

Status, socio-ecological drivers and management implications of free-grazing livestock in Vietnam's special-use forests

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Hiện trạng, động lực xã hội, sinh thái và giải pháp quản lý hoạt động chăn thả vật nuôi tự do trong các khu rừng đặc dụng ở Việt Nam

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ABSTRACT

Livestock grazing in Vietnam's special-use forest (SUF) system is both a social and ecological issue, reflecting the dependence of buffer-zone communities on forest resources while posing a challenge to biodiversity conservation. This study, conducted across 46 SUFs representing major ecological regions, combined quantitative and qualitative approaches to assess current grazing status, socio-ecological drivers, and management implications. Results revealed that 78.3% of SUFs had livestock grazing, with an average herd size of $45,486 \pm 2,350$ animals, of which 85.7% were free-ranging. Muong Nhe Nature Reserve was identified as a hotspot with 18,305 animals. The density of forest protection staff averaged 0.9 ± 0.4 persons per 1,000 ha—below the IUCN recommendation of about 2 persons per 1,000 ha—indicating limited human resources and management capacity. Regression analysis showed a strong correlation between herd size and the number of conservation violations ($r = 0.985$; $R^2 = 0.97$; $p < 0.01$), confirming herd size as a reliable indicator of ecological pressure. Qualitative analysis identified five key drivers: land scarcity, traditional practices, livelihood dependence, inadequate budgets, and weak coordination. The study proposes four management strategies: (i) strengthening institutional capacity and ecological monitoring technology; (ii) promoting co-management mechanisms; (iii) spatial planning for controlled grazing and alternative livelihoods; and (iv) integrating a One Health approach into conservation policies. The findings provide national-level empirical evidence on the socio-ecological mechanisms of livestock grazing, supporting adaptive management and sustainable development in buffer-zone communities.

TÓM TẮT

Hoạt động chăn thả vật nuôi trong hệ thống rừng đặc dụng (RĐD) của Việt Nam là vấn đề xã hội và sinh thái, phản ánh sự phụ thuộc sinh kế của cộng đồng vùng đệm vào tài nguyên rừng và đặt ra thách thức cho bảo tồn. Nghiên cứu tại 46 khu RĐD đại diện các vùng sinh thái sử dụng kết hợp phương pháp định lượng và định tính để đánh giá hiện trạng, động lực xã hội và sinh thái và hàm ý quản lý. Kết quả cho thấy 78,3% khu có chăn thả, với quy mô đàn trung bình 45.486 ± 2.350 cá thể, trong đó 85,7% là chăn thả rông. Khu Dự trữ Thiên nhiên (DTTN) Mường Nhé là điểm nóng với 18.305 cá thể. Mật độ lực lượng bảo vệ rừng

(LLBVR) đạt $0,9 \pm 0,4$ người/1.000 ha, thấp hơn khuyến nghị của IUCN (khoảng 2 người/1000ha), cho thấy sự thiếu hụt nguồn nhân lực và hạn chế trong năng lực tổ chức quản lý tại các khu RDD. Phân tích hồi quy cho thấy mối tương quan mạnh giữa quy mô đàn và số vụ vi phạm ($r = 0,985$; $R^2 = 0,97$; $p < 0,01$), chứng minh quy mô đàn là chỉ báo đáng tin cậy của áp lực sinh thái. Phân tích định tính xác định năm động lực chính: thiếu đất, tập quán truyền thống, phụ thuộc sinh kế, thiếu ngân sách và phối hợp yếu. Nghiên cứu đề xuất bốn nhóm giải pháp: (i) tăng cường năng lực và công nghệ giám sát; (ii) thúc đẩy đồng quản lý; (iii) quy hoạch vùng chăn thả và sinh kế thay thế; (iv) lồng ghép tiếp cận One Health trong bảo tồn. Kết quả cung cấp bằng chứng thực nghiệm cấp quốc gia về cơ chế xã hội và sinh thái của chăn thả, làm cơ sở cho chính sách quản lý thích ứng và phát triển bền vững vùng đệm.

