vietnam, the Mong Cai (MC) breed became a popular dam line and is frequently kept under semi-extensive to semi-intensive management (Nga et al. 2014). In this case, pig production often substantially contributes to the farm income (Ieda et al. 2015).

There is a general assumption that local pig breeds, such as the Ban or MC breed, are particularly "hardy" and "robust". Adaptive capacity could indeed represent a valuable trait of local pig breeds, but has hardly ever been proven scientifically. "Robustness" would, however, need to be reflected in the lifetime efficiency of local sows and in low mortality rates of

their piglets in order to benefit smallholders. However, numerous studies have proposed that high mortalities together with weak linkages to veterinary services constrain smallholder pig production in developing countries and diminish the benefits farmers can achieve (Wabacha et al. 2004; Kagira et al. 2010; Riedel et al. 2012). Governmental organizations therefore consider the improvement of animal health as a cornerstone for rural development (e.g., Nga et al. 2014), allowing to untap the potential "robustness" of local breeds and to enhance the lifetime efficiency of sows. Against this background, it was aimed at comparing and evaluating the lifetime efficiency of local Vietnamese Ban and MC sows kept under extensive and semi-extensive management using data generated by an on-farm performance testing system. It was hypothesized that the magnitude of the effect of avoiding premature culling and of reproductive interventions on sow lifetime efficiency differs between breeds kept under the management typical for the breed and production system. In addition, predictors of early pre-weaning mortality in piglets born to sows of both breeds were investigated. It was hypothesized that these predictors differ according to the breed of the dam and production system.

Materials and methods

Study site

For this study, nine villages from two districts and four communes/wards of Son La province, situated in the uplands of northwestern Vietnam, were selected. The majority of the one million inhabitants of Son La province are from an ethnic minority group. The provincial poverty rate amounts to 64% (World Bank 2013). The villages differ in regard to their distance to towns, the ethnicity of their villagers, the period under recording, and the pig production system in place (Table 1). The smallholder pig production systems in northern Vietnam are subject to dynamic developments and could be classified as demand-driven, resource-driven, or intermediate, as reported by Lemke et al. (2006) and Haussner (2012). In the remote resource-driven villages with poor infrastructure (Tong Tai, Pa Dong), Ban sows were overrepresented, whereas in demand-driven villages in proximity to Son La town (Ban Buon, Ban Bo, Ban Co), MC sows dominated. In the remaining intermediate villages (Ban Dau, Ot Luong, Bo Duoi, Na Huong), the production system was transitioning toward commercialization. In the demand-driven system, market demand drives pig production intensity, and inputs and services for pig production are available and regularly accessed by farmers. Off-farm revenues often substantially contribute to the farm income (Haussner 2012). Smallholders managing such a semi-extensive pig production system were shown to prefer the MC breed as dam line due to its feed intake spectrum and capacity,

Table 1 Overview of the study site

	District								
	Son La city				Mai Son				
Commune/ward	Chieng Coi	Chieng An	Chieng An	Chieng Co	Chieng Co	Na Bo	Na Bo	Na Bo	Na Bo
Village	Ban Buon	Ban Bo	Ban Co	Ban Dau	Ot Luong	Bo Duoi	Na Huong	Pa Dong	Tong Tai
Distance to Son La (km)	3	6	5	25	20	50	45	55	50
Ethnicity	Black Thai	Black Thai	Black Thai	Black Thai	Black Thai	Black Thai	Black Thai	Hmong	Hmong
Pig production system[a]	Demand-driven	Demand-driven	Demand-driven	Intermediate	Intermediate	Intermediate	Intermediate	Resource-driven	Resource-driven
Period under recording	2002–2012	2002–2012	2006–2012	2007–2012	2004–2012	2002–2009	2003–2009	2004–2010	2004–2012
Mong Cai sows/piglets (N)[b]	39/2552	33/2135	–/410	–/328	26/1206	11/632	22/1411	–	–
Ban sows/piglets (N)[b]	–	–/158	–/165	11/542	25/1338	11/200	8/201	19/832	15/875

[a] The smallholder pig production systems in northern Vietnam are subject to dynamic developments: they could be classified as demand-driven, resource-driven, or intermediate, as reported by Lemke et al. (2006) and Haussner (2012).

