

# Forage Preferences and Nutritional Ecology of Timor Deer: Implications for Conservation Management

Rezki Amalyadi\*

University of Mataram, Faculty of Animal Science, Department of Animal Science, Indonesia

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The Timor deer (*Cervus timorensis*) represents one of Indonesia's key wildlife species, valued for its ecological roles, cultural heritage, and economic potential. This review compiles evidence from 50 scientific studies that examine its biology and ecology, with particular attention to forage resources as a determinant of health, reproduction, and population dynamics. The species shows selective feeding patterns, generally favoring protein-rich, low-fiber plants, and demonstrates a preference for cultivated forages such as *Pennisetum purpureum* compared to wild vegetation. Nutritional quality is shaped by forage diversity, seasonal fluctuations, and environmental conditions including rainfall, temperature, and altitude. Adequate feed supply enhances body condition, antler development, and reproductive success, whereas nutritional deficits compromise immunity and survival. Conservation-oriented interventions highlight the value of locally available forage, context-specific supplemental feeding, and feed preservation methods like silage production to reduce seasonal shortages. Addressing the combined challenges of selective browsing, habitat variability, and dietary specialization is critical. Integrated management strategies not only improve resilience against ecological pressures but also contribute to sustaining viable populations in the long term. Overall, strengthening forage-based management emerges as a central pathway for securing the conservation future of *Cervus timorensis*.

**Keywords:** conservation management, forage preference, nutritional ecology, *Cervus timorensis*, silage technology

## 1 Introduction

The Timor deer (*Cervus timorensis*) is a keystone species with considerable ecological, cultural, and economic value. Its role in shaping habitat structure and sustaining local biodiversity underscores the need for effective conservation measures (Gilpin, 2018; Turner, 2023). Central to this effort is the availability and quality of forage, which directly determine the species' health, reproduction, and long-term viability. Previous studies highlight that *R. timorensis* exhibits selective feeding behavior, preferring forage rich in crude protein and low in lignin and tannins – traits essential for growth and reproductive success (Ginantra et al., 2018; Pazla & Sriagtula, 2021). Innovative forage-based solutions, such as the integration of legumes like *Leucaena*, have been proposed to mitigate feed scarcity during dry seasons, with positive implications not only for deer survival but also for broader ecosystem stability (Ngongo et al., 2021).

Despite these insights, comprehensive evaluations linking forage characteristics, deer nutritional status, and conservation outcomes remain limited. Addressing this gap, the objectives of this review are to:

- examine the current population trends and threats facing *R. timorensis*;
- assess the role of local forage in supporting its nutritional needs, emphasizing preferred species and their nutrient profiles;
- formulate conservation strategies that integrate sustainable forage management with broader ecological goals.

By bridging ecological functions with forage-based interventions, this review aims to advance evidence-based strategies that strengthen both species resilience and ecosystem sustainability.

\***Corresponding Author:** Rezki Amalyadi, University of Mataram, Faculty of Animal Science, Department of Animal Science, Majapahit Street No. 62, Dasan Agung, Selaparang, Mataram City, West Nusa Tenggara, 83125, Indonesia, e-mail: [rezkiamalyadi@staff.unram.ac.id](mailto:rezkiamalyadi@staff.unram.ac.id) ORCID: <https://orcid.org/0009-0008-6595-3562>

## 2 Material and Methods

This systematic review analyzed the forage preferences of Timor deer (*Cervus timorensis*) in their native habitats and the implications for nutritional management and conservation planning. A structured literature search was performed in the Scopus database, chosen for its comprehensive coverage of peer-reviewed studies in zoology, ecology, and agricultural sciences. The search employed a Boolean strategy combining the terms: “*Cervus timorensis*” AND (“forage” OR “feeding preference” OR “diet” OR “nutrition”) AND “conservation management.” To ensure both foundational and recent findings were captured, the scope was limited to English-language articles published between 2004 and 2025.