1. INTRODUCTION

Free-ranging livestock grazing within and around Special-Use Forests (SUFs) is a persistent challenge to biodiversity conservation and sustainable forest management in Vietnam. SUFs, which include national parks and nature reserves, play a vital role in maintaining ecosystems, genetic resources, and ecological services. Yet, recent assessments revealed that livestock grazing occurs in over two-thirds of SUF management units, with tens of thousands of buffaloes, cattle, and goats encroaching into ecological restoration and even core zones [1]. The lack of planned grazing areas in buffer zones recorded in 58% of surveyed sites forces local communities, particularly in mountainous and ethnic minority regions, to rely on forest resources for animal husbandry.

Globally, uncontrolled grazing has been shown to drive major ecological change. In China, Li et al. (2023) [2] reported that livestock altered the spatial behavior of the endangered snow leopard (*Panthera uncia*), highlighting competition between wild and domestic ungulates. Pudiyatmoko (2017) [3] found that cattle grazing in Indonesia's Baluran National Park reduced mammalian species richness and disrupted activity patterns, while Salvatori et al., (2022) [4] showed that free-ranging livestock intensified interspecific competition among mammals. In Northeast Asia, Hu et al. (2024) [5] demonstrated that cattle and wild ungulates exert contrasting effects on litter decomposition and nutrient cycling, underscoring species-specific ecological roles.

In Vietnam, similar patterns have been

observed. Free-ranging livestock in SUFs such as Muong Nhe, Pu Luong, and Than Sa-Phuong Hoang have caused understory loss, soil compaction, and erosion, degrading habitats for small mammals, birds, and amphibians [1]. In the Central Highlands, Vu Anh Tai et al. (2023) [6] reported that overgrazing has reduced forage biomass and the nutritional quality of native grasslands, threatening both livestock productivity and vegetation recovery. These findings emphasize that ecological degradation is reinforced by livelihood dependence, land scarcity, and weak enforcement capacity.

Although Decree No. 156/2018/NĐ-CP prohibits grazing in strictly protected zones, enforcement remains weak due to limited human and financial resources [7]. The IUCN (2025) [8], under its *Nature for Health (N4H)* initiative, has recognized livestock grazing as a priority within the One Health framework, given the risk of disease transmission between wildlife and domestic animals. This illustrates the interconnectedness of ecological, health, and livelihood dimensions in grazing management.

Socio-economically, free-ranging livestock represents both an economic necessity and a cultural tradition. Maina and Nzengya (2022) [9] found that in Kenya, poorer households near forests depend more on protected areas for grazing, a trend mirrored in Vietnam's upland regions. However, integrated solutions have shown promise. Co-management and Payment for Forest Environmental Services (PFES) programs have reduced grazing pressures and fostered conservation-

compatible livelihoods [1]. In Nepal, Lama et al. (2020) [10] reported that buffer-zone zoning and controlled grazing improved ecosystem health and reduced conflict.

Despite progress, research on the socio-ecological mechanisms driving livestock grazing in Vietnam remains limited. Most studies are descriptive, lacking quantitative analysis of the links between ecological impacts, livelihood drivers, and institutional responses. Therefore, this study aims to: (1) assess the current status and spatial distribution of livestock grazing within Vietnam's SUF system; (2) analyze socio-economic and institutional factors influencing free-ranging livestock; (3) quantify the relationship between herd size and conservation pressure; and (4) propose management implications to align biodiversity conservation with sustainable livelihoods.

2. RESEARCH METHODS

2.1. Study scope

This study was conducted across 46 special-use forests (SUFs) representing Vietnam's eight forest ecological zones: Northwest, Northeast, Red River Delta, North Central, South Central, Central Highlands, Southeast, and Mekong Delta. The classification follows Circular No. 22/2021/TT-BNNPTNT issued by the Ministry of Agriculture and Rural Development (MARD, 2021). SUFs were selected based on three main criteria: (i) evidence of livestock grazing within the forest; (ii) a complete management structure with active forest protection forces (FPFs); and (iii) availability of sufficient periodic reports or secondary data. Each SUF was treated as an independent sample unit, representing the natural, socio-economic, and management conditions of each ecological region.

2.2. Data collection

Two main data sources were used: secondary and primary data, collected simultaneously to ensure accuracy and cross-validation.

