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Nam Wa buffalo and Lua extensive farming: seasonal forest grazing and local governance in Nan, Thailand

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Indigenous livestock breeds persist through close interactions between animal traits, farming practices, and locally governed landscapes, particularly in upland regions where production relies on mobility and low external inputs. This study aims to document how the Nam Wa buffalo, an indigenous swamp buffalo landrace associated with Lua communities in Nan Province, northern Thailand, is maintained through seasonal grazing, farmer selection, and local governance. Based on qualitative fieldwork conducted between 2022 and 2024, including semi-structured interviews with 40 interlocutors, participant observation, and consultation with local livestock institutions, the study documents seasonal mobility between village rice fields (thung na) and forest grazing areas (pang kwai), farmer-led selection of functional traits, and collective regulation of grazing commons. Results identify Nam Wa buffalo populations across five districts of Nan Province and show that herders value agility, strong hooves, calm temperament, maternal reliability, and herd cohesion under extensive, low-input conditions. Seasonal movements are collectively coordinated, while ritual practices associated with grazing areas and buffalo care contribute to regulating access, timing, and responsibilities among herders. Locally reported decline is associated with land-use change, crop-livestock conflict, restricted grazing access, and limited circulation of breeding males. Rather than providing a genetic or demographic assessment, the study identifies socioecological conditions through which herders maintain the landrace in practice. The findings suggest that future conservation initiatives should consider seasonal mobility, local selection objectives, access to grazing mosaics, and farmer knowledge alongside genetic and productivity assessments.

KEYWORDS

Nam Wa buffalo (*Bubalus bubalis*), Lua ethnic group, indigenous livestock, seasonal mobility, pastoral governance, ethnoveterinary knowledge, *in situ* conservation

Introduction

Indigenous livestock breeds constitute essential biological and socioecological assets for farming systems in upland and marginal environments, where production is shaped by environmental variability rather than standardized inputs (Hoffmann, 2010; FAO, 2015). In such contexts, livestock breeds persist less through formal selection schemes than through prolonged interactions between herders' practices, environmental constraints, animal

behavior, and locally embedded knowledge systems (Köhler-Rollefson, 2003; Gandini and Villa, 2003; Rege and Gibson, 2003).

In mainland Southeast Asia, water buffalo (*Bubalus bubalis*) have historically been integral to agricultural and pastoral life. Although mechanization has diminished their use in many lowland areas (Chantalakhana and Bunyavejchewin, 1994), buffaloes have not disappeared from rural landscapes. In upland regions, where steep terrain, fragmented landholdings, forest-edge ecologies, and seasonal rainfall limit machinery-based farming, they remain multifunctional animals. They provide manure, household savings and social value while converting locally available forage into productive resources, functions increasingly recognized as important to the sustainability of low-input livestock systems (Deb et al., 2016; Minervino et al., 2020).

Asia also hosts the largest diversity of buffalo types and local populations (FAO, 2015).

Thailand recognizes several local buffalo types associated with particular districts and ecologies (Na-Chiangmai et al., 2016). In Nan Province, the Nam Wa buffalo was officially recorded in 2013 as a Geographical Indication under the Thai system of protected local products and recognized as a Native Thai Animal Breed through an application lodged by the Nan Provincial Livestock Office. The name refers to the Nam Wa River Basin in northern Thailand. Local documentation emphasizes the animal's capacity to forage on mountain slopes and its resilience under highland conditions. Yet formal recognition has not been matched by detailed research connecting animal traits, seasonal management, land access, and local institutions.

The Nam Wa buffalo is closely associated with Lua communities in Nan Province, including households whose histories involve movements between upland settlements and the Chiang Klang lowlands. Among these households, buffalo provide savings and manure and became important for traction in irrigated rice cultivation as farming practices were reorganised following resettlement, a role that has since declined with mechanization. Their seasonal movement continues to connect paddy farming with forest grazing (Lainé et al., 2023). Buffalo keeping is also embedded in household labor, ritual obligations, and collectively negotiated access to grazing areas.

This *Brief Research Report* draws on an ongoing research program on Lua communities and Nam Wa buffalo in Nan Province, combining livestock-focused description with ethnographic attention to herd mobility, local selection, animal health, ritual coordination, and common-resource governance. Building on previous work from the same program (Lainé et al., 2023; Lainé et al., 2024; Lainé et al., 2026), it aims to document how this upland buffalo landrace is maintained through extensive low-input farming, seasonal mobility, local knowledge, and social institutions.