[b] Number of Mong Cai sows (N = 131) and Ban sows (N = 89) and number of piglets born to Mong Cai sows (N = 8674) and piglets born to Ban sows (N = 4311) that qualified for the statistical analysis

prolificacy, and gentle behavior (Roessler et al. 2009). Extensive pig production in the resource-driven system, on the contrary, is based on farm-owned resources (Lemke et al. 2006), and pigs are frequently kept semi-scavenging (Haussner 2012; Muth et al. 2017). Revenues from cropping form the major part of the household income in the remote villages while pig keeping is rather a sideline activity (Haussner 2012). Farmers inhabiting the remote villages stated to prefer the Ban breed because of its feed intake spectrum and capacity, disease tolerance, carcass quality and due to its health and strength (Herold et al. 2010). The intermediate system is undergoing a transformation from the resource-driven to the demand-driven system with an increasing number of farmers keeping MC sows and practicing crossbreeding (Haussner 2012). For more detailed information on breeding, housing, feeding and health care of the pigs in the study villages, reference is made to Lemke et al. (2006) and Haussner (2012).

Data collection

Records were collected from 2002 to 2012. In the early phase, an on-farm performance testing system was established. The participating farmers recorded information on reproductive events on data sheets, which were collected bi-monthly by research staff from the provincial Veterinary Department and entered into a database (PigCHAMP®, Ames, IA, USA). At the end of the study, information on 275 Ban and 238 MC breeding sows born between 1999 and 2010 was registered. On the sow-level, the records included the location of the sow (village and household) and the dates of birth, service, parity, weaning, and removal from the herd. Occasionally, pedigree records, the reason for removal and the boar used for mating were available. On the litter-level, the numbers of piglets that were born alive, stillborn, weaned, or lost before weaning were collected together with the date of the event.

Definition of traits

The longevity of Ban and MC sows was defined as the period elapsed from the entrance of a gilt into reproduction until the removal of the sow. The lifetime efficiency of a sow was defined according to Sasaki and Koketsu (2008) as the number of piglets born alive or weaned per year during the lifetime of the sow. Lifetime efficiency was calculated by dividing the sum of the live born (weaned) piglets of a sow by the sow's longevity and then multiplying by 365. The age at first farrowing was defined as the period between the day of birth and the first farrowing. The conception rate was calculated by dividing the number of farrowings by the number of matings of a sow. The annual replacement costs were calculated by dividing the average cost of a gilt (975,000 Vietnamese Dong) by the sow longevity and then multiplying by 365. On the litter-level, the average numbers of piglets born alive and weaned per farrowing were considered. The farrowing interval was defined as the average farrowing-to-farrowing period of multiparous sows. The lactation period was defined as the period from the day of farrowing until weaning.

Statistical analysis

All statistical analyses were conducted by SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). The proportions of the sows being removed at a certain parity number, as well as the medians and the 25th and 75th percentiles of the characteristics of prolificacy and fertility of breeding sows, were calculated using FREQ and MEANS. This data is provided in the Online Resource Supplement for this article.

In order to analyze the effect of the number of parity at removal on the lifetime efficiency and replacement costs of Ban and MC sows, the data set was checked for connectedness and plausibility. Only sows with consecutive records from the first farrowing until removal were considered. Only sows for which the first farrowing was documented at least 3 years before the recording was terminated in the respective farm qualified for analysis. On the other hand, sows that received no reason for removal or that had too few contemporaries in their villages were excluded from the analysis. Thereby, the number of data sets was reduced to 89 Ban sows and 131 MC sows with 291 and 582 litters, respectively (Table 1). A general linear model (GLM) was fitted separately for each breed, with the number of parity at removal (five levels, parities ≥5 were aggregated) and village (six and five levels for Ban and MC sows, respectively) as fixed effects. Least-squares means were calculated for each parity class and separated by a *t* test using the Tukey-Kramer adjustment for *P* values. Differences were considered significant at $P < 0.05$.

