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# Effectiveness of grassland management practices for One-Horned Rhino (*Rhinoceros unicornis*) conservation in Chitwan National Park

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## ABSTRACT

Grasslands in Chitwan National Park (CNP), Nepal, are vital for the Greater One-horned Rhinoceros (Rhinoceros unicornis), providing essential food resources, cover, and breeding sites. This study evaluated the role of grassland management in enhancing rhino habitat quality by comparing managed and unmanaged areas. We systematically surveyed 66 vegetation plots (5 × 5 m), recording variables such as grass cover, height, crown cover, presence of invasive species, Shannon diversity, evenness, habitat type, and distance to water and human settlements. Rhinos were detected in 88% of managed plots versus 49% of unmanaged plots, showing a strong preference for actively managed habitats. Linear regression analysis indicated that grass cover, habitat type, invasive species, diversity indices, crown cover, and proximity to settlements significantly influenced rhino presence, explaining 97% of habitat-use variation. Managed grasslands supported higher densities of palatable grasses, including *Saccharum spontaneum*, *Cynodon dactylon*, and *Phragmites karka*, had lower invasive species cover, and offered more open vegetation structure, improving forage quality and movement. These results demonstrate that interventions such as controlled burning, mowing, and invasive species control enhance habitat suitability, sustain forage availability, and promote natural rhino behavior. The study underscores the critical importance of active grassland management for maintaining high-quality habitat and ensuring long-term conservation of the Greater One-horned Rhinoceros in CNP.

## KEY WORDS

Grassland; Controlled burning; Habitat quality; Invasive species; Vegetation diversity

## ARTICLE HISTORY

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## Introduction

One-Horned Rhinoceros (*Rhinoceros unicornis*), a flagship species of the Indian subcontinent, depends heavily on riverine grasslands for food, cover, and breeding [1,2]. In Nepal, Chitwan National Park (CNP) harbors the largest Rhino population, but its prime grassland habitats are under increasing pressure from invasive species, succession into woodlands, human disturbances, and altered flooding regimes [3,4]. While anti-poaching measures have stabilized and even increased Rhino numbers, the quality and availability of suitable grasslands remain a pressing conservation concern [5]. The challenge is particularly acute because unmanaged grasslands tend to decline in forage value due to invasion by alien species like *Mikania micrantha* and *Chromolaena odorata*, while poorly planned management interventions may also disrupt natural ecological processes [6]. This dual challenge underscores the need to assess how management practices influence grassland quality and their role in sustaining Rhino populations. Globally and nationally, research on *R. unicornis* has focused on population status, distribution, and threats, with recent studies highlighting climate and land-use change as major drivers of habitat loss [4]. In Nepal, studies have examined the dietary ecology of Rhinos, confirming their strong preference for tall grasses such as *Saccharum spontaneum* in floodplains, while others have explored the hydrological dynamics of floodplain vegetation that shape grassland availability for mega fauna [2,7]. A systematic review of three decades of research shows that while Rhino conservation has achieved remarkable success in reducing poaching, habitat-related studies remain limited compared to demographic or threat-oriented research [4]. Recent work has also raised concerns about reduced genetic diversity in CNP's Rhino population, indicating that habitat fragmentation and limited dispersal may undermine long-term population viability [8]. Collectively, these studies emphasize that habitat quality particularly grassland condition remains one of the least understood but most critical aspects of Rhino conservation.

Despite the recognition of grassland importance for Rhinos, very few studies have compared the ecological value of managed versus unmanaged grasslands in Nepal's Rhino habitats. Current management strategies in CNP include annual burning, cutting, and clearing of grasslands, but the ecological outcomes of these interventions on forage diversity, invasive species control, and Rhino usage patterns remain poorly documented [4,5]. Most studies have been descriptive at the population level, with little emphasis on fine-scale habitat quality differences and how these translate into conservation outcomes. Therefore, a critical gap exists in understanding whether management interventions actually enhance Rhino habitat or unintentionally reduce its ecological value compared to unmanaged systems. Addressing this gap will provide evidence-based guidance for adaptive grassland management in CNP, ensuring the long-term survival of *R. unicornis* in Nepal.