Materials and methods

The study is based on qualitative fieldwork initiated in 2022 across seven villages in Nan Province where Nam Wa buffalo husbandry is practised, with particular attention to Ban Huai Phan, a socially mixed village with a substantial Lua population in Chiang Klang district, and settlements in Thung Chang, Chaloe

Phra Kiat, and Bo Kluea districts. Nine field missions of five to 7 days each were conducted between 2022 and 2024. Sites were selected for their historical association with Lua settlement, continuing buffalo husbandry, access to seasonal forest grazing areas, and local recognition of Nam Wa buffalo management. The study was designed to document places where this system remains socially and materially active rather than to constitute a statistically representative sample of Nan Province.

The research combined semi-structured interviews, informal discussions, participant observation, and consultation of local livestock records within an ethnozoological approach (Hunn, 2011; Albuquerque et al., 2019) and an ethno-ethological orientation (Brunois, 2005). Forty interlocutors participated, including 32 male buffalo owners aged 29–67, as well as village elders, ritual specialists, community leaders, village animal health volunteers, and local livestock officers. Participants were identified through purposive sampling and recommendations from village representatives and herders. Interviews lasted approximately 1 hour and were repeated and cross-checked across successive field visits. They addressed herd histories, selection criteria, seasonal mobility, reproduction, feeding, animal health and ethnoveterinary care, ritual obligations, changes in land access, and threats to buffalo keeping.

The ethnozoological approach (Hunn, 2011) was used to document local animal categories, practical classifications, and knowledge associated with buffalo management, while the ethno-ethological orientation (Brunois, 2005) focused on how herders interpret buffalo behavior across paddy fields, forest paths, mineral sites, and grazing areas. Participant observation accompanied everyday husbandry rather than constituting separate standardized observation sessions. During village stays, herders were followed through routine activities, particularly morning and evening herd supervision, feeding, field grazing, health monitoring, and seasonal movements between rice fields (*thung na*) and forest grazing areas (*pang kwai*). Observations documented herd composition and leadership, feeding behavior, interactions among animals, reproductive management, injuries, treatment practices, and ritual acts. Interviews and observation were iterative: situations observed during daily activities were discussed with herders, while issues raised in interviews guided attention during subsequent visits.

Interviews were conducted in Thai and, where necessary, with local assistance for Lua terms and ritual vocabulary. Depending on participants' preferences and field circumstances, interviews were audio-recorded or documented through detailed fieldnotes. Notes and transcripts were reviewed iteratively around animal traits, seasonal movement, reproduction, health management, ritual regulation, land access, and perceived decline, and cross-checked against repeated observations and local records where available.

Ethnoveterinary inquiry was integrated into interviews and participant observation rather than conducted as a separate survey. It covered common health problems and injuries, plant-based treatments, commercial veterinary medicines, and access to veterinary assistance. These observations were interpreted alongside a published companion study from Ban Huai Phan documenting relationships between buffalo feeding, Lua medicinal repertoires, and ethnoveterinary preparations (Lainé et al., 2026).

Additional information was gathered through discussions with local livestock officers, village animal health volunteers, and Department of Livestock Development (DLD) staff. Local owner lists, village counting practices, and DLD records were used to contextualize herd size, vaccination, and breeding support. Because the study did not undertake genetic, demographic, or productivity measurements, reported decline, inbreeding concerns, and breeding-male scarcity are treated as local assessments rather than population estimates.

Ethical approval for the animal-related research was obtained from the Kasetsart University Institutional Animal Care and Use Committee (approval no. ACKU-65-VTN-003). The ongoing research programme is also authorised by the National Research Council of Thailand (NRCT) under research permit No. 0401/4817, issued on 2 April 2025. Informed consent was obtained from all participants before interviews and observations.

Results

Population distribution and reported decline

The Nam Wa buffalo is locally recognized across five districts of Nan Province: Bo Kluea, Chaloe Phra Kiat, Mae Charim, Chiang Klang, and Wiang Sa. Lua communities are present in several of these districts, although Nam Wa buffalo husbandry also extends across settlements with different ethnic and historical backgrounds. No dedicated census of the Nam Wa population exists, as it remains included within the overall buffalo census for Nan Province, which recorded more than 12,000 buffaloes in 2025 (Nan Provincial Statistical Office, 2025).