(i) *Secondary data*: obtained from 2022–2024 reports of SUF Management Boards, Provincial Forest Protection Departments, the

Vietnam Administration of Forestry, and the Forest Protection Department. Indicators included: livestock herd size (buffaloes, cattle, goats, horses, pigs) in buffer zones; total forest area (ha); FPF density (staff per 1,000 ha); average patrol frequency (trips/month); number of grazing-related violations; and the extent of technology adoption (e.g., UAVs, SMART software, camera traps). These data provided an objective basis for assessing grazing intensity and management capacity across sites.

(ii) *Primary data*: collected via structured questionnaires sent to 174 SUF Management Boards nationwide (by official correspondence and email). A total of 46 valid responses were received, corresponding to the 46 SUFs analyzed. The questionnaire contained four sections: (1) general information on the management unit and herd size; (2) grazing form and spatial extent; (3) socio-economic and cultural factors influencing grazing; and (4) environmental impacts and compliance assessment. Both closed- and open-ended questions were used, employing a five-point Likert scale (1 = very low, 5 = very high) to obtain both quantitative and qualitative insights.

Case study: To better understand local context, an in-depth case study was carried out at Muong Nhe Nature Reserve (Dien Bien Province)—identified as a national grazing hotspot. Ten semi-structured interviews were conducted with management staff and 56 household interviews across five buffer-zone communes (Muong Nhe, Leng Su Sin, Chung Chai, Sin Thau, Nam Ke). Field observations were also undertaken at grazing sites to record vegetation, soil, water, and landscape impacts, with photographic documentation and GPS-based evidence.

2.3. Data analysis

Data were processed using SPSS, Excel, and QGIS software.

Quantitative analysis: conducted in three steps: (1) descriptive statistics to determine grazing occurrence, herd structure, FPF density, patrol frequency, and technology

adoption; (2) classification of management capacity by FPF density: high (≥ 2 persons/1,000 ha), medium (1.0–1.9), and low (< 1.0); (3) correlation and linear regression between herd size (X) and number of conservation violations (Y) using the model $Y = a + bX$, evaluated by R^2 and statistical significance (p-value).

Qualitative analysis: performed using thematic coding of open-ended responses and interview data. Information was grouped into five categories of underlying causes: lack of grazing land, traditional cultural practices, livelihood dependence, limited management budget, and weak institutional coordination. Each factor was rated on a five-point Likert scale and quantified by respondents' selection frequency, revealing the key socio-economic drivers of grazing behavior.

Spatial analysis: spatial data of 46 SUFs were standardized to the VN-2000 coordinate system and processed using QGIS 3.34. This enabled mapping of grazing distribution and violation hotspots, overlaid with buffer-zone

boundaries and management indicators. The results identified the spatial extent, intensity, and patterns of grazing activity, supporting spatially adaptive management recommendations.

3. RESULTS

3.1. Livestock scale and composition

Analysis of data from 46 SUFs nationwide shows that livestock grazing is widespread and systematic. Among 46 valid responses, 36 SUFs (78.3%) confirmed the presence of grazing at varying intensities. The total livestock population was $45,486 \pm 2,350$ animals (SD), comprising buffaloes (49.9%, $22,739 \pm 1,180$), cattle (29.0%, $13,216 \pm 960$), goats (4.0%, $1,831 \pm 220$), horses (0.3%, 149 ± 30), and others (pigs, poultry, honeybee colonies) (16.6%, $7,551 \pm 640$) (Figures 1 and 2). This structure reflects the strong linkage between traditional agricultural livelihoods and forest resources, especially among upland ethnic minority communities.

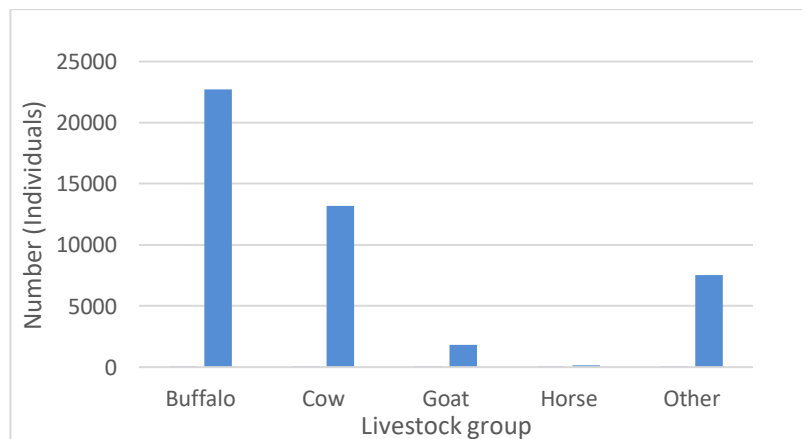


Figure 1. Livestock herd size in 36 special-use forests in Vietnam.

