Received: 19 December 2019 | Revised: 26 May 2020 | Accepted: 4 June 2020

DOI: 10.1111/asj.13411

ORIGINAL ARTICLE

Animal Science Journal WILEY

The phenotypic characteristics and relational database for Vietnamese native pig populations

Shinya Ishihara[1] | Fukuhiro Yamasaki[2] | Pham Hai Ninh[3] | Nguyen Cong Dinh[3] | Aisaku Arakawa[4] | Masaaki Taniguchi[4] | Ngo Thi Kim Cuc[3] | Satoshi Mikawa[1] | Masaru Takeya[2] | Kazuhiro Kikuchi[1,5]

[1]Institute of Agrobiological Sciences, National Agriculture and Food Research Organization (NARO), Tsukuba, Japan

[2]Genetic Resources Center, NARO, Tsukuba, Japan

[3]National Institute of Animal Science, Hanoi, Vietnam

[4]Institute of Livestock and Grassland Science, NARO, Tsukuba, Japan

[5]The United Graduate School of Veterinary Science, Yamaguchi University, Yamaguchi, Japan

Correspondence
Kazuhiro Kikuchi, Institute of Agrobiological Sciences, National Agriculture and Food Research Organization (NARO), Owashi 1-2, Tsukuba, 305-8634, Ibaraki, Japan.
Email: kiku@affrc.go.jp

Present address
Shinya Ishihara, Department of Animal Science, Nippon Veterinary and Life Science University, Musashino, Tokyo, Japan

Funding information
Science and Technology Research Partnership for Sustainable Development (SATREPS) from the Japan Science and Technology Agency (JST)/Japan International Cooperation Agency (JICA), Grant/Award Number: JPMJSA1404

Abstract

Although there are a number of Vietnamese native pig (VnP) populations, some are on the verge of extinction, and therefore adequate management and conservation are necessary. In this study, we conducted a field survey of VnP populations and analyzed interrelationships among their characteristics. We also established a relational database for management of field data on these populations. For data collection, we conducted interviews with farmers and visual inspection of 32 VnP populations in 22 provinces of Vietnam, as well as taking photographs of individual animals. Data on the characteristics of VnP populations were subjected to multiple correspondence analysis (MCA). For establishment of the database, normalization and table partitioning were performed to eliminate redundancy and ensure consistency of the collected data items. Passport data, characteristics data, and image data were collected from a total of 1,918 VnPs and entered as a normalized table. Upon MCA, most of the populations were not separated from each other, but the Mong Cai, O Lam, and Chu Prong populations were separated from the other populations. Thus, we have constructed a relational database from comprehensive information on the characteristics of VnP populations.

KEYWORDS
characteristics, database, native pigs, Vietnam

1 | INTRODUCTION

In Vietnam, 26 native pig breeds are known to exist (NIAS, 2015). Vietnamese native pig (VnP) breeds have acquired unique biological fitness and characteristics due to a long history of breed improvement and fixation (Dang-Nguyen et al., 2010). In addition, VnP breeds have potential as donors for organ xenotransplantation because of their similarity to humans in terms of size and physiological characteristics. Thus, VnP breeds are significant as genetic resources in terms of diversity. However, introgression of western breeds into Vietnam since the 20th century (Lemke et al., 2008) aimed at increasing meat productivity has occurred at the expense of genetic erosion in VnP breeds. In the northern area of Vietnam, the ratio of sows of purebred VnP breeds was 72% in 1994, but this had decreased to 45% by 1997, and

to 12% by 2006, by which time the ratios of exotic breeds and crossbreeds were 14% and 74%, respectively (Lemke et al., 2008). Also, five VnP breeds have become extinct (NIAS, 2015; Pham et al., 2014), and nine are reported to be at some risk of extinction (NIAS, 2015). Thus, the genetic diversity of VnP breeds has gradually reduced, although the government has been making efforts to conserve such breeds. Crossbreeding involved many generations of backcrossing has occurred in the H'mong pig breed in the northern region of Vietnam (Berthouly-Salazar et al., 2012). As a result, the original characteristics of purebred VnPs are being gradually lost due to genetic erosion.

The most basic information useful for the conservation and management of native breed populations includes their visible characteristics and population distribution. This information needs to be managed by means of an appropriate database system. Various databases for domestic animals have been developed worldwide. For example, the ILRI (International Livestock Research Institute) has been developing the Domestic Animal Genetic Resources Information System (DAGRIS) since 1999, and the FAO has established the Domestic Animal Diversity Information System (DAD-IS) (FAO, 2001). However, the information on VnP breeds, such as their visible characteristics and geographical distribution, is still insufficient for the establishment of databases applicable to conservation and population management.

In this study, our objectives were to collect field data, such as those pertaining to populations, their distribution and characteristics, and to analyze the collected data to improve our understanding of the current situation of VnP populations, as well as the relationships between their characteristics. We also aimed to devise a relational database scheme for accumulation and management of the collected field data that would be useful for conservation of VnP populations with appropriate management.