Ban Huai Phan maintains more than 200 buffaloes, according to the latest village-level count conducted by the village animal health volunteer who liaises with the Department of Livestock Development (DLD). By contrast, herders and livestock officers described marked decline or near disappearance of buffalo husbandry in several former Nam Wa-raising areas, particularly in the upper districts. They associated this decline with land sales, conversion of agricultural and forest-edge areas to maize and cassava, crop-livestock conflicts and compensation costs, restricted grazing access, and declining interest in buffalo keeping among younger generations.

Herders and livestock officers also expressed concern about inbreeding when herds become isolated or breeding males are scarce. DLD-supported initiatives, including the Cattle and Buffalo Bank for Farmers, have introduced breeding males into some local herds. Herders nevertheless described access to suitable males as intermittent and dependent on herd proximity and household arrangements.

Morphological, behavioral, and selection characteristics

Lua herders identify the Nam Wa buffalo through a combination of morphological and behavioral characteristics. Animals are described as medium-sized and relatively slim, with crescent or half-moon shaped horns, a straight backline, small outward-flaring ears, and calm or “sweet” eyes. These characteristics are summarized in Table 1.

Selection, however, emphasizes functional traits. Herders particularly value rounded, strong hooves for movement across steep, muddy, and rocky terrain; calm temperament and ease of handling; maternal ability and reproductive reliability; and strong herd cohesion. Older females are frequently described as herd leaders during grazing and seasonal movement. These recurrent criteria connect the animals selected and retained by herders to the conditions in which they move, forage, and reproduce.

Present-day herders recognize several features associated with Nam Wa buffalo, particularly horn shape, ear form, tail length, and backline, in the nineteenth-century buffaloes depicted in the mural paintings of Wat Phumin (Figure 1). Their recognition places contemporary descriptions of Nam Wa morphology within a longer visual history of buffalo keeping in Nan. While these representations cannot establish biological or genetic continuity, they provide historical depth to the local identification of the Nam Wa as a buffalo type long associated with the landscapes of the province.

Seasonal mobility, feeding, and reproduction

Buffalo management among Lua farmers follows a seasonal rhythm closely linked to rice cultivation, summarized in Table 2. During the dry season, from November to April, buffaloes remain near village rice fields (*thung na*), where they graze on rice straw (*fang khao*), stubble, weeds, and aquatic plants near streams and small rivers. They contribute manure to soil fertility, receive vitamins and minerals (*krue le*), and are supervised daily. During the rainy season, from May to October, herds are moved to forest grazing areas (*pang kwai*), where animals graze more freely and owners visit them periodically.

Rainy-season forest grazing gives access to a wider diversity of forage resources and is associated by herders with improved body condition. It also exposes animals to particular risks. Snakes and dhole (*Cuon alpinus*), and historically Asian black bears (*Ursus thibetanus*), are reported as threats to buffaloes in the upper districts. Injuries also occur in *pang kwai* when animals slip or fall, or become trapped by their horns in small trees or bamboo.

Before returning to the village, animals may be checked by their owners, village animal health volunteers, or DLD veterinarians. Since 2022, buffaloes in the study area have received annual vaccination against foot-and-mouth disease through the DLD, with assistance from village animal health volunteers. In Ban Huai Phan, DLD records and interviews document a major foot-and-mouth disease outbreak in 1995. Herders still recall the episode as a significant moment in local herd history because many animals were affected and substantial buffalo mortality occurred.

Seasonal mobility also structures reproduction. Herders report that mating occurs mainly during the rainy season, when different herds mix in forest grazing areas, with pregnancies continuing into the following dry season. When a female comes into heat outside this period, her owner may temporarily bring her to a breeding male kept by another household before returning her to the household herd. Reproduction thus depends on relations between owners and access to breeding males as well as on seasonal herd movement.

TABLE 1 Morphological, behavioral, and functional characteristics of the Nam Wa buffalo reported by Lua herders and livestock officers.

Characteristic	Reported description	Practical significance reported by herders
Horns	Crescent or half-moon shaped	Recognition of Nam Wa morphology
Body	Medium-sized, relatively slim	Mobility in upland terrain
Backline	Straight	Recognition of Nam Wa morphology
Ears	Small, slightly outward-flaring, often with white hair inside	Recognition of Nam Wa morphology
Eyes	Calm appearance, described as “sweet”	Associated with docility
Hooves	Rounded and strong	Movement on steep, muddy and rocky terrain
Udder	Well-developed, usually four teats	Associated with maternal and reproductive reliability
Behavior	Alert but docile, strong herd cohesion	Ease of handling and collective movement



TABLE 2 Seasonal management of Nam Wa buffaloes among Lua farmers in Nan Province.

