# Can't see the forbs for the grasses – Forb ecology in Indian grasslands

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## Abstract

Grasslands are one of the world's most widespread and diverse ecosystems. However, ecological research in grasslands has largely focused on grasses and woody plants, while forbs, which are non-graminoid herbaceous plants, are often overlooked despite their considerable contributions to biodiversity and ecosystem functioning of grasslands. In this review we synthesize current knowledge on the ecological roles of forbs in Indian grasslands by merging evidence from the global literature with 31 studies conducted across diverse Indian grassland ecosystems. Global studies demonstrate that forbs mainly contribute to species richness, pollination, nutrient cycling, ecosystem resilience, and post-disturbance recovery, whereas Indian research has primarily documented forbs within floristic assessments or medicinal uses, with relatively few studies unambiguously investigating their functional roles. Despite their ecological and livelihood importance, forbs remain comparatively understudied in grassland disturbance research, particularly in relation to how their functional traits and species-specific strategies influence persistence and recovery under repeated disturbances such as grazing. This review emphasizes the need to recognize forbs as distinct functional groups of Indian grasslands and identifies priority areas for future research to support more effective conservation, restoration, and sustainable management of these ecosystems.

**Key words:** Forbs, Indian grasslands, biodiversity, grassland ecology

## 1. In a Nutshell

- Global studies suggest that forbs underpin grassland diversity, pollination services, nutrient cycling and resilience, among other ecosystem functions.
- In India, 74% of all grassland studies in the past decade never analysed forbs separately from grasses.
- Forb traits and functions need mechanistic study to guide grassland responses to local and global environmental changes, management, and restoration.

## 2. Introduction

Grasslands, including open grasslands, grassy shrublands and savannas, cover approximately 23% of Earth's terrestrial surface (MacDougall et al., 2026). These naturally occurring open ecosystems offer critical habitats to a number of globally endangered fauna, despite large portions of it lacking any formal protection (Bond & Parr 2010; Kiffner et al., 2020; Majgaonkar et al., 2026). Grasslands sustain large populations of livestock and wild herbivores, which, in the form of meat and dairy, act as a source of minerals, vitamins and protein for millions of people (Sheth et al., 2025). Global carbon stock stored in surface soil is approximately three times the amount of carbon stored in terrestrial vegetation and twice the size of atmospheric carbon pool (Schmidt et al., 2011). Open ecosystems, for millennia, have supported vulnerable livelihoods such as nomadic and agrarian pastoralism across the globe (Sheth et al., 2025). Over 38% of the world's population lives in drylands — mainly grassland and desert — and thus depends directly on these ecosystems for its life and livelihood (Zhao et al., 2020). Despite such high ecological and economic value, grasslands have received far less attention than forests. This bias has been termed “Biome Awareness Disparity” (Lehmann & Parr, 2016; Silveira et al., 2022). This is particularly true in South and Southeast Asia, where such apathy has been present since the colonial period (Ratnam et al., 2016). Despite their historic natural occurrence in the region, colonial foresters trained in European forestry techniques classified these sparsely treed landscapes as degraded forests (Riedel 2021; Ratnam et al., 2016; Ratnam et al., 2011). Such colonial practices have left lasting legacies in the region. For example, India’s national vegetation classifications still do not formally recognise open-canopy ecosystems, with ~69% of those mapped in the semi-arid zone labelled as wastelands (Madhusudan & Vanak, 2023). Research efforts have followed a similar pattern too. Much of the ecological work in south and southeast Asia has focused primarily on megafauna and forests, and grassland studies remain isolated rather than forming a coherent body of work (Sheth et al., 2025).