The retrieved 182 records were imported into Mendeley Reference Manager. After removing duplicates, 137 unique studies remained. Screening was conducted in multiple stages: title screening to remove irrelevant

taxa, abstract screening to exclude non-nutritional or behavioral studies, and full-text screening to eliminate articles lacking quantitative data or methodological transparency. Additional exclusions applied to papers without access to full text, review articles without new data, and conference proceedings of insufficient detail. After this process, 72 studies remained for in-depth evaluation.

A quality appraisal was applied to the full texts, assessing sampling design, clarity of forage identification, reliability of nutrient analyses, and the presence of conservation-relevant discussion. Based on these criteria, 50 studies met the inclusion standards and were retained for synthesis. Data were extracted on:

- forage species composition,
- seasonal variation in diets,
- nutritional content (e.g., protein, fiber, and mineral profiles),
- ecological factors influencing forage availability.

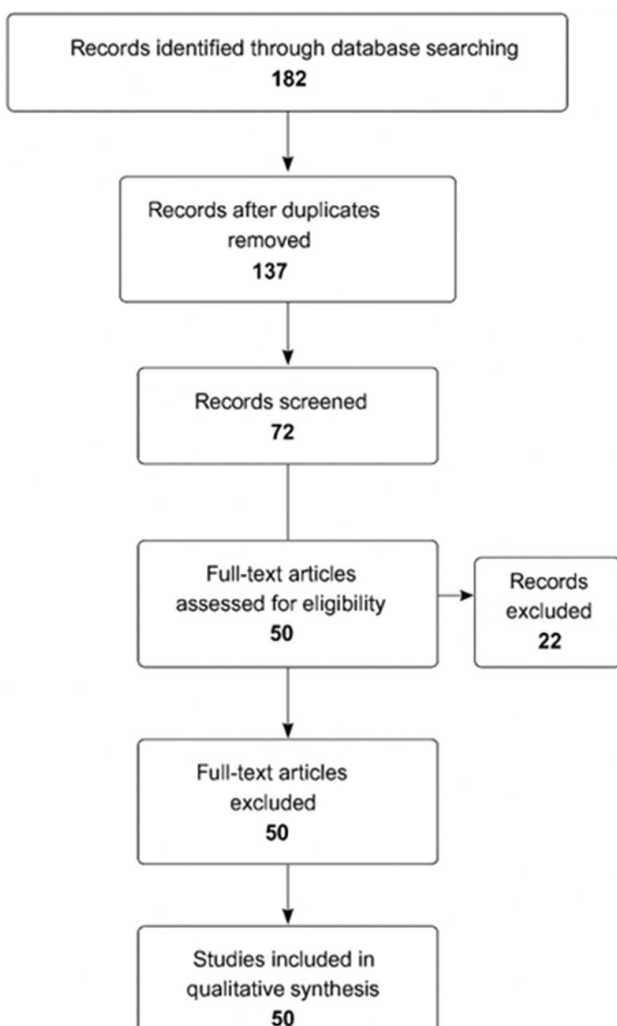
The review followed PRISMA guidelines, with both a flow diagram and PRISMA checklist applied to enhance methodological rigor, transparency, and reproducibility.

## 3 Results and Discussion

### 3.1 Biological and Ecological Characteristics of the Timor Deer

The Timor deer (*Cervus timorensis*) is a deer species native to Indonesia, with its original distribution limited to Java and Bali (Fauzi & Soetanto, 2020; Kedang et al., 2022; Rahman et al., 2020). Over time, it has been translocated to other parts of Indonesia as well as to several countries abroad. The potential natural range in Java and Bali is estimated at 3,784.43 km<sup>2</sup>, while introduced populations now occupy approximately 36,352.61 km<sup>2</sup>, particularly in protected areas stretching from West Nusa Tenggara to Papua (Rahman et al., 2020). This species inhabits diverse ecosystems, including savannas, monsoon forests (Ginantra et al., 2018), and lowland coastal forests that provide suitable shelter and forage resources (Pattiselanno & Koibur, 2018).