Season	Location	Main management and herding practices
Rainy season (May–Oct)	Forest grazing areas	Free grazing, mating, limited human intervention, periodic visits, salt supplementation, ritual offerings to forest spirits
Dry season (Nov–Apr)	Village rice fields	Grazing on rice stubble and weeds, manure fertilization, ploughing, daily supervision

Health management and local knowledge

Health management combines formal veterinary intervention with locally grounded observation and care. DLD vaccination campaigns are coordinated with village animal health volunteers, who also conduct livestock counts, relay information to herders, and assist with health monitoring. Recent campaigns concerning lumpy skin disease, for example, were communicated through these intermediaries, although no buffaloes in Ban Huai Phan were reported as affected.

Ethnoveterinary practices documented during the research program address wounds and skin problems, parasites, bleeding, postpartum recovery, insects, and snake bites (Lainé et al., 2026). Herders described around a dozen preparations, generally using plants available in local grazing environments. *Thunbergia laurifolia* leaves and flowers are fashioned into a collar following snake bites; young leaves of *Mangifera sylvatica* are crushed and rubbed onto the skin as an insect repellent; *Spondias pinnata* bark is boiled to clean wounds;

and fresh *Chromolaena odorata* leaves are crushed, sometimes with tobacco, and applied to fresh wounds. *Centotheca lappacea*, locally known as *Ya repair*, is used for postpartum care, with the whole plant applied topically to female buffaloes.

Preparations are generally simple, involving crushing or boiling plant material and topical application. Commercial veterinary medicines are also widely used and may be combined with local preparations. Plant-based treatments remain particularly useful for minor ailments and emergencies when animals are grazing far from veterinary services. Herders also emphasized injuries and accidents during rainy-season forest grazing as recurrent health concerns.

Ritual regulation as herd and landscape governance

Ritual practices accompany the seasonal organization of buffalo husbandry and access to grazing areas. Ritual calendars structure the



FIGURE 2
Sukwaan kwai ceremony held in Pieng Kor, Chaloem Phra Kiat District, Nan Province (© Suriyawut, 2025).

timing of seasonal movements to *pang kwai* and the return of herds to *thung na*. In each village, decisions about when herds should move are discussed collectively among buffalo owners and formalized through ritual acts, creating shared points of coordination between households.

Offerings to forest spirits associated with grazing areas (*phi pang kwai*) are tied to specific grazing zones rather than abstract territorial boundaries. Each *pang kwai* is associated with a spirit location (*tu phi*), and households moving buffaloes into a given area are expected to make appropriate offerings. Herders also describe *pong*, permanently wet and mineral-rich places that attract buffaloes but are considered dangerous because of accidents, illness, or misfortune. When a *pong* is located in the village area, offerings are made during Lua New Year. Forest *pong* require ritual attention when buffaloes graze in the forest. Neglecting these obligations is said to expose animals to accidents or predation.

Sukwaan kwai, shown in Figure 2, is a buffalo blessing performed after periods of intensive work such as plowing or field preparation. During the ceremony, herders speak directly to their buffaloes, thank them, and apologize for demanding labor. Offerings commonly follow the rule of one chicken per buffalo, and symbolic elements such as feathers may be placed on the animal. Several households reported that these ceremonies were more frequent in the past but continue today in adapted form.

Narratives associated with ritual practice also circulate among herders. Stories of buffaloes lost to predators or fatal accidents after a household neglected ritual obligations are recounted as cautionary examples, linking appropriate conduct toward particular grazing places with responsibilities for the animals using them.

Discussion

The Nam Wa buffalo case shows how a local livestock population is maintained through the conditions that make particular animal traits useful and reproducible. Strong hooves, agility, calm temperament, maternal reliability, and herd cohesion are valued because they fit the environments in which buffaloes move and are managed. Comparable attention to temperament, conformation, reproductive performance, and environmental tolerance has also been reported for river buffaloes, including

Murrah buffaloes (Sangwan et al., 2021; Kumar et al., 2022). These observations are consistent with broader work on animal genetic resources showing that adaptation is produced and maintained through interactions between genotype, environment, and management (Hoffmann, 2010; FAO, 2015; Minervino et al., 2020). For Nam Wa buffaloes, that environment is heterogeneous: paddy fields, forest grazing areas, mineral sites, paths, river margins, ritual places, and negotiated access all enter into the conditions under which animals are kept.