This paper seeks (i) to assess the distribution of One-Horned Rhino across the grassland habitats in Chitwan National Park to determine their role in supporting the Greater One-Horned Rhinoceros (Rhinoceros unicornis); (ii) to examine how vegetation and habitat factors influence the distribution of the One-Horned Rhino and (iii) to evaluate the effectiveness of

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grassland management in Chitwan National Park to determine their role in supporting the One-Horned Rhinoceros (*Rhinoceros unicornis*).

## Materials and Methods

### Study area

Chitwan National Park (CNP), established in 1973 and a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site since 1984, spans approximately 952.63 square kilometers (km²) in Nepal's Terai lowlands [9]. The park features diverse habitats, including Sal (*Shorea robusta*) forests, riverine forests, wetlands, and extensive grasslands, which are vital for endangered species, notably the One-Horned Rhinoceros (*Rhinoceros unicornis*), representing nearly 90% of Nepal's rhino population [4]. Grasslands, covering about 20% of the park, provide forage and wallowing areas, dominated by *Saccharum spontaneum*, *S. ravennae*, *Arundo donax*, and *Phragmites karka* [10]. Dynamic processes such as seasonal fires, flooding, and erosion create a mosaic of grasslands and riverine forests. Lowland alluvial areas host catechu (*Acacia catechu*) and rosewood (*Dalbergia sissoo*), with Simal (*Bombax ceiba*) and Rhino apple (*Trewia nudiflora*) providing preferred rhino fruits [11]. The understorey offers shelter via species like beautyberry (*Callicarpa macrophylla*) and gooseberry (*Phyllanthus emblica*). Invasive plants such as *Mikania micrantha* and *Chromolaena odorata* threaten grassland quality by altering structure and reducing forage [6].

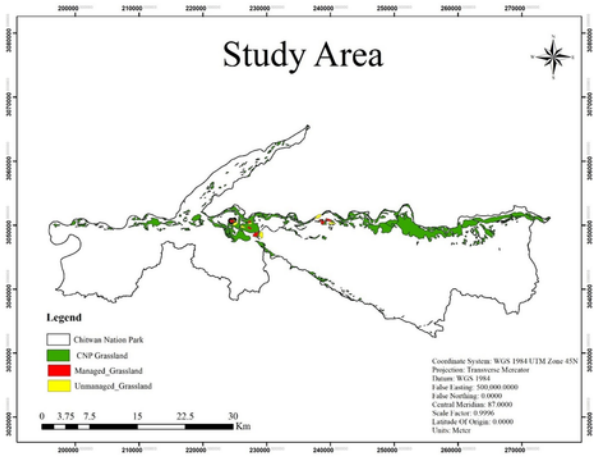


**Figure 1.** Study area showing managed and unmanaged grasslands in CNP.

### Preliminary survey

A reconnaissance survey was initially conducted to assess the habitat condition and vegetation diversity of the grasslands. During this phase, ground surveys were carried out to evaluate the structural composition, species distribution, and overall status of the study sites.

### Grassland classification, sampling design and vegetation survey

Grasslands in Chitwan National Park were categorized as managed, involving controlled burning, mowing, and invasive species removal, and unmanaged, with no active interventions. A systematic random sampling design was applied at 0.5% intensity. Each plot measured 5 meter × 5 meter (m) (25 m²) to capture species heterogeneity (NTFP Inventory Guideline, 2069; Fig. 2). A total of 66 plots were surveyed across twelve grasslands six managed (165.5 ha, n = 33) and six unmanaged (165.5 ha, n = 33) with plots evenly distributed to account for spatial variation. All plant species within plots were identified and counted following Schemnitz [12]. Clumped grasses were recorded as single individuals while climbing and creeping species were assessed indirectly through associated trees [13]. Species identification was supported by herbarium references, botanical experts, and local knowledge, with scientific names verified using standard references [14-19]. Data are collected based on the parameter in Table 1.