Sows with four or more parities were arbitrarily defined as stayable sows. For these, Spearman rank correlations (rho) between lifetime efficiency and sow- and litter-level characteristics of prolificacy and fertility were calculated using CORR.

For the evaluation of early pre-weaning piglet mortality, data on 4311 and 8674 piglets from 706 and 917 litters of Ban and MC sows, respectively, were available. The piglets were grouped in birth year and village cohorts. Only cohorts with ≥50 piglets per sow breed qualified for the analysis. The survivor function until weaning was calculated according to the Kaplan-Meier method (LIFETEST). Cox proportional hazard models were applied for each sow breed separately using PHREG. The data sets were right-censored at day 21 if the piglet had not died until this age. Litter size, gestation length, parity number, and season were considered as predictors of early pre-weaning mortality. Because cross-fostering is not practiced in either production system (informal observation) this potential predictor was not considered. Litter size

and gestation length were categorized according to the upper and lower 25th percentiles, respectively. Large litters were defined as litters with >9 and >13 total born piglets (including stillborn piglets) for Ban and MC sows, respectively. Short gestations were classified as gestation lengths of <111 and <112 days for piglets born to Ban and MC sows, respectively. Parity had five levels, whereas piglets born in parity numbers ≥5 were aggregated. Season was classified into three levels, with a dry cold (November to January), a dry warm (February to April) and a hot wet season (May to October). Before running the model, the predictors were collectively subjected to proportionality testing. In case of non-proportionality, a time-dependent covariate was added. Clusters of village and birth year were used as strata.

Results

The sow breeds showed a different distribution over the numbers of parity at removal. Only 38% of the Ban sows, but 51% of the MC sows, reached four or more parities. The median for lifetime efficiency based on the number of piglets born alive per year of sow lifetime amounted to 6.1 and 11.6 piglets for Ban and MC sows, respectively. For the number of piglets weaned per year of sow lifetime, the median lifetime efficiency amounted to 4.6 and 9.2 piglets for Ban and MC sows, respectively.

Table 2 displays the effect of the number of parity at removal on sow lifetime efficiency for both breeds. Ban sows that have been removed after four parities farrowed 3.2 live born piglets more per life year than those that had been removed after two parities ($P < 0.05$). In other words, if the sow was kept for four instead of two parities, 29 days less of feeding were required to produce one piglet. Ban sows that completed five or more parities weaned a significantly higher number of piglets per life year compared with sows that were removed after one or two parities ($P < 0.05$). MC sows with just one parity at removal displayed a significantly lower lifetime efficiency compared to sows of all other parity classes ($P < 0.05$), whereas MC sows with five or more parities exhibited a significantly higher lifetime efficiency compared to sows that had completed fewer parities ($P < 0.05$). To farrow and wean one piglet, MC sows with five or more parities had to be fed for approximately 3 to 4 weeks. Table 2 also shows that, as expected, the replacement costs declined for both breeds, with an increased number of parities at removal.

The Spearman rank correlations of sow- and litter-level reproductive characteristics with the traits of lifetime efficiency of stayable Ban and MC sows are presented in Table 3. For Ban sows, the magnitude of the correlation coefficient for the farrowing interval with the number of piglets weaned per life year (rho = −0.328) was lower than with the number of live born piglets per life year (rho = −0.600). There was a strong negative correlation between the length of lactation period and both lifetime efficiency traits for Ban sows (rho = −0.634 and −0.768 for the number of live born and weaned piglets per life year, respectively). Prolificacy was strongly correlated with the lifetime efficiency for both breeds. Conception rate (rho = 0.501 and 0.374 for the number of live born and weaned piglets per life year, respectively) and age at first farrowing (rho = −0.361 and −0.424 for the number of live born and weaned piglets per life year, respectively) exhibited moderate correlations to the lifetime efficiency of MC sows.