Farmer-led selection is central to this process. Lua herders do not select primarily for size or market weight. They favor animals able to move through steep, wet, and forested terrain, remain manageable within collective herds, reproduce under low-input conditions, and avoid unnecessary conflict with people and crops. The emphasis placed on rounded, strong hooves is particularly revealing, since morphology is valued through what an animal can actually do in a landscape. Descriptions comparing *kwai nam wa* with the larger *kwai thuy* similarly point to locally differentiated buffalo types in northern Thailand (Na-Chiangmai et al., 2016; Manopak et al., 2024). More broadly, these findings accord with community-based animal genetic resource research showing that farmers' breeding objectives frequently encompass adaptation, behavior, reproduction, and management requirements alongside conventional productivity traits (Köhler-Rollefson, 2003; Rege and Gibson, 2003; Gandini and Villa, 2003).

The buffaloes represented in the nineteenth-century murals of Wat Phumin, painted between 1867 and 1874 (Paknam and Kanokpongchai, 1986), add historical depth to this local recognition. Contemporary herders identify in these representations several features they associate with Nam Wa buffaloes, particularly horn shape, ear form, tail length, and backline. The murals cannot establish biological continuity or genetic ancestry. They nevertheless provide a visual record through which present-day herders situate familiar buffalo morphology within a longer history of buffalo keeping in Nan. Local identification of the Nam Wa thus draws on accumulated familiarity with animals in this landscape as well as on present-day morphological characteristics.

Seasonal mobility is equally important. Movement between *thung na* and *pang kwai* reduces dependence on purchased feed, allows animals to exploit heterogeneous forage, and returns manure to cultivated fields during the dry season. In Ban Huai Phan, this seasonal arrangement took shape through successive resettlement trajectories and the reorganisation of upland cultivation and irrigated rice farming associated with Na Laek Pa. As rice cultivation became concentrated in the lowlands, continued access to forest grazing areas allowed buffalo husbandry to remain part of the changing agrarian landscape (Lainé, 2027). Similar arguments have been made in pastoral and agro-pastoral studies, where mobility constitutes a practical response to spatial and seasonal variability (Scoones, 1995; Turner, 2011). The Nam Wa system is not pastoralism in the classic large-scale rangeland sense, but it shares this principle. Movement distributes animals across seasonally available resources while creating opportunities for herd mixing and reproduction. Household arrangements used when females require access to breeding males outside the main mating period further show that reproduction depends on relations between owners as well as on animal availability.

This becomes particularly relevant when considering breeding interventions. Introducing buffaloes from other regions may increase access to breeding males or introduce traits associated with higher productivity, but animals selected under more intensive production systems may also carry higher nutritional and management requirements than locally adapted stock. Such introductions can have consequences beyond herd genetics: they may increase dependence on purchased feed, alter household labor and breeding objectives, and reduce the practical advantages of animals able to reproduce under extensive forest-grazing conditions. For Lua households, where breeding animals circulate through seasonal herd mixing and arrangements between owners, decisions over which males enter local herds also have a social dimension. Breeding interventions therefore need to consider how introduced animals fit existing feeding regimes, mobility patterns, household resources, and locally valued traits rather than treating productivity as an interchangeable improvement (Köhler-Rollefson, 2003; Rege and Gibson, 2003; FAO, 2007).

Ritual practices add another layer to this organization. Offerings at *tu phi*, obligations associated with *pang*, and ceremonies such as *sukwaan kwai* establish recognized moments and places through which owners coordinate movement and articulate responsibilities toward buffaloes. The cautionary accounts recorded during fieldwork, in which accidents or predation followed neglected ritual obligations, give these responsibilities a narrative life beyond individual ceremonies. Such stories circulate among herders and reinforce expectations concerning conduct toward animals and grazing places. This resonates with work on common-resource governance showing that collective management often depends on locally recognized rules, obligations, and situated authority alongside formal regulation (Ostrom, 1990; Fernández-Giménez and Le Febvre, 2006). It also extends previous work from the same research program showing how ritual sites participate in shaping interspecific encounters and animal presence in Nan landscapes (Lainé et al., 2024).

Health management makes the coexistence of institutional and locally grounded forms of care particularly visible. DLD vaccination campaigns and village animal health volunteers now form part of everyday herd management, while herders continue to use plant preparations for wounds, skin problems, insects, postpartum care, snake bites, and other problems encountered when buffaloes are distant from formal veterinary services. The remedies documented here, including preparations based on *Thunbergia laurifolia*, *Mangifera sylvatica*, *Spondias pinnata*, *Chromolaena odorata*, and *Centotheca lappacea*, involve crushing, boiling, or direct topical application and may coexist with commercial veterinary medicines. This combination accords with ethnoveterinary research showing that local therapeutic knowledge can form part of plural and situational repertoires of animal care rather than operating separately from veterinary medicine (McCorkle, 1986; Mathias, 2007).