2 | MATERIALS AND METHODS

2.1 | Field survey

We carried out interviews with farmers and ascertained the visually observable characteristics of individual VnPs in 22 provinces throughout Vietnam (Figure 1 and Table 1). In Vietnam, breed distinction is not clear because some ethnic minorities use the same local name for pig breeds, even if the breed is distributed in a quite distant province. For this reason, we adopted the breed definitions (26) published in the report of National Institute of Animal Science (Ishihara et al., 2018; NIAS, 2015). We basically collected samples from available 21 breeds (Group A in Table 1) except for the extinct five breeds. During the field survey and sample collection, we notified additional possibilities of breeds (3, Group B in Table 1). In addition to this definition of breeds, we also collect samples from those that are given the same name but are distributed in different provinces and categorized as a different group (8, Group C in Table 1). In this study, we defined the "populations" (total 32 in 3 Groups). Each population was collected from more than three districts or communes in at least one province. With regard to the data collected,

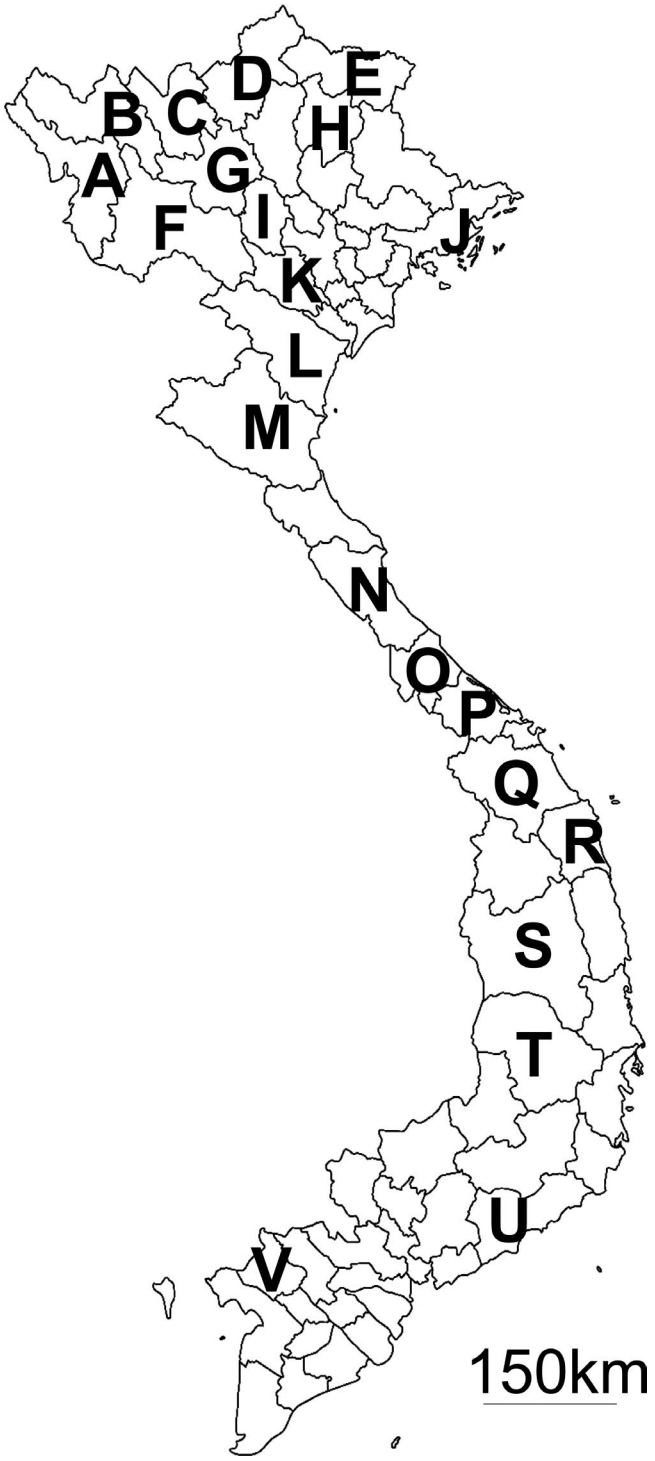

FIGURE 1 Map of Vietnam and locations for sampling of the Vietnamese native pig populations. A–V represent the Vietnamese provinces sampled, as detailed in Table 1

we focused on reproductive sows on each farm. First, we confirmed whether or not each sow was a pure native pig through interview with the farmers. We then collected data on the geographical location and observable characteristics of the pig. If it was revealed that the sow had been derived through crossing with any western breed, we did not collect information about it. In brief, we recorded the local name, province, district, commune, and farm information

TABLE 1 Sampling locations and local names of native pig populations in Vietnam and their abbreviations

Population	Group	Province[a]	Local name	No.
BanDB	C	Dien Bien (A)	Ban	67
ML	A	Dien Bien (A)	Muong Lay	3
MT	A	Lai Chau (B)	Muong Te	60
BanLCH	C	Lai Chau (B)	Ban	60
DenLCA	A	Lao Cai (C)	Den	30
MK	A	Lao Cai (C)	Muong Khuong	60
HU	A	Ha Giang (D)	Hung	60
LP	A	Ha Giang (D)	Lung Pu	60
TN	A	Cao Bang (E)	Tap Na	80
HL	A	Cao Bang (E)	Ha Lang	30
HUO	B	Cao Bang (E)	Huong	21
DKS	B	Cao Bang (E)	Dong Khe Spot	8
DenCB	C	Cao Bang (E)	Den	30
BanSL	A	Son La (F)	Ban	60
BanYB	C	Yen Bai (G)	Ban (or H'Mong pig)	221
BanBK	C	Bac Kan (H)	Ban	61
LU	A	Phu Tho (I)	Lung	58
MC	A	Quang Ninh (J)	Mong Cai	60
HB	A	Hoa Binh (K)	Man	265
CoTH	C	Thanh Hoa (L)	Co	61
MEO	A	Nghe An (M)	Meo	60
XV	B	Nghe An (M)	Xao Va	60
KH	A	Quang Binh (N)	Khua	32
VP	A	Quang Tri (O)	Van Pa	60
AL	A	Hue (P)	A Luoi (or Co)	34
CoQN	C	Quang Nam (Q)	Co	60
KS	A	Quang Ngay (R)	Kieng Sat	60
CP	A	Gia Lai (S)	Chu Prong	25
CoGL	C	Gia Lai (S)	Co	11
SOC	A	Dak Lak (T)	Soc	59
CoBT	A	Binh Thuan (U)	Co	60
AG	A	An Giang (V)	O Lam	42
			Total	1918