The Kaplan-Meier survival function (Fig. 1) indicated that the mortality of piglets born to Ban and MC sows was highest in the first week of life. Before day 21 postpartum, 13 and 15% of piglets born to Ban and MC sows, respectively, had

Table 2 Effect of the number of parities at removal on the lifetime efficiency and replacement costs of Ban and Mong Cai sows

	Number of parities at removal									
	1		2		3		4		5+	
Trait[a]	No.	LSM (SE)	No.	LSM (SE)	No.	LSM (SE)	No.	LSM (SE)	No.	LSM (SE)
Ban										
NBA/Y/L	17	4.5^{c} (0.5)	24	5.0^{bc} (0.4)	13	6.6^{ab} (0.5)	14	8.2^{a} (0.5)	19	8.3^{a} (0.5)
NW/Y/L	18	3.4^{c} (0.5)	24	3.8^{bc} (0.5)	13	5.1^{abc} (0.6)	14	5.9^{ab} (0.6)	19	6.4^{a} (0.5)
COST (‘000 VND)	18	666^{a}	24	442^{b}	13	328^{c}	14	297^{c}	20	199^{d}
Mong Cai										
NBA/Y/L	15	5.3^{c} (0.9)	21	9.7^{b} (0.8)	27	9.8^{b} (0.7)	13	12.1^{b} (1.0)	54	15.9^{a} (0.5)
NW/Y/L	15	3.6^{c} (0.9)	22	7.4^{b} (0.7)	27	7.4^{b} (0.7)	13	9.4^{b} (0.9)	54	13.3^{a} (0.5)
COST (‘000 VND)	15	729^{a}	22	540^{b}	27	362^{c}	13	328^{c}	54	220^{d}

Data presented as number of observations (n), least-squares means (LSM; within rows, LSM with different *lowercase letters* are significantly different at $P < 0.05$) and standard error (SE) of LSM

[a] Lifetime efficiency was defined as the number of piglets born alive (NBA/Y/L) or weaned (NW/Y/L) per year during the sow’s lifetime. Annual replacement costs (COST) were calculated by dividing the average cost of a gilt (975,000 Vietnamese Dong, VND) by the sow’s longevity and multiplying by 365. For the statistical analysis a log-transformation was performed. Here, the back-transformed values are presented

Table 3 Spearman rank correlations (rho) between the lifetime efficiency and the sow- and litter-level reproductive characteristics of the Ban (n = 34 and n = 19 for age at first farrowing) and Mong Cai sows (n = 67 and n = 39 for age at first farrowing) with four or more parities at removal

	Ban				Mong Cai			
	NBA/Y/L		NW/Y/L		NBA/Y/L		NW/Y/L	
	rho	*P* value	rho	*P* value	rho	*P* value	rho	*P* value
Sow-level traits								
Age at first farrowing	−0.102	0.679	0.221	0.363	−0.361	0.024	−0.424	0.007
Longevity	−0.176	0.318	0.075	0.675	0.172	0.164	0.201	0.102
Conception rate	0.165	0.352	0.038	0.830	0.501	<0.001	0.374	0.002
Litter-level traits								
NBA[a]	0.835	<0.001	0.777	<0.001	0.764	<0.001	0.560	<0.001
NW[b]	0.509	0.002	0.918	<0.001	0.461	<0.001	0.777	<0.001
Farrowing interval	−0.600	<0.001	−0.328	0.058	−0.508	<0.001	−0.406	0.001
Lactation period	−0.634	<0.001	−0.768	<0.001	−0.242	0.048	−0.269	0.028

Lifetime efficiency was defined as the number of piglets born alive (NBA/Y/L) or weaned (NW/Y/L) per year during the sow's lifetime

[a] Number of piglets born alive per farrowing

[b] Number of piglets weaned per farrowing

died. This corresponded to 52 and 80% of the total pre-weaning deaths of piglets born to Ban and MC sows, respectively.

The Cox proportional hazard models showed that litter size significantly influenced the survival of individual piglets born to sows of both breeds ($P < 0.05$; Table 4). For piglets born into large litters of both MC and Ban sows, the hazard of dying was increased by 3.0 and 1.8 times, respectively, compared to piglets born into smaller litters. Birth into a first parity or birth subsequent to a short gestational period implied a moderate increase in the risk of early pre-weaning death of piglets born to both sow breeds. The risk of early pre-weaning death was significantly increased in the dry cold and dry warm seasons compared to the hot wet season ($P < 0.05$). In fact, the risk of dying for piglets born to Ban sows was reduced by 40–45% in the wet season compared to the dry season, while the risk of dying for piglets born to MC sows was reduced by only 19–21%. The probabilities for survival did not differ when comparing the dry cold to the dry warm season.