The companion study from Ban Huai Phan provides a wider ecological context for these practices. It documented 59 plant species consumed by buffaloes, 20 of which also occurred in the Lua household medicinal repertoire, while all plants recorded in ethnoveterinary preparations were represented in the buffalo plant database (Lainé et al., 2026). These convergences do not establish intentional animal self-medication or a direct transfer of medicinal knowledge from buffaloes to humans. They point instead

to repeated observation of animal feeding, familiarity with plants, and long-term cohabitation in shared environments as part of the practical context in which herders interpret plant properties and adjust animal care. The specific remedies reported here make this relationship more concrete: useful plants are encountered within landscapes through which people and buffaloes repeatedly move. Herders also learn about these landscapes by following buffalo movements, observing their feeding preferences, recurring routes, use of water and mineral-rich sites, and changes in body condition (Lainé and Janyasuthiwong, 2026).

The conservation implications are therefore practical. This study does not evaluate genetic diversity, demographic viability, or productivity and cannot determine the relative effectiveness of genetic or production-based conservation measures. It does, however, identify socioecological conditions that such measures would need to engage with. Dedicated population counts, pedigree reconstruction, genetic diversity studies, and productivity measurements would be valuable next steps, particularly given locally expressed concerns about herd isolation and breeding-male scarcity. Breeding-male circulation cannot be understood as a technical matter alone when mating occurs through seasonal herd mixing and household arrangements, just as maintaining animals cannot be separated from access to *pang kwai*, low-input feeding, farmer selection, and collective coordination. *In situ* conservation of the Nam Wa buffalo would therefore benefit from bringing genetic and demographic assessment together with the farming system through which herders continue to maintain the landrace (FAO, 2007).

Conclusion

The Nam Wa buffalo illustrates how indigenous livestock conservation is inseparable from the socioecological systems in which animals are raised. Among Lua herders in Nan Province, buffalo husbandry is sustained through seasonal mobility between rice landscapes and forest grazing areas, farmer-led selection of functional traits, collective governance of grazing commons, ritual coordination, and the combination of local and institutional animal health practices.

The study does not provide a demographic, productivity, or genetic assessment of the Nam Wa buffalo. Instead, it identifies social, ecological, and practical conditions that future conservation and breeding programs would need to consider alongside such assessments. Genetic characterization, population monitoring, and productivity evaluation would provide important complementary evidence, particularly given local concerns about herd decline, isolation, and breeding-male scarcity. *In situ* approaches would also need to account for seasonal mobility, access to grazing mosaics, farmer selection criteria, low-input feeding regimes, and the local institutions through which herds are managed and reproduced.

Beyond Nan Province, the Nam Wa case shows how culturally grounded, low-input livestock systems can contribute to maintaining indigenous breeds in upland Southeast Asia. In cases such as the Nam Wa buffalo, conserving a breed also means sustaining the practices, landscapes, obligations, and forms of attention through which that breed continues to exist.

Data availability statement

The qualitative data supporting this study consist of fieldnotes, interview records, local terms, and observational materials collected in small communities where full anonymization cannot always be guaranteed. For ethical reasons, these materials are not deposited in a public repository. Anonymized excerpts and aggregated information relevant to the analysis are included in the manuscript. Further information may be made available by the corresponding author upon reasonable request and subject to ethical restrictions.

Ethics statement

Ethical approval for the animal-related research was obtained from the Kasetsart University Institutional Animal Care and Use Committee (approval no. ACKU-65-VTN-003). The ongoing 389 research programme is also authorised by the National Research Council of Thailand (NRCT) under research permit No. 0401/4817. Informed consent to participate in the study was obtained from all participants. Oral informed consent for the publication of the photograph showing identifiable participants (Figure 2) was obtained from both individuals concerned.

Author contributions

NL conceived and designed the study, coordinated the research framework, and led the writing of the manuscript. All authors contributed to the interpretation of the data, provided revisions

to the manuscript, and approved the final version for publication. Fieldwork and data collection were conducted jointly by all authors.

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Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. The authors disclose that generative AI (Paperpal) was used to support language editing, including checking overall coherence, consistency, and English grammar. All AI-assisted edits were carefully reviewed and verified by the authors, who take full responsibility for the content of the manuscript.

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