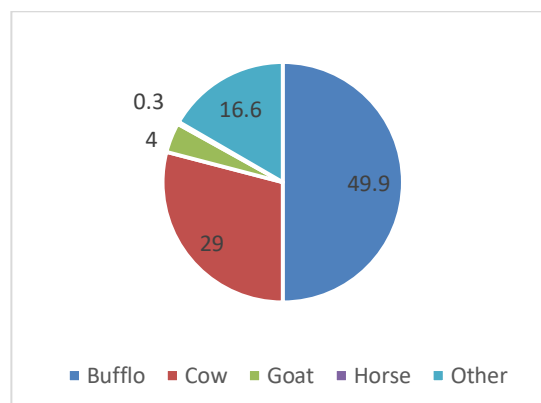


Figure 2. Livestock composition in 36 special-use forests in Vietnam.

3.2. Distribution and grazing forms

Livestock grazing in Vietnam's SUF system shows clear variation across ecological regions (Figure 3). Nationally, 86% of SUFs practiced free-ranging grazing, 14% adopted semi-grazing or penning, and only 41% had designated grazing zones. Mountainous regions such as the Northwest (100%), North Central (89%), and Central Highlands (88%) had the highest rates of free-ranging livestock, due to large forest areas and traditional cultural dependence on pastoral livelihoods. Conversely, deltaic and coastal regions such as the Red River Delta (70%) and Southeast (70%) showed a shift toward semi-grazing systems, reflecting improved management and control.

The proportion of planned grazing zones

differed notably by region. The Mekong Delta (70%) and Southeast (60%) had the highest levels of grazing-area planning, supported by integrated land-use and buffer-zone management. In contrast, the Northwest and Northeast achieved only around 25%, indicating limited resources and weak governance mechanisms. These findings confirm that free-ranging livestock remains dominant in SUFs, though a gradual transition toward controlled grazing is emerging, particularly in more developed regions. This trend reflects growing efforts to reduce ecological pressure and promote sustainable management that integrates conservation and community livelihoods.