Note: "Population" column shows abbreviations for each population. "Group" column is based on the breed definition (A; available breeds informed in the website (21), B; additional possibilities of breeds (3), and C; given the same name but are distributed in different provinces (8)).
[a]A–V represent the Vietnamese provinces sampled (see also Figure 1).

as passport data. The farm information included geographical data such as UTM_X, UTM_Y, zone, altitude, and accuracy using GPS (Gamin Inc., Olathe, KS, USA). We also recorded data on characteristics such as coat and skin color, and the shape of the backline, belly, face, ear, and snout (detailed in Table 2). Each characteristic was decided according to the classification shown in Table 2. In cases where the characteristics were difficult to distinguish, we defined the entry as "no data." Aside from these characteristics data, we surveyed the number of teats on each individual. In addition, we took at least three photographs of each individual as image data.

2.2 | Data analysis

We calculated the relative proportion of each characteristic for each of the VnP populations, omitting the Muong Lay and Dong Khe Spotted pig populations due to small sample size (Table 1). Pearson's chi-squared test was performed to evaluate the correlation between backline and belly shape. We then performed multiple correspondence analyses (MCA) using the FactoMineR package (Lê, Josse, & Husson, 2008) in R software to survey the relationship between characteristics and each population. The number of teats was not included in MCA because this is numerical data.

2.3 | Database construction

Relational databases are widely used for storage and management of accumulated data worldwide. Therefore, we developed a relational database scheme optimized for VnP populations by normalizing the collected data for consistency. In this process, we separated the data including individual passport data or characteristics and evaluation data into the different table to eliminate the redundancy. Every table contained a primary and foreign key providing a link to other tables and other fields that have similar or related contents/characteristics. The subordinate item to each Primary key was included in the same table. We set the junction table to control for many-to-many relationships. All individual data items were stored in database fields within the tables.

3 | RESULTS

We collected field data for 1,918 individuals making up 32 populations of VnPs. These individuals were distributed among 61 districts and 166 communes. The relative proportions of the characteristics of each population are shown in Figure 2, and photographs of the VnP populations are shown in Figure S1. More than 90% of individuals in 18 populations had a black coat color, whereas some individuals of Ban in Bac Kan, and Soc and Ban in Yen Bai had a black and white coat color (Figure 2). The Mong Cai (MC) and Co Binh Thuan (CoBT) populations had a scattered pattern of hair density in 98.3% and 96.7% of individuals, respectively (Figure 2). The Ban in Dien Bien (BanDB), Kieng Sat (KS), and Co in Thanh Hoa (CoTH) populations showed a hair mane ratio of 61.7%, 58.8%, and 56.7%, respectively (Figure 2). Most of the VnP populations had a specific hair color (more than 88% for Chu Prong (CP)), but skin color in O Lam pigs in An Giang (AG) was 35% white and 60% black-white (Figure 2).

TABLE 2 Characteristics of Vietnamese native pigs and their classification

Characteristic	Classification					
Coat Color	**Black**	**White**	**Black + White**	**Brown**	**No data**	
Coat Pattern	Plain	Spotted	6-spots	4-spots	No data	
Hair_Charact	Straight	Curly	No data			
Hair_Density	Average	Dense	Scattered	No data		
Hair_Mane	TRUE	FALSE				
Skin_Color	Black	White	Black + White	Brown	Spotted	No data
Skin_Charact	Smooth	Wrinkled	No data			
Tusks	TRUE	FALSE				
Face	Straight	Concave	No data			
Snout_A	Long	Short	No data			
Snout_B	Straight	Concave	No data			
Shape_Ear	Horizontal	Upward Curved	Downward	No data		
Shape_Belly	Slim	Drooping	No data			
Shape_Leg	Straight	Curved	No data			
Shape_Walk	On toe	On foot	No data			
Backline	Straight	Upward Curved	Swayback	No data		

More than 80% of individuals in MC, Huong (HUO), and Ha Lang (HL) had a swayback backline. Similarly, more than 80% of individuals in MC, HUO, and HL and BanDB had a drooping belly shape (Figure 2). On the other hand, most of the VnP populations had both a slim and drooping shape belly (Figure 2), and almost all had both a straight and swayback backline. Pearson's chi-squared test omitted individuals with an upward curved backline or no data because of negligibly low sample sizes. Consequently, 1,872 individuals were further investigated, and a significant correlation between backline and belly shape was identified ($p < .001$), notably a straight backline with a slim belly shape, and a swayback backline with a drooping belly shape.

The MCA results are shown in Figure 3. The contribution ratio of Principle component 1 and 2 was 15.7% and 7.3%, respectively. Almost all populations were integrated with each other, although some, such as HU, HUO, HL, MC, AG, and CP, were separated from the other populations (Figure 3a). The category distribution is shown in Figure 3b. Skin_Spotted, Skin_White Skin_BlackWhite, Face_others, Coat_White, Coat_Brown, Leg_Bandy, and Leg_Curved were separated from the other factors (Figure 3b).

The number of teats on each individual was shown in Figure 4. The mean teat number was 10.8 and ranged from 8 to 16 among VnPs. MC had the highest teat number (14.1 ± 0.9 *SD*) and MC population had 16 teats individual (6 individuals). ML had 13.0 ± 1.0 *SD* teat number although only two individuals were surveyed. AG, HL, and HUO had 12.9 ± 1.3 *SD*, 12.5 ± 0.9 *SD*, and 11.8 ± 1.5 *SD* teat number, respectively. AL had the fewest teat number in mean (10.0 ± 0.0 *SD*). One individual from HB and CoTH had eight teat numbers.