In terms of diet, *R. timorensis* demonstrates selective feeding behavior, utilizing at least 32 plant species consisting of graminoids, forbs, and woody plants (Ginantra et al., 2018). Forage selection is largely driven by availability and nutrient composition, with a preference for plants high in crude protein and low in lignin and tannins. In captive conditions, they favor mixed grasses such as *Pennisetum purpureum*, *Commelina benghalensis*, *Hierochloe horsfieldii*, and *Sorghum caudatum* (Sudibyoto et al., 2013). Physiological adaptations further support their ability to subsist on forage-based diets, especially



**Figure 1** A PRISMA flow diagram outlining the systematic review of Timor deer forage preferences is presented here

**Table 1** Overview of *Cervus timorensis* taxonomy and ecology

Aspect	Details
Taxonomy	<i>Cervus timorensis</i> (formerly <i>Cervus timorensis</i> )
Geographic distribution	native to Java and Bali, but has been introduced to other regions and countries (Fawzy et al., 2019; Rahman et al., 2020).
Natural habitat	habitats: savannas, monsoon forests, and lowland coastal forests (Ginantra et al., 2018; Pattiselanno & Koibur, 2018)
Feeding behavior	they selectively feed on 32 plant species and prefer high-protein plants
Physiological adaptations	they have adapted to forage-based diets and produce high-quality velvet antler (Ginantra et al., 2018; Sudibyo et al., 2013).

This synthesis offers a thorough overview of the Timor deer's biological and ecological characteristics, including its taxonomy, geographic distribution, natural habitat, feeding behavior, and physiological adaptations

by selecting species with optimal nutritional profiles essential for maintaining body condition and antler growth (Ginantra et al., 2018; Sudibyo et al., 2013). Dietary quality strongly influences the production of velvet antlers; older and heavier males tend to yield antlers of higher quality, rich in amino acids such as aspartic acid, glutamic acid, and proline (Sudibyo et al., 2013).

### 3.2 Diversity of Local Forage Species with Feeding Potential

In Wosu Village, Central Sulawesi, where Timor deer represent an introduced population, grazing fields were reported to be dominated by grasses (83%), particularly *Imperata cylindrica* and *Cyperus rotundus*, while the remaining 17% consisted of various weed species (Arifuddin & Toknok, 2020). On Menjangan Island in Bali – part of the species' native range – observations documented the consumption of 32 plant species, including graminoids, forbs, and woody plants (Ginantra et al., 2018). Likewise, an assessment conducted in East Java, another native distribution area, identified several

grass species suitable for sustaining captive populations of *Rusa timorensis* (Subeno et al., 2023). Taken together, these findings indicate that feeding ecology has been documented in both native (Java and Bali) and introduced (Central Sulawesi) contexts. However, the geographic origin of the population may function as an ecological moderator, potentially influencing forage selection patterns due to differences in habitat composition, plant availability, and adaptive responses. Therefore, interpretation of feeding potential should explicitly distinguish between native and introduced populations to avoid overgeneralization of dietary preferences across contrasting biogeographical settings.

For comparison, studies on other herbivores and forage systems provide contextual insights. In Taman Hutan Raya Abdul Latief (Abdul Latief Forest Park) in Sulawesi, Indonesia, six forage plant species were recorded as part of the diet of anoa (*Bubalus* spp.), including *Ficus racemosa* and *Elatostema integrifolium* (Aziz et al., 2023). Research from different regions also illustrates the nutritional variability of forage: *Calliandra calothyrsus* in West