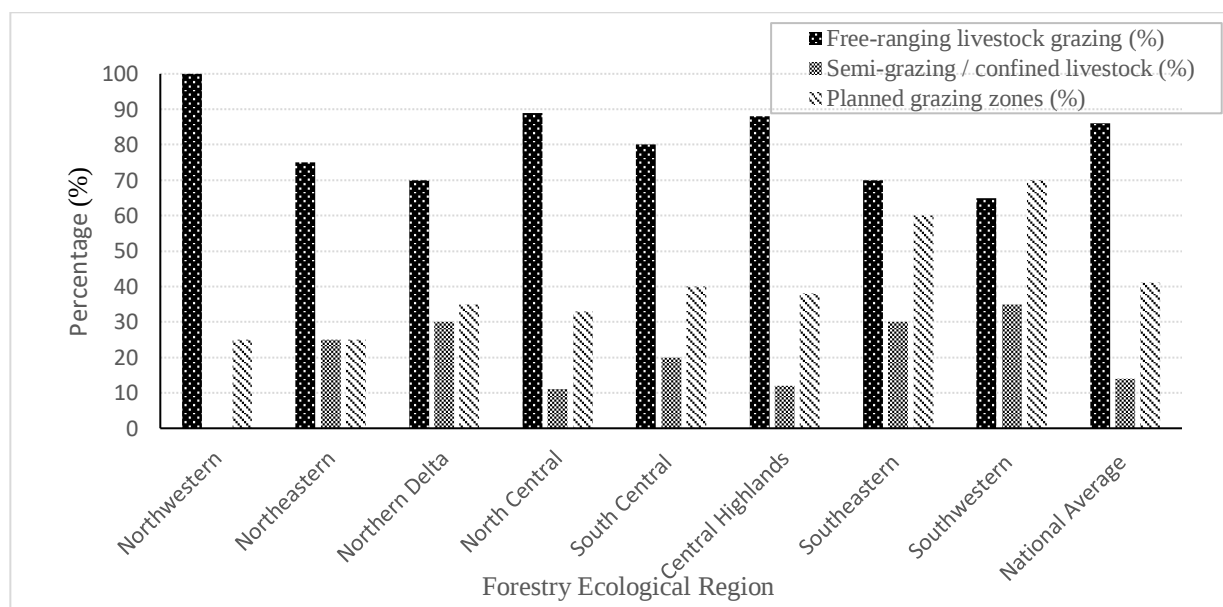


Figure 3. Grazing practices and planning status by ecological region

3.3. Management capacity for livestock grazing

Among the 46 SUFs, 39 (84.8%) provided data on forest protection force (FPF) density, averaging 0.9 ± 0.4 persons per 1,000 ha (SD; 95% CI: 0.7–1.1), lower than the IUCN recommendation of about 2 persons per 1,000 ha. Capacity classification showed 14 sites (35.9%) with high density (≥ 2.0), 13 sites (33.3%) with medium capacity (1.0–1.9), and 12 sites (30.8%) with low capacity (< 1.0). All 46 SUFs reported organized patrols, though

mostly using manual methods; only a small portion applied SMART, UAVs, or camera traps.

Only three sites provided detailed data on patrol frequency (45–660 patrols/year; mean 280 ± 120) and staff participation (2–2,100 person-times/year). Additionally, 36 out of 46 SUFs (78.3%) detected grazing violations, 15 (32.6%) had physical fencing, and 32 (69.6%) had coordination regulations with local authorities. However, only 8 of the 36 sites (22.2%) implemented administrative or financial penalties for violations.

Table 1. Management capacity indicators related to livestock grazing in Vietnam's SUF system (n = 46)

Indicator	Value/Proportion	Sample (n)
Average FPF density (persons/1,000 ha)	0.9 ± 0.4	39
High FPF density (≥2.0)	35.9% (14/39)	39
Medium FPF density (1.0–1.9)	33.3% (13/39)	39
Low FPF density (<1.0)	30.8% (12/39)	39
Organized patrols	100% (46/46)	46
SMART/UAV/Camera trap adoption	Minor proportion	46
Detected grazing violations	78.3% (36/46)	46
Fencing installed	32.6% (15/46)	46
Coordination with local authorities	69.6% (32/46)	46
Violation handling	22.2% (8/36)	36

In summary, the average FPF density (0.9 ± 0.4 per 1,000 ha) was well below the IUCN standard of 3–5 persons per 1,000 ha. While all SUFs conducted patrols, most relied on traditional methods, and only a few integrated technologies such as SMART, UAVs, or camera traps. Three sites reported detailed patrol frequency (45–660 times/year; mean 280 ± 120) and workforce (2–2,100 participants/year). Moreover, 78.3% recorded grazing violations, 32.6% had fencing, and 69.6% maintained coordination with local authorities. Among those detecting violations, only 22.2% imposed administrative or financial sanctions.

3.4. Socio-economic drivers of free-ranging livestock grazing – case study at Muong Nhe Nature Reserve

Survey results at Muong Nhe Nature Reserve (n = 66) identified three main driver groups influencing free-ranging livestock grazing: (i) economic–land, (ii) cultural–social,

and (iii) institutional–management. Among these, economic and land-related factors were the most dominant: 86.3% of households lacked grazing land, and 68.1% relied on free-ranging livestock as their primary livelihood. Free migration was reported in 30% of households, contributing to increasing pressure on forest resources. The cultural–social group maintained traditional grazing practices, with 77.3% of respondents viewing free-ranging as a low-cost and stable method. Institutional and management factors were identified as major constraints: 90% of respondents stated that forest protection forces were understaffed and unable to cover large areas; 80% considered existing management policies unclear or lacking zoning regulations; and 58% indicated the absence of suitable alternative livestock models. The interaction among these drivers sustains free-ranging grazing as a stable yet difficult-to-change social practice.