A scheme of the database is shown in Figure 5. After data normalization, the number of tables became 28. Eleven tables were for the Passport data (including image data), and 17 were for Characteristics and Evaluation (CE) data (Figure 5). The scheme required two intermediate tables (survey-researcher and survey-individual) for connecting the many-to-many relationships among the data (Figure 5).

4 | DISCUSSION

In this study, we analyzed the characteristics of VnP populations based on field data and developed a relational database scheme for conservation and management. MCA showed that the accumulated contribution rate was 22.9% because the number of factors analyzed was high and somewhat complex. However, we were able to derive a tentative overview of the characteristics of the VnP populations.

Differences in the Coat_color, Coat_Pattern, and Skin_color characteristics were apparent among the VnP populations, in comparison to the other characteristics (Figure 2). On the basis of these characteristics, HL, HU, and HUO showed clusters that were slightly separated from those of other VnP populations (Figure 3a). In addition, we classified the MC face as "other," as it is characterized by thickness around the chin and a wider forehead compared to other breeds. Consequently, MC was separated into a cluster distinct from the other VnP populations. MC, HL, and HUO constituted a neighboring cluster because these populations have a black and white coat and skin coloration. Furthermore, MC, HL, and HUO showed similar body shape (drooping shape belly and swayback backline). Admixture analysis ($K = 6$) using SNP also revealed that MC, HL, and HUO shared a common ancestor (Ishihara et al., 2018). These results suggested that MC, HL, and HUO share a close relationship through their common origin. However, the Cao Bang province where HL and

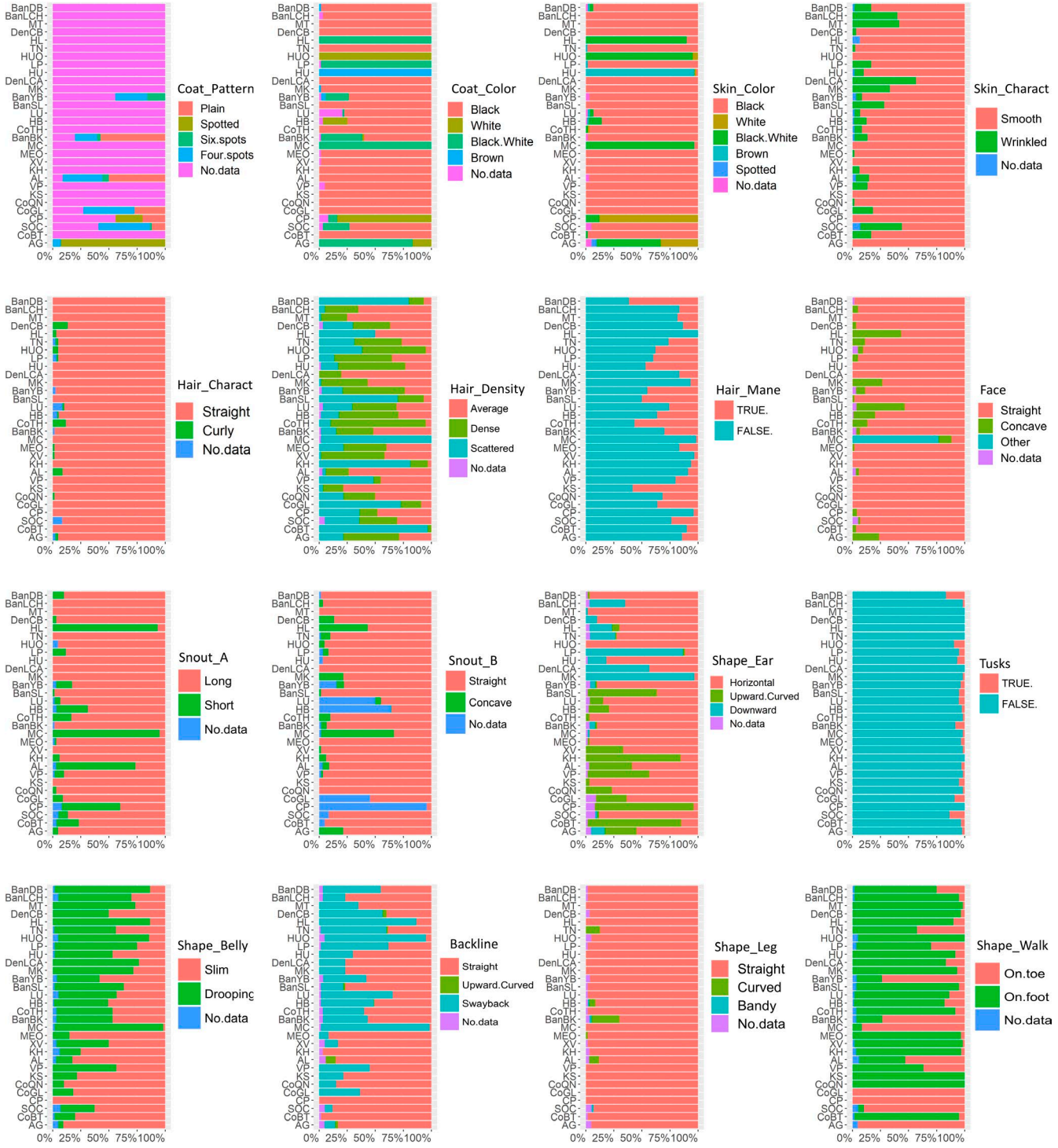

FIGURE 2 Cumulative bar plot of the characteristics of the various Vietnamese native pig populations. The labels are Ban Dien Bien, Ban Lao Cai, Muong Te, DenCB, Ha Lang, Tap Na, Huong, Lung Pu, Hung, Den Lao Cai, Muong Khuong, Ban Yen Bai, Ban Son La, Lung, Man, Co Thanh Hoa, Ban Bac Kan, Mong Cai, Meo, Xao Va, Khua, Co A Luoi, Van Pa, Kieng Sat, Co Quang Nam, Co Gia Lai, Chu Prong, Soc, Co Binh Thuan, and O Lam from top to bottom