**Table 2** Overview of Forage Resources, Biogeographic Status, and Environmental Drivers

Aspect	Key findings
Native and introduced distribution	native to Java and Bali; introduced to several regions including Central Sulawesi and other countries; ecological conditions may influence forage selection patterns between native and introduced populations
Local forage inventory (native range – Bali & Java)	Bali (Menjangan Island): 32 plant species consumed (graminoids, forbs, woody plants); East Java: various grass species suitable for captive populations
Local forage inventory (introduced range)	Central Sulawesi: grazing dominated by grasses (~83%), particularly <i>Imperata cylindrica</i> and <i>Cyperus rotundus</i>
Nutritional composition	crude protein: 60–202 g/kg DM; fiber: 132.5–354.8 g/kg DM; key minerals: Ca, Mg, K; nutrient variability reflects plant type and season
Seasonal availability	peak biomass generally occurs in mid-August; highest forage availability often observed post-burn in June in savanna-type systems
Environmental Drivers	forage growth and selection are influenced by rainfall, temperature, altitude, and disturbance regimes (e.g., fire), which differ between Bali's native habitats and introduced landscapes

These findings offer a thorough overview of the diversity, nutritional content, and seasonal growth patterns of local forage species that can be used for feeding in various captive and natural environments

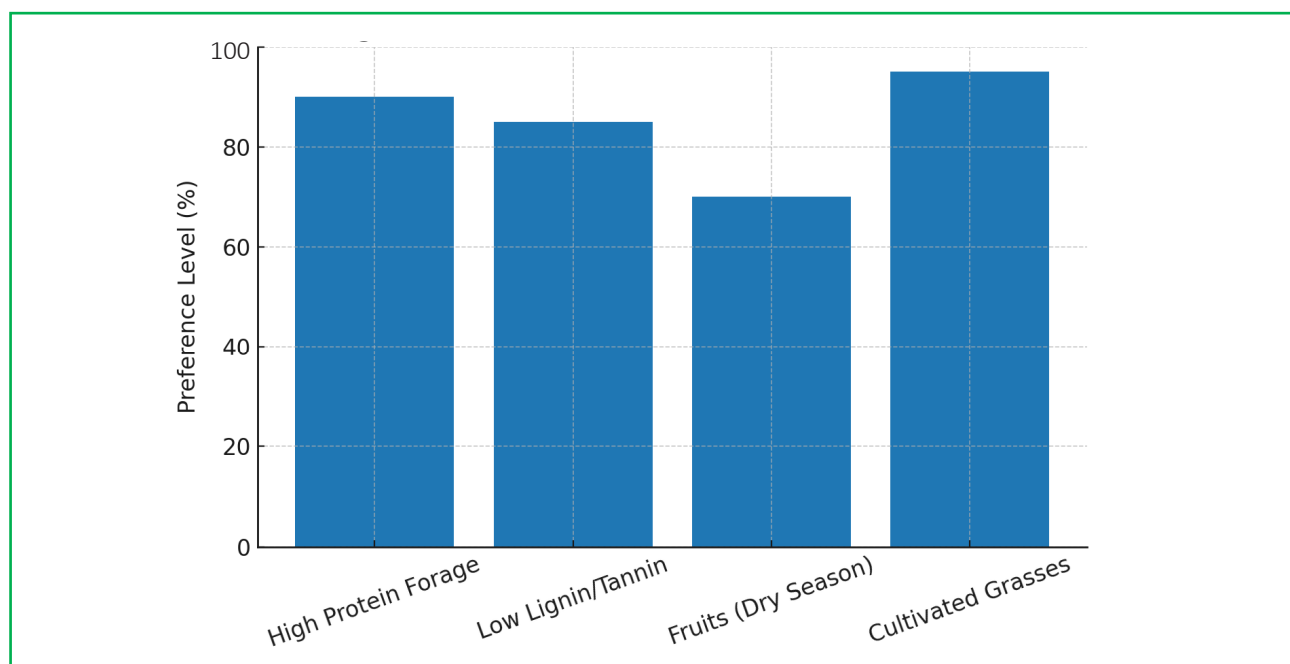
Sumatra showed high crude protein among 12 tested forages (Pazla & Sriagtula, 2021), *Leymus chinensis* in Inner Mongolia demonstrated seasonal protein fluctuations (Boloneva et al., 2021), and irrigated *Panicum maximum* in Brazil's Cerrado maintained growth during the dry season (Sousa et al., 2022). Such comparative findings underline that forage quality and availability are strongly shaped by species traits, environmental conditions, and management practices factors also critical to sustaining viable *R. timorensis* populations.