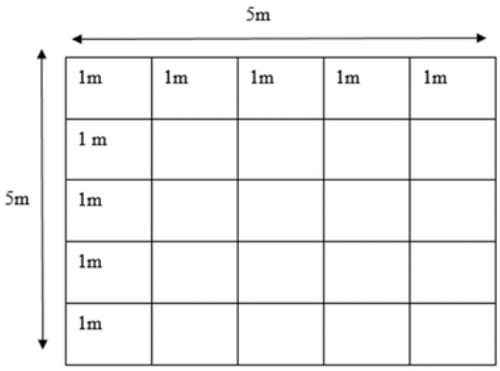


**Figure 2.** Vegetation inventory layout of quadrats.

**Table 1.** Environmental variables used for habitat assessment of One-horned Rhino.

| S.N | Variable Category | Variables | Unit | Data Source |
|---|---|---|---|---|
| 1 | Vegetation Structure | Grass Cover percent | % | Field Survey |
| 2 | Habitat Type | Habitat Type (0-unmanged,1-managed) | Categorical | Field Survey |
| 3 | Vegetation Disturbance | Invasion | Presence/ Absence | Field Survey |
| 4 | Biodiversity | Shannon | Index | Field Survey |
| | | Evenness | Index | Field Survey |
| 5 | Vegetation Structure | grass height | cm | Field Survey |
| 6 | Vegetation Structure | crown cover | % | Field Survey |
| 7 | Human Influence | Distance to settlement | Meter (m) | Field Survey and estimation |
| | | Distance to water source | m | Field Survey and estimation |

## Data Analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) and Microsoft Excel. Differences in One-horned Rhino occurrence between managed and unmanaged grasslands were assessed using a Chi-square test of independence to compare frequencies of Rhino presence across habitat types. Additionally, multiple linear regression was performed to examine the influence of key habitat variables and identify the characteristics most preferred by the species.



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### Vegetation data analysis metrics

Following Adam et al. and Maingi and Marsh, Shannon diversity, relative frequency, relative density, relative cover, and relative dominance of each plant species in every grid were calculated using standard formulas [20,21].

- Shannon–Wiener diversity was computed as $H = -\sum Pi * \ln Pi$, where Pi is the proportion of individuals belonging to species i.
- Evenness (E) = $H' / \ln(S)$
- where S = total number of species in the plot.
- Invasion %= (Area covered by invasive species/Total area surveyed) × 100%
- Where, H = Shannon–Wiener Diversity Index;
- Pi = proportion of individuals belonging to the ith species in the plot;
- ln = natural logarithm;
- $\sum$ = summation over all species.

Crown cover (CC %) was quantified in the field using a convex spherical densiometer, following the method outlined by Lemmon [22]. The densiometer features a grid of fixed points, and the observer records how many of these points are covered by tree canopy compared to open sky. The percentage of crown cover was calculated using the formula:

- CC % = (Number of grid points covered by canopy / Total number of grid points) × 100

After deriving species-level metrics and invasion percentages, means and standard deviations for managed and unmanaged grasslands were calculated using standard statistics:

### Grassland habitat preference of one-horned rhino

We assessed the habitat preference of One-horned Rhinos (*Rhinoceros unicornis*) in Chitwan National Park using 66 systematically distributed plots (5 × 5 m) across managed and unmanaged grasslands. A Multiple Linear Regression Model was applied to examine the relationship between grassland habitat variables (independent or predictor variables) and the number of rhinos observed (dependent or response variable). The predictor variables included Grass Cover, Habitat Type, Invasion (%), Shannon Diversity Index, and Distance to Water Source, Evenness, Grass Height, Crown Cover, and Distance to Human Settlements.