Table 2. Main causes of free-ranging livestock grazing at Muong Nhe Nature Reserve (n = 66)

No.	Main cause	Percentage (%)	Influence level	Driver group
1	Lack of grazing land	86.3	High	Economic–land
2	Lack of stable income	68.1	High	Economic–livelihood
3	Traditional grazing practices	77.3	High	Cultural–social
4	Unclear management policy	80.0	High	Institutional–management
5	Limited staff, large areas	90.0	High	Institutional–management
6	Lack of alternative livestock models	58.0	Medium	Economic–technical
7	Free migration	30.0	Low	Economic–social

3.5. Ecological impacts and quantitative relationship – case study at Muong Nhe Nature Reserve

Free-ranging livestock grazing caused multiple ecological impacts. Field data from Muong Nhe Nature Reserve ($n = 66$) showed that 73.0% of respondents observed vegetation degradation, 76.9% reported water pollution, and 68.2% perceived a decline in wildlife populations, particularly ungulates. A linear regression analysis between herd size (X ,

heads) and the number of conservation violations (Y , cases/year) revealed a very strong correlation ($r = 0.985$; $R^2 = 0.97$; $p < 0.01$) (Figure 4). The regression model [$Y = 0.0011X + 0.05$] indicates that for every 1,000 additional livestock, the number of violations increased by approximately 1.1 ± 0.3 cases/year (95% CI: 0.8–1.4). This confirms herd size as a reliable quantitative indicator of human-induced ecological pressure.

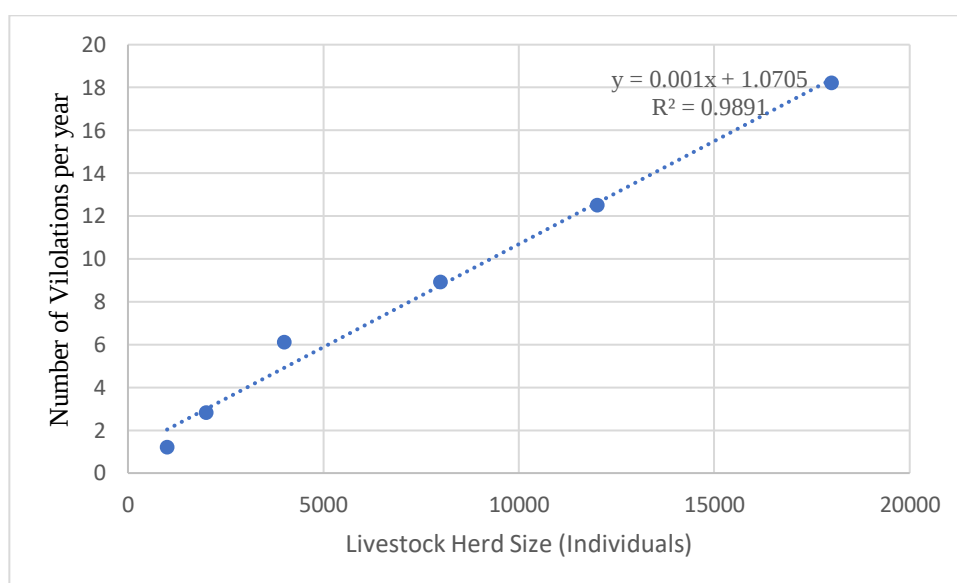


Figure 4. Correlation between herd size and number of conservation violations ($r = 0.985$; $p < 0.01$).

4. DISCUSSION

4.1. Ecological pressures and grazing impacts

Free-ranging livestock grazing represents a widespread ecological pressure across Asia's protected area network, including Vietnam's Special-Use Forest (SUF) system. Numerous studies from China, India, Nepal, Mongolia, Thailand, Myanmar, and Vietnam have demonstrated that livestock particularly cattle and buffalo cause substantial ecological alterations. These impacts include shifts in wildlife community composition, degradation of vegetation structure, and disruption of hydrological and nutrient cycles [2, 3, 5].

In Vietnam, free-ranging grazing within SUFs such as Muong Nhe, Pu Luong, and Than Sa-Phuong Hoang has resulted in the loss of understory vegetation, soil compaction, and increased erosion, thereby altering habitat quality for small mammals, birds, and amphibians [1]. These ecological pressures are further intensified

by socio-economic factors livelihood dependence on forests, the absence of planned grazing zones, and weak SUF management enforcement. The cumulative effects undermine biodiversity conservation objectives, particularly for threatened species reliant on understory cover and forest water quality.