HUO were bred is far distant from Quang Ninh province where MC was bred. Previous mitochondrial whole-genome analysis has shown that MC is closely related to the Bama miniature pig distributed in Guangxi province, China, which borders on Quang Ninh province and Cao Bang province (Tran et al., 2016). Also, the characteristics of MC are similar to those of the Luchuan pig distributed in Guangxi province (FAO, DAD-IS http://fao.org/dad-is). On the other hand, it has been considered that HL was introduced from southern China through trade and exchange thousands of years ago, and mitochondrial DNA analysis showed the relationship with Chinese pig breed (Bui, Ngyuen, & Vo, 2018). In addition, HUO is also characterized by a black coat over the head and at the buttocks, and a white coat

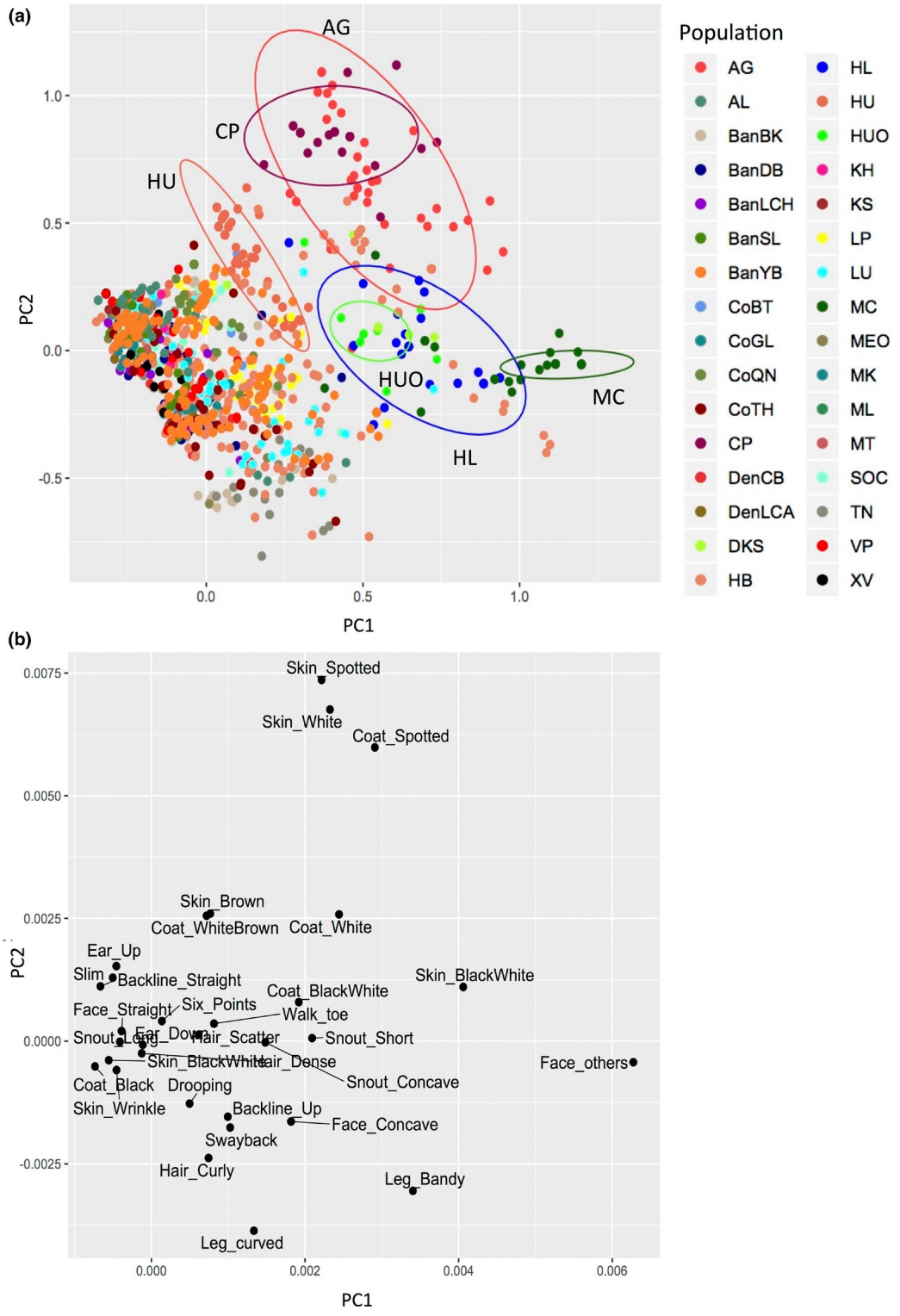

FIGURE 3 Multiple correspondence analysis of the characteristics of Vietnamese native pig populations. Upper panel (a) shows the distributions of the various Vietnamese native pig breeds and the ellipses (confidence levels 95%) for the O Lam (AG), Chu Prong (CP), Mong Cai (MC), Hung (HU), Huong (HUO), and Ha Lang (HL) populations. Lower panel (b) shows the distribution of the various characteristic factors. Some individuals had completely overlapped because they had the same characteristics

around the body (Figure S1), similar to that of the Bama miniature pig (Gong et al., 2019). In the previous study, it is stated the number of teats increased depended on domestication from wild boar to domesticated pig (Kurosawa, Tanaka, & Inaba, 1978). MC, HL, and HUO showed higher teat number compared to other VnP populations (Figure 4), and associate to the relationship to Chinese native pig breeds that have domesticated through the selective breeding. Although the origin of these populations is still unknown, MC, HL,