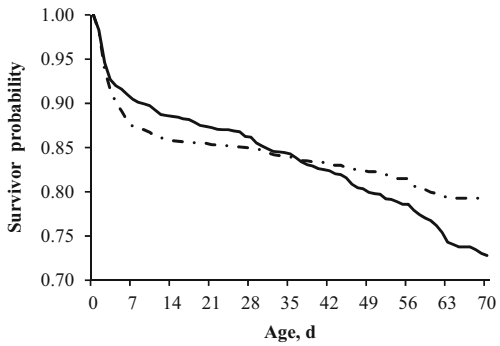

Fig. 1 Kaplan-Meier survivor function for suckling piglets born to Ban (*solid line*) and Mong Cai (*dashed line*) sows

Discussion

In the recent past, pig performance and sow management practices of smallholders in the SEAM have been extensively researched, but the analysis of the lifetime efficiency of local sows has been prevented because of the lack of longitudinal data. Lifetime efficiency results from the interplay of performance and the adaptive capacity ("robustness") of the sows and reflects the household's annual availability of piglets for sale or fattening. The extent to which improving longevity and stayability translate into gains in lifetime efficiency of local pig breeds kept under extensive and semi-extensive management has remained unclear. Despite the relatively small sample sizes after data cleansing, the present study has attempted to close this gap.

The MC sows clearly outperformed the Ban sows in terms of lifetime efficiency (Table 2), which can be attributed to the genetic improvement program applied to the MC breed, and basic differences in the housing and feeding of these breeds. In fact, a previous survey by Haussner (2012) showed that in villages where Ban sows were almost exclusively kept, farmers hardly confined their sows, whereas virtually all farmers in closer-to-town villages provided stables with appliances that protected MC sows from cold weather. Ban sow keepers will probably not invest in stables unless marketing options for their products—such as linkages to the urban upmarket segment—are developed and a sustaining source of income from pig production is secured. Le et al. (2016) have shown that building up a cooperative group and developing a marketing channel for specialty local Ban pork encouraged farmers to change their marketing habits. It is possible that the orientation toward markets could subsequently result in

Table 4 Number of observations (n), parameter estimates for the expected change in the hazard of each predictor relative to the referent (β), standard errors (SE), and probabilities ($Pr > X^2$) for Cox proportional hazard models on the early pre-weaning mortality of piglets born to Ban and Mong Cai sows

	Ban				Mong Cai			
Trait	No.	β	SE (β)	$Pr > X^2$	No.	β	SE (β)	$Pr > X^2$
Litter size[a]								
Small-medium	3484	1.000			7020	1.000		
Large	827	0.578	0.085	<0.001	1654	1.089	0.084	<0.001
Parity number								
1	1010	1.000			1442	1.000		
2	949	−0.182	0.092	0.047	1614	−0.410	0.090	<0.001
3	714	−0.218	0.105	0.037	1409	−0.257	0.090	0.004
4	511	−0.251	0.121	0.039	1134	−0.364	0.101	<0.001
5+	1127	−0.408	0.097	<0.001	3075	−0.366	0.086	<0.001
Gestation length[b]								
Short	1895	1.000			2799	1.000		
Medium-long	2416	−0.560	0.129	<0.001	5875	−0.271	0.054	<0.001
Season[c]								
Dry cold	978	1.000			2224	1.000		
Dry warm	1221	−0.096	0.083	0.247	2108	0.019	0.079	0.809
Wet hot	2112	−0.602	0.080	<0.001	4342	−0.213	0.089	0.016

[a] Large litters were defined as litters with >9 and >13 total born piglets (including stillborn piglets) for Ban and MC sows, respectively

[b] Short gestations were classified as gestation lengths of <111 and <112 days for piglets born to Ban sows and MC sows, respectively

[c] Seasons were classified as dry cold (November to January), dry warm (February to April), and hot wet (May to October)

modifications of the management practices of Ban sow keepers.