### 3.3 The Forage Preference and Feeding Behavior of Timor Deer

The Timor deer (*Cervus timorensis*) demonstrates distinct feeding preferences shaped by both seasonal conditions and forage quality. Field observations confirm that the species selectively consumes plants that are nutritionally advantageous and readily available. On Menjangan Island, for example, deer utilized 32 species comprising graminoids, forbs, and woody plants, with selection strongly influenced by local availability (Ginantra et al., 2018). Seasonal shifts are also evident: diets are dominated by *Cynodon dactylon* during the rainy season, whereas fruit intake increases substantially in the dry season (Takatsuki et al., 2023). Nutrient composition plays a central role, as deer consistently prefer plants with high crude protein and lower lignin and tannin levels (Ginantra et al., 2018), a pattern consistent with broader cervid studies where protein correlates positively with palatability (Dostaler et al., 2011). Physical traits of plants,

such as water regain capacity and solubility, further contribute to forage selection (Ginantra et al., 2018). To better illustrate these dynamics, Table 3 summarizes the comparative evidence on seasonal versus cultivated forage preferences of *R. timorensis*.

As this study was conducted as a review article, no primary field observations or laboratory analyses were performed. Data on forage preference and nutritional quality were synthesized from previously published peer-reviewed studies conducted in both native (Java and Bali) and introduced habitats. Reported dietary composition, feeding frequency, and selection indices were extracted and standardized where possible to enable comparative interpretation, and the preference levels presented in Figure 2 reflect a quantitative synthesis of these secondary data rather than direct behavioral measurements. Likewise, nutritional parameters such as crude protein, fiber fractions (e.g., NDF, ADF), and mineral content were compiled from laboratory-based analyses reported in the original studies and expressed in consistent units (g/kg dry matter) to ensure comparability. Thus, both forage preference and nutritional quality in this manuscript are quantitatively grounded but derived entirely from secondary data sources. A comparison of wild and cultivated forage species reveals that Timor deer exhibit divergent preferences. In controlled feeding experiments, Timor deer demonstrated a marked preference for a combination of grasses, including *Pennisetum purpureum* and *Sorghum caudatum*, which are frequently cultivated (Sudibyo et al., 2013). This



**Figure 2** The forage preferences of Timor deer (*Cervus timorensis*) are based on the nutritional quality and seasonal availability of the forage

**Table 3** Forage preferences of Timor deer (*Cervus timorensis*) across different contexts

Context	Forage type/species	Seasonal or cultivated	Key findings/notes	Reference
Menjangan Island	32 spp. (graminoids, forbs, woody plants)	seasonal, natural	selection driven by local availability	Ginantra et al., 2018
Rainy season diet	<i>Cynodon dactylon</i>	seasonal, natural	dominant grass species	Takatsuki et al., 2023
Dry season diet	fruits (various species)	seasonal, natural	increased fruit intake due to limited grass	Takatsuki et al., 2023
Nutrient-based choice	high protein, low lignin/tannin plants	both contexts	improves growth & reproduction	Ginantra et al., 2018; Dostaler et al., 2011
Captive feeding	<i>Pennisetum purpureum</i> , <i>Commelina benghalensis</i> , <i>Hierochloe horsfieldii</i> , <i>Sorghum caudatum</i>	cultivated	consistently preferred in managed settings	Sudibyo et al., 2013

predilection for cultivated species may be attributable to their elevated nutrient content relative to wild species. This phenomenon has been observed in other species of deer, where cultivated plants with higher crude protein content are preferred over their wild counterparts (Dostaler et al., 2011).