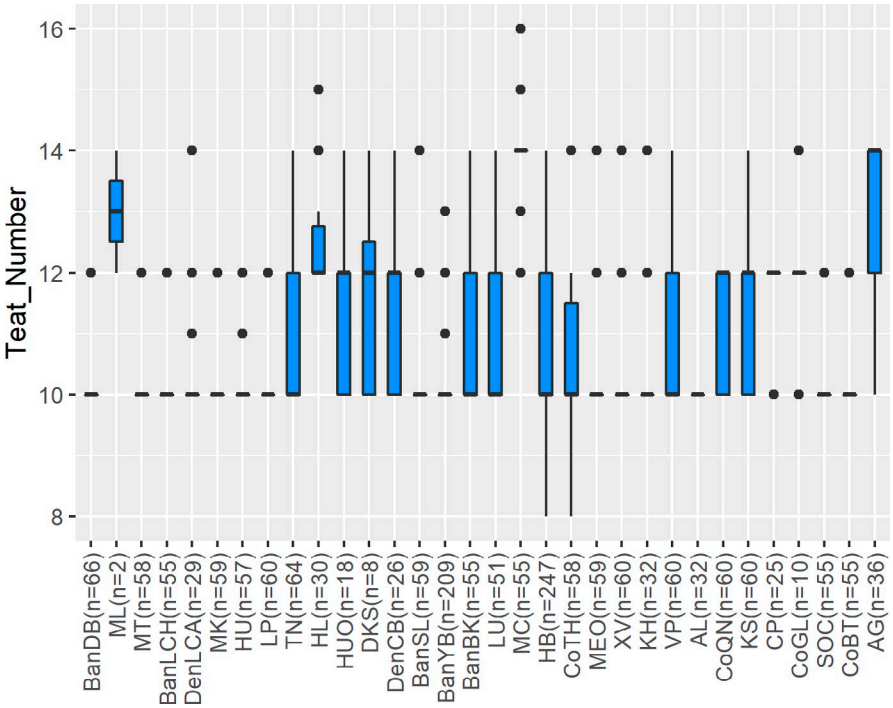

FIGURE 4 Comparison of the number of teats in each population. The boxplot of the number of teats is shown for each Vietnamese pig populations. The middle line in the box represents the median, upper, and lower areas of the center box indicate the 25th (Q1) and 75th (Q3) percentiles, respectively, and the upper and lower whisker indicate maximum and minimum value, respectively. The values which either exceed Q3 + 1.5 IQR or fall below Q1–1.5 IQR, where IQR = Q3−Q1, are considered as outliers

and HUO may have some relationship to Chinese native pig breeds such as the Luchuan pig and Bama miniature pig on the basis of their characteristics and geographic distribution.

Populations from the southern region of Vietnam are distributed in three areas: CP and Soc in the central highland area, AG in the Mekong Delta (NIAS, 2015), and CoBT on the South-Central coast. Our MCA analysis indicated that AG and CP were separated from CoBT and SOC (Figure 3), not only on the basis of their white hair and skin color (Figure 3), but also the spotted coat pattern of AG (Figure 2). Although the origin of AG and CP has not been well defined, it has been reported that AG is kin to Ba Xuyen, a VnP that has already become extinct (NIAS, 2015). Ba Xuyen is a composite breed resulting from crossing of Berkshire with a VnP breed. A previous study using SNP analysis has shown that Ba Xuyen is genetically close to a Landrace but not close to VnPs (Ishihara et al., 2018). In addition, microsatellite analysis for VnP breed revealed AG is genetically close to western breeds such as Landrace, Yorkshire, and Duroc (Nguyen et al., 2020). On the other hand, SOC has a phenotype similar to native pigs in the Northern and Central regions of Vietnam. Previous SNP and microsatellite analysis showed that SOC is genetically close to CP (Nguyen et al., 2020; Ishihara et al., 2018). This study showed that AG and CP have a similar white color phenotype, although the genetic background of these populations could differ. The phenotypic characteristics can be similar in spite of the different genetic background because the characteristics are a result of selective breeding in domestic animals.

Our results suggested that some characteristics, such as Shape_belly, Shape_ear, Backline, Hair_density, and Hair_mane, did not show clear differences among the VnP populations, and even showed variation within the same populations. For example, only LP and MK showed a high incidence (87% and 97%, respectively) of a "Downward" Shape_ear, although LP and MK did not form a separate cluster because another VnP breed also showed a 5%–57% "Downward" Shape_ear incidence. Thus, VnP populations had various phenotypic characteristics, even within the same population. Historically, small householders in Vietnam have mated sows randomly, even including wild boar (Lemke & Zárate, 2008). From the 1960s, such small householders began mating sows with MC, Ban or exotic breeds to increase meat production efficiency (Herold, Roessler, Willam, Momm, & Zárate, 2010). In addition, previous studies have suggested that VnP breeds had genetic introgression from exotic breeds through uncontrolled admixture and backcrossing between breeds (Berthouly-Salazar et al., 2012; Ishihara et al., 2018). Such crossbreeding by some small householders could have been responsible for the unclear phenotypic characteristics of VnP populations, creating the various characteristics observed. Thus, genetic dilution by introgressive hybridization could have occurred in VnP populations. The field data in this study were collected over a wide area and reflected the current situation of VnP populations that have been exposed to genetic dilution.