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \varepsilon$$

Where:

- Y = number of One-horned Rhinoceros observations per plot (obs) [dependent variable];
- $\beta_0$ = intercept of the regression model;
- $\beta_1$–$\beta_9$ = regression coefficients representing the effect size of each predictor variable;
- $X_1$ = grass cover (%);
- $X_2$ = habitat type (0 = unmanaged grassland, 1 = managed grassland);
- $X_3$ = invasive species cover (%);
- $X_4$ = Shannon–Wiener Diversity Index (H′);
- $X_5$ = distance to water source (meters);
- $X_6$ = species evenness;
- $X_7$ = grass height (centimeters);
- $X_8$ = crown cover (%);
- $X_9$ = distance to human settlement (meters);
- $\varepsilon$ = random error term accounting for unexplained variation

Scatter plots were created with the dependent variable on the Y-axis and independent variables on the X-axis to visualize their relationships. Statistical significance was determined using p-values at a 0.05 significance level ($\alpha = 0.05$). A p-value ≤ 0.05 indicated a statistically significant relationship between the predictor and response variable, whereas a p-value > 0.05 suggested no significant association in the model.

## Results

### Distribution of one horned rhino in both managed and unmanaged grassland

One-horned rhinoceros signs and direct sightings were recorded in 29 managed plots (88%) and 16 unmanaged plots (49%) out of 33 plots in each category (Table 2). The association between grassland type and Rhino presence was significant (Chi-square test of independence ($\chi^2$) = 10.06, degree of freedom (df) = 1, p = 0.0015), indicating that Rhinos were significantly more likely to occur in managed plots than in unmanaged plots.

**Table 2.** Distribution of one-horned Rhinos across managed and unmanaged grasslands in Chitwan National Park.

| Grassland Type | Rhino Present | Rhino Absent | Total Plot |
|---|---|---|---|
| Managed Plot | 29 | 4 | 33 |
| Unmanaged Plot | 16 | 17 | 33 |
| **Total** | 45 | 21 | 66 |

Out of the total 45 Rhino observed plot, 64% were recorded in managed grasslands and 36% in unmanaged grasslands (Figure 3). These results indicate a clear preference of one-horned Rhinos for managed habitats, likely due to better forage quality, lower human disturbance, or habitat structure in managed grasslands. The higher frequency of Rhinos in managed plots emphasizes the importance of grassland management interventions for the conservation of this species in Chitwan National Park. These findings suggest that management practices aimed at maintaining vegetation diversity, controlling invasive species, and sustaining grass cover significantly increase the likelihood of Rhino utilization.

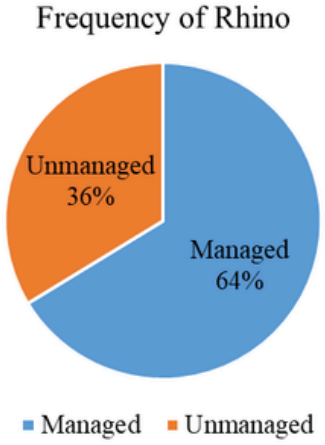


**Figure 3.** Frequency of Rhino across the managed and unmanaged Grassland.



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## Vegetation and habitat factors influencing rhino occurrence in managed and unmanaged grasslands

A multiple linear regression model was used to examine the effects of vegetation and habitat variables on the probability of rhino occurrence in the study area. The model explained a large proportion of the variation in rhino occurrence, with an adjusted coefficient of determination ($R^2$) of 0.970. The residual standard error was 0.871 (df = 56), and the overall model was highly significant ($F_{9,56}$ = 230.7, p < 0.0001) (Table 3 and 4).

**Table 3.** Model Summary.

| Metric | Value |
|---|---|
| Residual Std. Error | 0.871 (df = 56) |
| Multiple R-squared | 0.974 |
| Adjusted R-squared | 0.9695 |
| F-statistic (f) | 230.7 (df=9 ,56) |
| p-value | < 0.0001 |

**Table 4.** The vegetation and habitat parameters that significantly influence the probability of Rhino occurrence in the study area.