The Timor deer displays a behavioral tendency towards selective feeding, which is influenced by the nutritional content and physical properties of the available forage plants. These species exhibit a marked preference for cultivated species that are higher in nutrient content. Furthermore, there is a demonstrable change in the composition of their diet with the changing seasons. A comprehensive understanding of these preferences is imperative for the effective management of their habitats and the assurance of their nutritional requirements.

### 3.4 Nutritional Implications for Health, Reproduction, and Seasonal Timing

The relationship between forage preference and reproductive timing in *Cervus timorensis* is biologically meaningful. In cervids, reproductive cycles are closely linked to seasonal resource dynamics. Periods of elevated forage quality – particularly during the rainy season when crude protein (CP), digestible energy (DE), and *in vitro* dry-matter digestibility (IVDMD) are higher – support optimal body condition, spermatogenesis, ovulation, and early gestation (Ginantra et al., 2018; Sudibyo et al., 2013). Access to high-quality forage prior to and during the breeding season enhances fat deposition and endocrine function, which are critical determinants of conception success. Comparative evidence from mule deer shows that low-DE diets reduce body mass and fat reserves, subsequently lowering pregnancy and twinning rates (Tollefson et al., 2010). Similarly, white-tailed deer and other temperate cervids demonstrate that adequate nutritional intake in late summer and early

autumn improves reproductive outcomes, whereas poor maternal nutrition before parturition reduces offspring survival (Marshal et al., 2005; López et al., 2025). Although these findings are not species-specific to *R. timorensis*, they indicate a consistent cervid pattern: reproductive performance is tightly coupled with pre-breeding nutritional status. Mineral balance further influences reproductive efficiency. Deficiencies in selenium, copper, and manganese are associated with impaired fertility and skeletal abnormalities (Flueck, 2020), while excessive intake of condensed tannins may reduce protein bioavailability and limit carrying capacity (Jones et al., 2010; Windels & Hewitt, 2011). Consequently, seasonal or cultivated forage preferences that enhance protein and mineral intake likely exert a direct positive effect on reproductive timing and success. In summary, Table 3 reflects more than ecological variation; it suggests a close functional relationship between seasonal forage availability, selective feeding behavior, and reproductive performance. Nutritional peaks during high-biomass seasons likely synchronize with energetically demanding reproductive phases, indicating a biologically integrated link between habitat productivity and population viability.

### 3.5 Conservation and Captive Management Implications Linked to Quantitative Findings

The conservation and captive management implications should be interpreted in light of the quantitative nutritional patterns identified in this review. Reported crude protein values (60–202 g/kg DM), fiber fractions (132.5–354.8 g/kg DM), and mineral profiles indicate that cultivated and early-successional forages consistently provide superior digestibility and protein availability compared with late-successional or structurally mature vegetation. This quantitative evidence directly supports the strategic inclusion of nutritionally dense local feed resources in captive systems. For example, diets

supplemented with domestically produced pulses such as peas, faba beans, and lupine beans have been shown to be economically advantageous for captive deer, improving productivity while reducing feed cost per unit of live weight gain (Proskina & Cerina, 2021). These economic outcomes are mechanistically consistent with higher dietary protein and energy density. Similarly, the documented dietary contribution of C4 plants in Père David's deer demonstrates how specific forage functional groups can significantly support nutritional maintenance (Zha et al., 2024). The economic efficiency of incorporating locally produced pulses, with measurable reductions in feed costs per kilogram of live weight gain (Proskina & Cerina, 2021), aligns with the quantitative nutritional thresholds required to sustain body condition and reproductive performance. Moreover, natural forage utilization reduces reliance on high-cost supplements while maintaining ecological functionality. For instance, grazing by wild herbivores such as red deer contributes to habitat-specific nutrient cycling, reducing the need for mechanical or livestock-based vegetation management (Riesch et al., 2022).