In this study, we constructed a basic database with a structure optimized for VnPs characteristics (Figure 5). It is anticipated that this structure will expand to include genomic data such as genetic variation and also sequencing data. For long-term conservation, gene banking, one of the approaches for ex situ conservation, should be employed to complement in situ conservation (FAO, 2011). For establishment of a gene bank, it is recommended that the information on source, taxonomy, and phenotypic characteristics should be collected, as well as genetic data for donor animals such as microsatellite or SNP data (FAO, 2011). Genetic information can be useful for supporting conservation strategies, including evaluation of genetic diversity and relationships within and between populations, and for identifying genes that can affect productivity and adaptation (FAO, 2011). In addition to

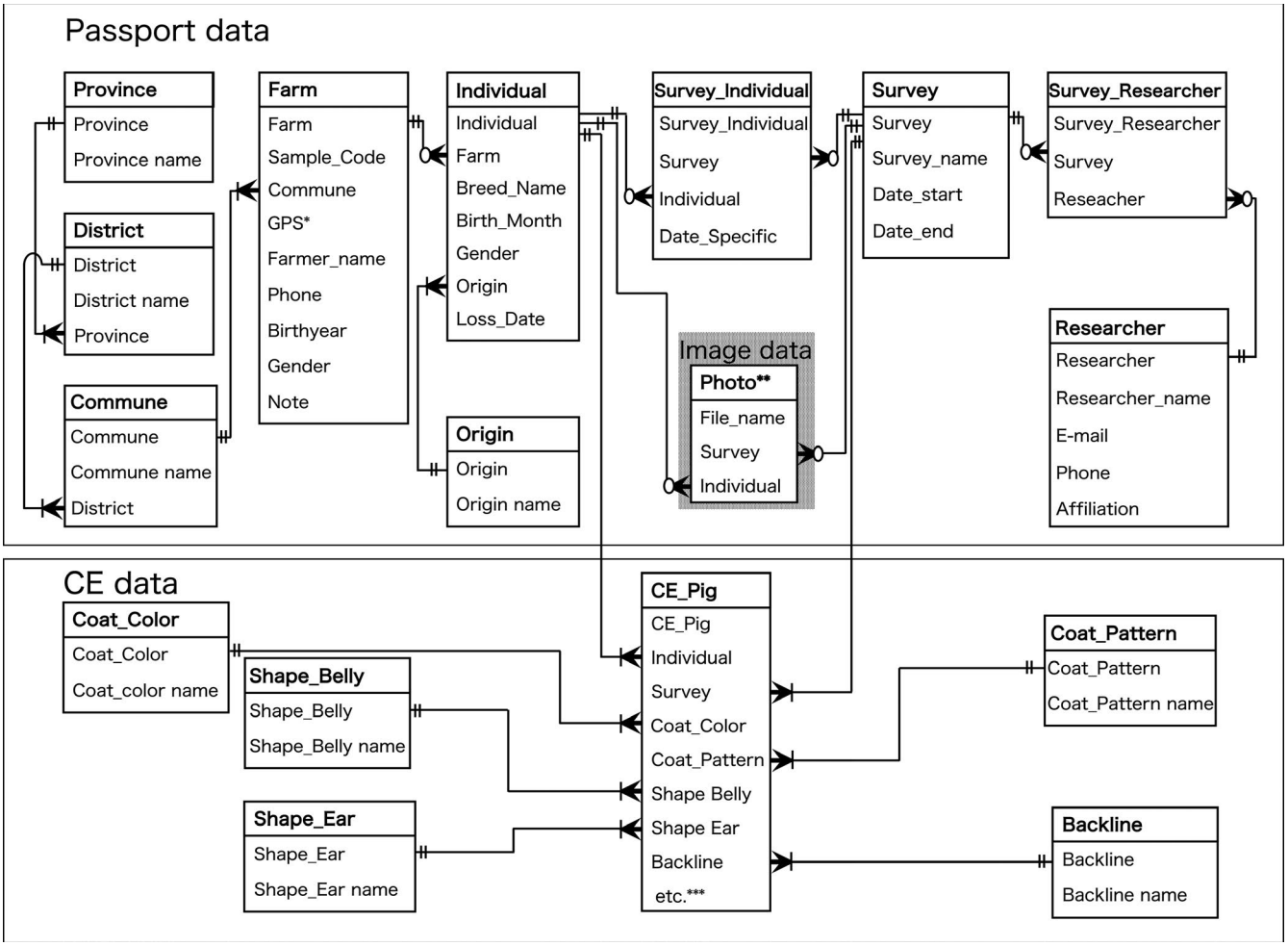

FIGURE 5 Entity–relationship diagram of the database for Vietnamese native pig. The association between the tables was described according to the Crow's Foot notation. GPS* data in the Farm table include UTM_X, UTM_Y, zone, altitude, and accuracy. "Photo**" refers to image data and also some aspects of CE data. "etc***" refers to other characteristics listed in Table 2. CE stands for characteristics and evaluation

the data we have collected, accumulation of genetic information will be a powerful tool for appropriate conservation and management of VnP populations.

5 | CONCLUSION

Here, we have presented detailed characteristics of VnPs and a scheme for database construction. This study has revealed two main findings. First, the characteristics of VnPs have diverged even within the same populations, although some populations partially demonstrate the same characteristics. Second, a relational database suitable for VnP populations has been devised. Although VnP populations are important genetic resources and are currently under threat of extinction, no well-integrated information system for them exists. It is anticipated that the present relational database for Vietnam will provide integrated information on VnP populations. This database includes passport data for each breed and their characteristics, as well as providing statistical data on the accumulated information, allowing users to easily retrieve data on VnP populations in the future.