| | Coefficients: | | | |
|---|---|---|---|---|
| | **Estimate** | **Estimate** | **t value** | **Pr(>\|t\|)** |
| (Intercept) | 19.097 | 1.052 | 18.158 | <0.0001*** |
| Grass Cover percent | -0.078 | 0.015 | -5.11 | 0.000004 ** |
| Habitat type | 0.57 | 0.256 | 2.231 | 0.030 * |
| Invasion (%) | -0.354 | 0.049 | -7.272 | <0.0001*** |
| Shannon | -0.836 | 0.179 | -4.669 | 0.00002 *** |
| Distance to water source | - 0.002 | 0.001 | 3.653 | 0.0006 ** |
| Evenness | -1.073 | 0.304 | -3.532 | 0.0008 ** |
| Grass height (cm) | -0.009 | 0.009 | -1.088 | 0.281 |
| Crown cover (%) | -0.095 | 0.019 | -4.944 | 0.000007 ** |
| Distance to settlement | 0.00133 | 0.00032 | 4.152 | 0.0001 ** |

Several vegetation and habitat parameters as shown in table 4 significantly influenced rhino occurrence. Grass cover (%) had a negative effect (β = -0.078, p = 0.000004), indicating that rhinos preferred areas with moderate rather than dense grass. Similarly, areas with higher invasive species cover (%) were avoided (β = -0.354, p < 0.0001), highlighting the negative impact of invasive plants on habitat suitability. Shannon diversity (H′; β = -0.836, p = 0.00002) and evenness (β = -1.073, p = 0.0008) also negatively influenced rhino occurrence, suggesting a preferencefor more homogeneous grassland areas. Crown cover (%) negatively affected rhino presence (β = -0.095, p = 0.000007), consistent with their use of open habitats. Habitat type, coded as 1 for managed and 0 for unmanaged, had a positive effect on rhino occurrence (β = 0.570, p = 0.03), indicating that rhinos were more likely to occur in managed grasslands. Distance to settlements also positively influenced rhino occurrence (β = 0.00133, p = 0.0001), suggesting that rhinos preferred areas farther from human activity. Other variables, including grass height and distance to water, were not significant predictors.