In smallholder systems, culling is practiced for different reasons, which can have intertwined biological, economic and/or managerial causes. However, keeping sows until they reached four to five (or more) parities seemed to be reasonable for both breeds, because the lifetime efficiency of the sows was increased, which reduces labor and financial maintenance costs for sow upkeep (Table 2). In addition, the replacement costs for higher parity sows would decline, although it has to be noted that the values of the carcasses of culled gilts and multiparous sows were neglected in the present study. In contrast, Riedel et al. (2014) stated that, with respect to the traditional husbandry system of southwestern China, the culling of local sows after completing only one parity was advantageous due to the lower feed requirements of growing gilts. This discrepancy could be explained by the much lower differential between the farrowing interval and the age at first farrowing for the sows investigated by Riedel et al. (2014) when compared to the Ban and MC sows.

Studies originating from other regions of the SEAM reported similar litter sizes than those observed for the Ban (Chittavong et al. 2013; Riedel et al. 2014) and the MC breed (Ieda et al. 2015). Because of its strong association with lifetime efficiency (Table 3), the present work supports the importance of enhancing prolificacy. Overcoming nutrient deficiencies through interventions in feeding were frequently considered as a prerequisite for enlarging litter sizes at birth and weaning (Pham et al. 2010; Chittavong et al. 2013). The establishment or improvement of breeding programs could represent another approach to enhancing prolificacy. However, the sustainable implementation of community-based breeding programs for pigs in northern Vietnam proved to be difficult (Muth et al. 2014; Roessler et al. 2015). Interventions in the reproduction management of sows in order to reduce non-productive periods seemed to be promising in improving the lifetime efficiency of the MC breed in particular (Table 3). In contrast to Ban sows, the lifetime efficiency of MC sows was correlated with age at first farrowing and conception rate. Again, confinement and thus better heat detection in MC sows could have resulted in the differences in lifetime efficiency that were observed between the breeds, but these could also be attributed to a greater availability of boars or semen because of the proximity of close-to-town villagers to service providers (Roessler et al. 2009; Haussner 2012).

High piglet mortalities led to a general limitation in smallholder piglet production. According to the results of this study, different approaches for both breeds are required. In spite of its positive correlation to the lifetime efficiency of sows, the higher prolificacy of MC sows seemed to result in weaker piglets at birth and an increased risk of death (Table 4), particularly through overlaying, which was the most frequently

reported reason for early pre-weaning death of piglets born to MC sows. Creep feeding and piglet protection bars could increase the pre-weaning survivability of piglets in this case (More et al. 2005; Hong et al. 2006). For piglets born to Ban sows, the hazard of dying was strongly influenced by the season (Table 4), following a similar pattern to that reported by Basumatary et al. (2009) for suckling piglets reared in Eastern Himalaya smallholder farms. Once again, this difference in early piglet mortality between breeds might be explicable by the housing conditions or veterinary care (Haussner 2012). The survivability of piglets born to Ban sows in particular eroded after 28 days (Fig. 1), which could be related to enteric disorders and poor hygienic conditions (Hong et al. 2006). Under these conditions, a rather wet and hot climate could additionally compromise piglet survivability.

In conclusion, keepers of Ban and MC sows would benefit from promoting sow longevity and stayability because of higher lifetime efficiency and lower replacement costs. Improving veterinary structures could thus prove essential for exploiting the potential "robustness" of sows of local breeds kept under extensive and semi-extensive management and could translate into quantifiable benefits. The lifetime efficiency of MC sows could additionally be enhanced by improvements to reproduction management. Interventions to reduce the early pre-weaning mortality of piglets need to be adapted to the sow breed and production system.

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Compliance with ethical standards

Statement of animal rights For this retrospective study, compliance with international, national, and/or institutional guidelines for the care and use of animals was not required.

Conflict of interest The authors declare that they have no conflict of interest.

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