ACKNOWLEDGMENTS

This research was partly supported by a Science and Technology Research Partnership for Sustainable Development (SATREPS) from the Japan Science and Technology Agency (JST)/Japan International Cooperation Agency (JICA) (JPMJSA1404). DNA samples from Vietnamese breeds are available under a material transfer agreement from National Institute of Animal Science.

CONFLICT OF INTEREST

All authors declare no conflict of interest.

ORCID

Masaaki Taniguchi https://orcid.org/0000-0001-8194-3577
Kazuhiro Kikuchi https://orcid.org/0000-0002-7198-9237

REFERENCES

Ba, N. V., Arakawa, A., Ishihara, S., Nam, L. Q., Thuy, T. T. T., Dinh, N. C., … Taniguchi, M. (2020). Evaluation of genetic richness among Vietnamese native pig breeds using microsatellite markers. *Animal Science Journal*, *91*(1), 1–10. https://doi.org/10.1111/asj.13343

Berthouly-Salazar, C., Thévenon, S., Van, T. N., Nguyen, B. T., Pham, L. D., Chi, C. V., & Maillard, J. C. (2012). Uncontrolled admixture and loss of genetic diversity in a local vietnamese pig breed. *Ecology and Evolution*, *2*(5), 962–975. https://doi.org/10.1002/ece3.229

Bui, T. A., Nguyen, H. D., & Vo, T. T. B. (2018). Complete mitochondrial genome sequence and phylogenetic status of Halang Pig (*Sus scrofa*). *Asian Journal of Biology*, *6*(2), 1–8. https://doi.org/10.9734/AJOB/2018/41995

Dang-nguyen, T. Q., Tich, N. K., Nguyen, B. X., Ozawa, M., Kikuchi, K., Manabe, N., … Nagai, T. (2010). Introduction of various vietnamese indigenous pig breeds and their conservation by using assisted reproductive techniques. *The Journal of Reproduction and Development*, *56*(1), 31–35. https://doi.org/10.1262/jrd.09-165K

FAO (2001). Preparation of the first report on the state of the world's animal genetic resources. Guidelines for the Development of Country Reports. Rome.

FAO (2011). Molecular genetic characterization of animal genetic resources. FAO Animal Production and Health Guidelines. No. 9. Rome.

Gong, H., Xiao, S., Li, W., Huang, T., Huang, X., Yan, G., … Yang, B. (2019). Unravelling the genetic loci for growth and carcass traits in Chinese Bamaxiang pigs based on a 1.4 million SNP array. *Journal of Animal Breeding and Genetics*, *136*(1), 3–14. https://doi.org/10.1111/jbg.12365

Herold, P., Roessler, R., Willam, A., Momm, H., & Zárate, A. V. (2010). Breeding and supply chain systems incorporating local pig breeds for small-scale pig producers in Northwest Vietnam. *Livestock Science*, *129*(1–3), 63–72. https://doi.org/10.1016/j.livsci.2010.01.004

Ishihara, S., Arakawa, A., Taniguchi, M., Luu, Q. M., Pham, D. L., Nguyen, B. V., … Kikuchi, K. (2018). Genetic relationships among Vietnamese local pigs investigated using genome-wide SNP markers. *Animal Genetics*, *49*(1), 86–89. https://doi.org/10.1111/age.12633

Kurosawa, Y., Tanaka, K., & Inaba, H. (1978). The variations of teat number in wild boar population. *The Japanese Journal of Swine Husbandry Research*, *15*(2), 103. https://doi.org/10.14899/youton1964.15.103.

Lê, S., Josse, J., & Husson, F. (2008). FactoMineR: An R package for multivariate analysis. *Journal of Statistical Software*, *25*(1), 1–18. https://doi.org/10.18637/jss.v025.i01

Lemke, U., Mergenthaler, M., Roßler, R., Huyen, L. T. T., Herold, P., Kaufmann, B., & Zárate, A. V. (2008). Pig production in Vietnam - a review. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, *3*(023), 1–15. https://doi.org/10.1079/PAVSNNR20083023

Lemke, U., & Zárate, A. V. (2008). Dynamics and developmental trends of smallholder pig production systems in North Vietnam. *Agricultural Systems*, *96*(1–3), 207–223. https://doi.org/10.1016/j.agsy.2007.08.003

National Institute of Animal Science (NIAS). (2015). Science and Technology Research Partnership for Sustainable Development (SATREPS) project establishment of cryo-bank system for Vietnamese native pig resources and sustainable production system to conserve bio-diversity. Hanoi, Vietnam: National Institute of Animal Science, [cited 16 March 2020]. Available from URL: https://satreps-vnp.vn/overview-of-project/.

Pham, L. D., Do, D. N., Nam, L. Q., Van Ba, N., Minh, L., Hoan, T. X., … Kadarmideen, H. N. (2014). Molecular genetic diversity and genetic structure of Vietnamese indigenous pig populations. *Journal of Animal Breeding and Genetics*, *131*(5), 379–386. https://doi.org/10.1111/jbg.12068

Tran, T. N. T., Ni, P., Chen, J., Le, T. T., Steve, K., Han, J., & Wang, H. (2016). The complete mitochondrial genome of Mong Cai pig (*Sus scrofa*) in Vietnam. *Mitochondrial DNA Part B: Resources*, *1*(1), 226–227. https://doi.org/10.1080/23802359.2016.1155424

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Ishihara S, Yamasaki F, Ninh PH, et al. The phenotypic characteristics and relational database for Vietnamese native pig populations. *Anim Sci J*. 2020;91:e13411. https://doi.org/10.1111/asj.13411