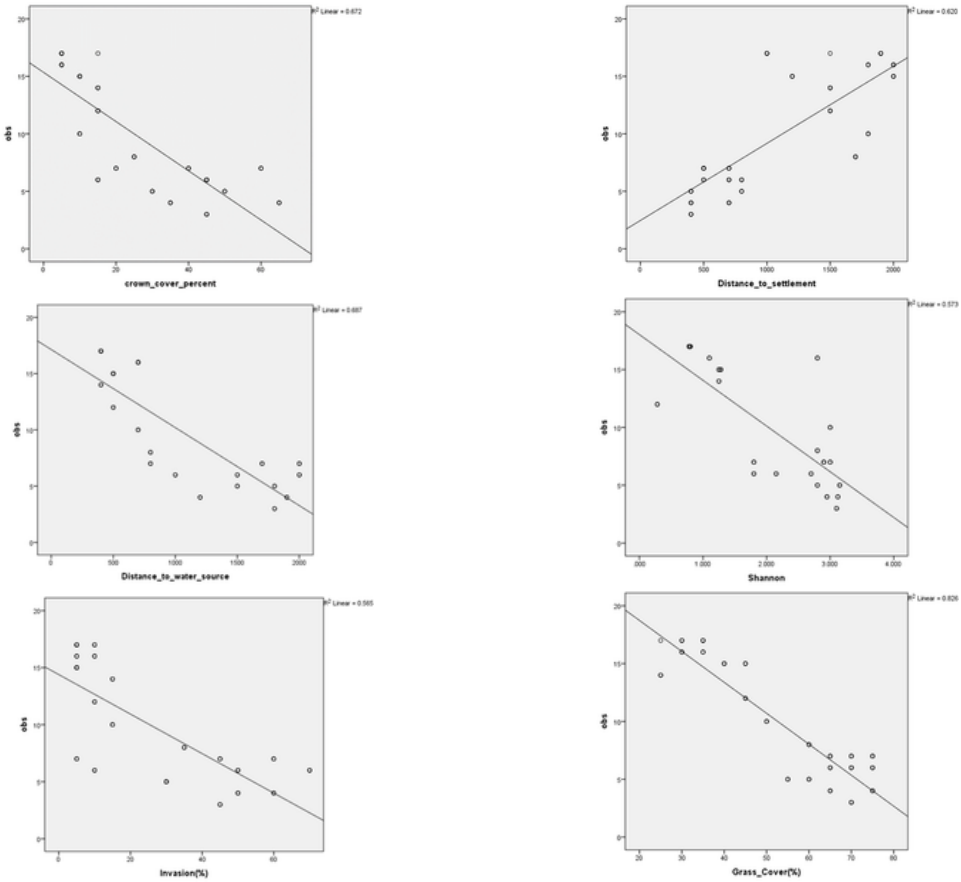


**Figure 4.** Scatter plot showing the relationship between environmental factors and the number of One-Horned Rhino sighting across the plot, with fitted regression line.



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Overall, the results (Figure 4) demonstrate that One-Horned Rhinos preferentially utilize managed grasslands with open, managed grasslands with moderate grass cover, low invasive species presence, and minimal human disturbance, emphasizing the importance of targeted grassland management for conservation.

### Effectiveness of grassland management practices

Grassland management practices are deliberate interventions aimed at maintaining or enhancing the structure, composition, and productivity of grasslands, thereby supporting wildlife and ecosystem functions [23]. In Chitwan National Park, common interventions include controlled burning, mowing or slashing overgrown vegetation, removal of invasive species, and occasional regulated grazing to control grass height and promote regeneration of palatable grasses. These practices prevent encroachment by coarse or woody species, improve forage availability, and maintain open habitats suitable for large herbivores such as the greater one-horned Rhinoceros (*Rhinoceros unicornis*) [24,25].

In our study, overall mean values of vegetation parameters differed between managed and unmanaged plots (Table 5). Managed grasslands exhibited lower Shannon diversity (H′ = 1.25) but higher grass cover (23%), crown cover (12%), and lower invasive species presence (15%) compared to unmanaged plots (H′ = 2.38, grass cover = 51%, crown cover = 38%, invasion = 41%). Distances to water sources and settlements also varied, with managed areas located farther from both. These differences reflect the effects of management interventions. Controlled burning stimulates fresh grass growth and reduces coarse or invasive vegetation. Mowing and selective removal of invasive species further improve forage quality, diversity, and palatability. Managed plots supported higher abundances of palatable grasses such as *Saccharum spontaneum* (Jhatka), *Cynodon dactylon* (Dubo), *Leersia hexandra* (Karaute ghas), and *Desmostachya bipinnata* (Kush), whereas unmanaged plots were dominated by coarse, less palatable species like *Imperata cylindrica* (Siru). Overall, these management practices maintain open grassland structure, control invasive species, and enhance habitat quality, providing favorable conditions for rhino grazing and movement.

**Table 5.** Comparison of vegetation parameter between Managed and Unmanaged Grassland.

| Grassland Type | Shannon Diversity (H') | Distance to settlement (m) | Evenness | Distance to water (m) | Grass Cover (%) | Crown cover (%) | Invasion (%) |
|---|---|---|---|---|---|---|---|
| Managed (Mean) | 1.25 | 1500 | 0.211 | 450 | 23% | 12% | 15 % |
| Unmanaged (Mean) | 2.38 | 800 | 0.68 | 1110 | 51% | 38% | 41% |

## Discussion

Our study shows that active grassland management is very important for improving habitat quality for the Greater One-horned Rhinoceros (*Rhinoceros unicornis*) in Chitwan National Park. The results clearly reveal that rhinos prefer managed grasslands, where we recorded their presence in 88% of the plots, compared to only 49% in unmanaged grasslands. This strong difference indicates that rhinos are highly dependent on well-maintained grasslands for feeding and movement. These findings support earlier studies, which have reported that *Saccharum spontaneum* is one of the most important and preferred grass species for rhinos [1,26].