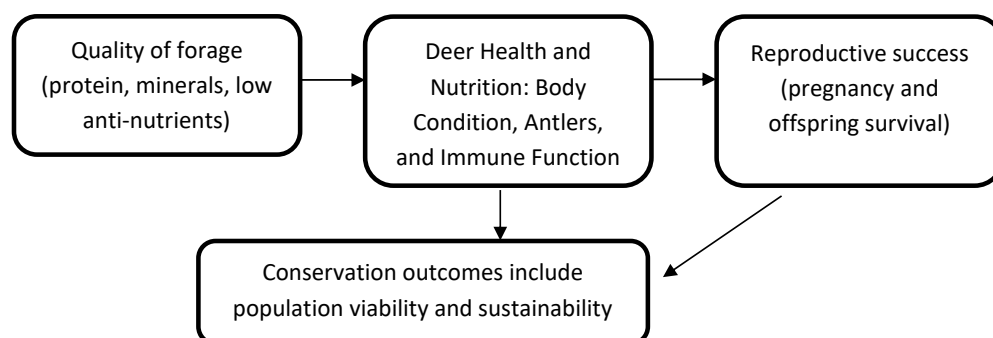
From a conservation perspective, quantitative evidence on forage quality and seasonal variability also informs ecological feeding strategies. Supplemental feeding may buffer nutritional deficits during low-biomass periods, but its implementation must consider ecosystem-level nutrient dynamics. Empirical findings indicate that artificial feeding can alter spatial distribution and potentially disrupt nutrient balance (Ossi et al., 2017; Trepel et al., 2025). In contrast, maintaining access to diverse natural forage – particularly species meeting protein and digestibility benchmarks identified in this review – supports ecological equilibrium. The availability of alternative natural forage has been shown to reduce browsing pressure in managed landscapes (Felton et al., 2022), while red deer grazing regulates nutrient dynamics in open habitats, reinforcing conservation objectives (Riesch et al., 2022). Furthermore, integrating

knowledge of forage selection trade-offs with predation risk enhances adaptive management strategies for both migratory and resident deer populations (Peterson et al., 2022). Overall, the quantitative nutritional parameters synthesized in this review provide a functional basis for management recommendations: conservation and captive feeding programs should prioritize forage types that meet documented protein, digestibility, and mineral thresholds, while maintaining seasonal ecological processes that sustain long-term population viability.

### 3.6 Challenges and Future Research Directions: Context-Specific Analysis (Wild vs. Captive Systems)

Research on forage preference in deer faces structural and methodological constraints that differ between wild and captive contexts. In free-ranging populations, browsing selectivity remains a major analytical limitation. Deer preferentially consume plant species or plant parts with higher crude protein and lower concentrations of structural fiber and anti-herbivore compounds, making ecosystem-level impact predictions complex (Månsson et al., 2007; Sample et al., 2022). This selectivity is not uniform; it varies among plant taxa and even within plant tissues, complicating biomass-based impact assessments and habitat management strategies (Renaud et al., 2003; Sample et al., 2022). Environmental variability further modifies diet composition. Drought intensity, rainfall distribution, and seasonal phenology alter forage quality – particularly crude protein concentration, fiber fractions (NDF, ADF), and digestibility – thereby limiting extrapolation across habitats (Lashley & Harper, 2012; Renaud et al., 2003; Sample et al., 2022). In wild systems, seasonal declines in digestible energy during dry periods can directly influence body condition and reproductive readiness.