4.2. Social and institutional drivers

Free-ranging livestock grazing is a widespread ecological pressure across the protected area networks of Asia, including Vietnam's Special-Use Forest (SUF) system. Numerous studies conducted in China, India, Nepal, Mongolia, Thailand, Myanmar, and Vietnam have shown that livestock particularly cattle and buffalo cause significant ecological alterations. These impacts include shifts in the composition of wildlife communities, degradation of vegetation structure, and disruption of hydrological and nutrient cycles [2, 3, 5, 6].

In Vietnam, free-ranging livestock grazing in SUFs such as Muong Nhe, Pu Luong, and Than Sa–Phuong Hoang has resulted in the loss of understory vegetation, soil compaction, and increased erosion, thereby altering the habitat quality for small mammals, birds, and amphibians [1, 6]. These ecological pressures are exacerbated by socio-economic factors, including livelihood dependence on forest resources, the absence of designated grazing zones, and weak enforcement of SUF management regulations. The cumulative impacts undermine biodiversity conservation goals, particularly for threatened species that depend on understory vegetation and forest water quality.

4.3. Management Implications and Policy Directions

Sustainable control of free-ranging livestock in Special-Use Forests (SUFs) requires an integrated socio-ecological approach that unites ecological management, socio-economic solutions, and institutional reform.

(i) Strengthening law enforcement and ecological monitoring. Livestock grazing continues to degrade habitats and threaten wildlife populations in several countries [10, 11, 12]. Violations often cluster near forest boundaries and during favorable grazing seasons [9, 13]. Vietnam should therefore adopt spatially and seasonally targeted enforcement, apply stricter penalties under *Decree No. 156/2018/NĐ-CP* [7], and utilize technologies such as SMART, UAVs, and camera traps for real-time monitoring and adaptive management [14].

(ii) Zoning and co-management frameworks. Functional zoning—strict protection in core areas and conditional management in buffer zones—can reduce grazing pressure while maintaining livelihoods. In the Yellow River Source Region, a core–buffer model decreased livestock density and enhanced vegetation productivity [14]. Co-management among rangers, local authorities, and communities improves compliance and reduces conservation–livelihood conflicts [1, 15]. Moreover, establishing grazing quotas based

on ecosystem tolerance aligns with the intermediate disturbance hypothesis and promotes biodiversity [16].

(iii) Diversifying livelihoods and incentive mechanisms. Poverty and land scarcity remain key drivers of forest encroachment [9]. Sustainable change requires livelihood alternatives such as forage cultivation, semi-intensive husbandry, and conservation-based ecotourism. Integrating these into co-management agreements ensures accountability and transparent benefit-sharing [15] (Parr et al., 2013).

(iv) Adaptive governance and multi-sectoral linkages. Establishing livestock-free zones should occur within adaptive frameworks that include clear ecological targets, livelihood safeguards, and participatory monitoring. Cross-sectoral programs such as *Nature for Health (N4H)* demonstrate the value of integrating conservation, health, and development agendas to strengthen field-level capacity [8].

Overall, sustainable livestock management in SUFs demands concurrent progress in ecological protection, participatory governance, and livelihood resilience within a socio-ecological and One Health framework.

5. CONCLUSION

Our nationwide assessment reveals a systemic livestock conservation interface across Vietnam's Special-Use Forests (SUFs). Beyond land-use conflicts, free-ranging livestock also creates health interfaces at shared resources such as grazing sites, streams, and watering points, underscoring the need to integrate a One Health approach into protected area governance and monitoring frameworks.

The results indicate that ecological impacts vegetation degradation, water pollution, and wildlife decline are closely linked to socio-institutional drivers including land scarcity, livelihood dependence, traditional husbandry practices, and limited management capacity. The Muong Nhe Nature Reserve exemplifies this socio-ecological coupling: large herds congregate at interface zones, violations

scale with herd size, and communities remain dependent on open-range grazing. Addressing these interconnected issues requires coordinated, cross-sectoral solutions rather than isolated interventions.

We propose a three-pillar strategy: (i) enforce spatial separation and modernize monitoring systems using SMART, UAVs, camera traps, and environmental sentinels (water, dung, parasites); (ii) promote co-management and buffer-zone fodder production systems to reduce forest dependency; and (iii) institutionalize One Health practices such as vaccination, deworming, biosecurity, and coordinated ranger veterinary reporting. Implemented together, these measures can reconcile biodiversity conservation with rural livelihoods and strengthen the resilience of SUFs as adaptive socio-ecological systems.

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