In our study as table 6, managed grasslands contained a higher proportion of palatable and nutritious grasses, including *Saccharum spontaneum*, *Cynodon dactylon*, and *Phragmites karka*. These species provide essential forage for rhinos. On the other hand, unmanaged grasslands were dominated by coarse grasses such as *Imperata cylindrica* and were heavily invaded by *Mikania micrantha*, an aggressive climber that reduces light availability and smothers native vegetation. The presence of these poor-quality and invasive species lowers the forage value in unmanaged areas. Similar findings have been reported by Dutta & Mahanta, Bist, and Awasthi et al. [25,27,28]. Our results also show that rhinos prefer areas where grasslands and forests overlap, creating a mixed habitat that offers both food and shade. In addition, rhinos were frequently found near water sources, which are essential for drinking, wallowing, and cooling. This matches the conclusions of Kafley, who emphasized the importance of wetlands and water availability in rhino habitat selection [29]. Taken together, our study highlights that management practices such as controlled burning, mowing, and removing invasive plants significantly improve grassland condition. These actions help maintain fresh grass growth, increase visibility, and support a higher diversity of palatable plant species. As a result, managed grasslands provide better feeding opportunities and safer movement paths for rhinos.

Overall, our findings confirm that active grassland management is crucial for sustaining healthy rhino populations in Chitwan National Park. Continued efforts in habitat restoration and regular monitoring will be essential to maintain suitable habitats and support the long-term conservation of this endangered species.

**Table 6.** Comparison of managed and unmanaged Grasslands for One-Horned Rhino with literature support.

| S.N. | Parameter | Previous Findings | Current Study (2025) |
|---|---|---|---|
| 1 | Key Forage Species | *Saccharum spontaneum* identified as the most preferred grass species [1,26]. | Confirms *Saccharum spontaneum* as the most important forage species; also highlights *C. dactylon* and *P. karka* as important in managed grasslands. |
| 2 | Habitat Preference | Rhinos prefer contiguous grasslands with adequate water sources and less disturbance [29]. | Rhinos prefer mixed forest–grassland mosaics closer to water bodies and areas with active management. |



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| | | | |
|---|---|---|---|
| 3 | Invasive Species Impact | Invasives such as *Mikania micrantha* decrease forage availability [28]. | Unmanaged grasslands dominated by *Mikania micrantha* and *Imperata cylindrica* show low rhino presence (49%). |
| 4 | Effect of Grassland Management | Managed/semi-managed habitats support higher rhino density [4]. | Rhino occurrence: 88% in managed vs. 49% in unmanaged plots, indicating strong response to management. |
| 5 | Vegetation Structure Influence | Habitat structure and native species richness positively influence herbivore distribution. | Managed plots show higher diversity and palatable species, increasing rhino use. |
| 6 | Habitat Suitability Beyond Core Areas | Rhinos frequently use areas outside core zones [30]. | Confirms continued use of peripheral grasslands, especially those under management practices. |
| 7 | Overall Conclusion | Availability of palatable grasses and water sources shapes rhino distribution. | Active grassland management (burning, mowing, invasive removal) significantly enhances habitat suitability and rhino occurrence. |

## Conclusion

This study shows that grassland management strongly affects wildlife, especially the Greater One-horned Rhinoceros, in Chitwan National Park. Rhinos were found in 88% of managed plots but only 49% of unmanaged ones, showing a clear preference for well-maintained habitats. Key factors influencing wildlife presence include grass cover, habitat type, invasive species, crown cover, diversity, evenness, and distances to water and settlements. Regression analysis indicated that higher invasion, crown cover, and diversity reduced wildlife use, while habitat type and distance to settlements increased it. Managed grasslands with palatable grasses, open structure, and low invasive species provide better food, movement, and safety. Maintaining and restoring such areas is vital for long-term conservation.

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## Author Contributions

Nirvika and Prabin developed the research concept. Nirvika, Samik, and Dinesh carried out the fieldwork and data collection. Pooja and Dinesh analyzed the data. Nirvika and Samik prepared and wrote the manuscript. Prabin provided overall supervision and guidance throughout the study.

## Competing Interest

There is no competing interest.

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