In captive systems, constraints differ. Nutrient supply is controllable, but risks include reduced dietary diversity and imbalance between protein, energy, fiber, and



**Figure 3** This conceptual framework illustrates the link between forage quality, deer health, reproductive success, and Timor deer (*Cervus timorensis*) conservation outcomes

minerals. Nutrient analysis in captivity typically relies on proximate composition, fiber fraction analysis (NDF/ADF), and *in vitro* dry matter digestibility (IVDMD). Digestibility is a critical parameter because high fiber content reduces metabolizable energy availability even when crude protein appears adequate. Feeding trials demonstrate that silage and fermented forages can stabilize nutrient supply during seasonal scarcity, maintaining digestibility and intake levels (Kung Jr et al., 2018; Mahanna & Chase, 2003; Montes Pérez et al., 2015; Nurcholis et al., 2019). Fermentation optimization and mixed-forage silage formulations further enhance nutrient preservation and digestibility (Ali et al., 2023; Dawuti et al., 2024). Beyond nutritional stability, supplemental feeding reduces browsing pressure in natural habitats and influences spatial distribution, although poorly regulated supplementation may disrupt ecological nutrient dynamics (Putman & Staines, 2004; Ossi et al., 2017; Trepel et al., 2025). This synthesis underscores the adaptive feeding ecology of *Cervus timorensis*, emphasizing its significance for conservation and management.

Seasonality represents the strongest integrative factor linking nutrition, health, and reproduction. During rainy seasons, forage typically exhibits higher crude protein and lower lignification, improving digestibility and supporting fat accumulation and reproductive preparation. In contrast, dry-season forage often shows elevated fiber and reduced energy density, which may necessitate dietary shifts toward fruits or cultivated supplements to maintain energy balance. In cervids, insufficient digestible energy prior to breeding reduces body condition and pregnancy rates (Marshall et al., 2005; Tollefson et al., 2010), while mineral imbalances impair skeletal integrity and immune competence (Flueck, 2020). Conversely, excessive condensed tannins limit protein bioavailability and overall carrying capacity (Jones et al., 2010; Windels & Hewitt, 2011). Thus, seasonal forage dynamics have direct physiological implications for reproductive timing, fetal development, and offspring survival.

This synthesis reinforces the adaptive feeding ecology of *Cervus timorensis*, emphasizing the need for differentiated strategies. In wild populations, research should prioritize seasonal nutrient profiling, digestibility assessments under climate variability, and long-term monitoring of body condition indices relative to habitat productivity. In captivity, controlled feeding trials evaluating silage inclusion rates, fiber thresholds, mineral balance, and reproductive performance are essential (Ali et al., 2023; Dawuti et al., 2024). Future investigations should define reproductive nutritional thresholds, quantify seasonal digestible energy requirements, and assess long-term ecological effects of dietary

simplification. Integrating nutrient analysis, digestibility metrics, and seasonal reproductive indicators will strengthen evidence-based conservation and adaptive management of *Cervus timorensis*.

#### 4 Conclusions

The Timor deer (*Cervus timorensis*) demonstrates strong ecological adaptability through selective foraging behavior and seasonal dietary shifts, closely tied to the availability and nutritional quality of its food sources. Its preference for plants rich in crude protein and low in lignin and tannins is critical for maintaining health, reproduction, and antler growth, while deficiencies in minerals and exposure to anti-nutritional compounds can undermine physiological performance. These feeding dynamics highlight the importance of integrating local forages, legumes, and innovative approaches such as silage and fermented feeds into both wild habitat management and captive breeding programs. To translate these findings into conservation policy, supplemental feeding should be regulated to minimize ecological imbalances, while habitat management strategies must prioritize the preservation and cultivation of high-quality forage species. Future policy-oriented efforts should emphasize controlled feeding trials, long-term monitoring of forage diversity under changing climates, and the development of adaptive management frameworks that align ecological requirements with sustainable conservation objectives for *Cervus timorensis*.

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#### Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

#### Author Contributions

Rezki Amalyadi conceptualized and designed the study; performed data collection, analysis, and interpretation; drafted and critically revised the manuscript; and approved the final version for submission.

#### AI and AI-Assisted Technologies use Declaration

The author declares that no artificial intelligence (AI) or AI-assisted technologies were used in the writing, analysis, or preparation of this manuscript.

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