Figure 1. Representative examples of the high species diversity of forbs in Indian grasslands. (a) *Catharanthus pusillus*(Murray) G.Don. in Maharashtra. (b) *Drosera burmanni* Vahl in the Nilgiris (c) *Impatiens sp.* In the Nilgiris. (d) *Parasopubia delphiniifolia* (L.) H.-P.Hofm. & Eb.Fisch. in Maharashtra (e) *Gymnadenia conopsea* (L.) R.Br. in Uttarakhand. (f) *Striga sp.* in Tamil Nadu. (g) *Biophytum poterioides* Edgew. & Hook.f. in Tamil Nadu (h) *Geranium sp.* in Nilgiris. (i) *Utricularia malabarica* Janarth. & A.N.Henry in Kerala. *(j) Bonnaya sp.* in Tamil Nadu. All photographs by Abhirami Ravichandran

Grasslands are traditionally defined as ecosystems dominated by grasses and other graminoids, with sparse tree and shrub cover (White, 1983; Rawat & Adhikari, 2015). Such physiognomic definitions help distinguish grasslands from other vegetation types, but they emphasise the structural dominance of grasses (Parr et al., 2014). In reality, grasslands are composed largely of graminoids and forbs, and together, they contribute to the biodiversity, structure and functioning of the ecosystem (Dixon et al., 2014)Fig 1. Nevertheless, grassland ecology has traditionally taken a grass-centric view. Studies focus predominantly on grasses, trees and tree–grass interactions, while individual forb and non-grass graminoid species, and their ecological roles remain poorly studied from most parts of the world (but see Siebert et al., 2024; Morris & Scott-Shaw, 2019; Mitchell & Bakker, 2016; Roscher et al., 2018). Forbs play unique ecological functions in global grasslands, ranging from acting as a source of food and medicine to large populations of people to supporting diverse insect communities (Laden & Wrangham, 2005; Wadley et al., 2020; Botha et al., 2017; Siebert et al., 2024). They respond differently from grasses to disturbance and warming, and may contribute to productivity and post-fire persistence even when overall species diversity does not change (Fynn et al., 2004; Peng et al., 2017; Orzell et al., 2024). ). Nevertheless, herbaceous diversity remains poorly documented across the global south. A global synthesis on grassland diversity and ecology suggests that forbs might account for a considerable portion of grassland flora, with endemic forbs consisting almost 12–25% of grassland diversity in Brazil and African savanna (Siebert et al., 2024). There is a particular lacuna of knowledge from south and southeastern Asia. While the few available research suggest high herb diversity in the region, there is a severe lack of studies exploring the contribution of forbs to grassland biodiversity and functions (Ratnam et al., 2016).

This gap is particularly relevant for India, whose grasslands are not a single entity but comprise several ecosystem types spanning a wide range of geological and environmental conditions. India's grasslands range from arid and semi-arid savanna grasslands and woodlands in the Deccan Peninsula to wet alluvial grasslands of gangetic floodplain to wet montane grasslands of the Western Ghats to dry high-altitude ecosystems of the trans-himalayas (Mande et al., 2025). These ecosystems constitute parts of India’s Open Natural Ecosystems (ONEs) and provide essential ecosystem services, support local economy and aid species conservation (Madhusudan and Vanak 2023, Majgaonkar et al., 2026, Sheth et al., 2025). Despite their immense socio-ecological potential, these ecosystems have historically been treated as “wastelands”, and India’s land management policy, much like its colonial predecessor, has engaged in converting these habitats into “productive lands” through social forestry, watershed development and biofuel production (Ratnam et al., 2016, Majgaonkar et al., 2026, Ratnam et al., 2011). Such misclassification has pushed Indian grasslands and savannas to the margin of public imagination of nature and has shifted the focus from understanding the ecology of these habitats to value production and revenue generation (Baka et al., 2017.). Despite these systemic hindrances, grassland ecology research has developed considerably in India over the last few decades with studies across the country trying to understand grassland diversity, structure and function and its

vulnerability to local and global changes (Sankaran and McNaughton, 1999, Kohli et al., 2021, Mande et al., 2025, Bhan et al., 2025, Nerlekar et al., 2022).

However, the focus of grassland research in India has primarily been on grasses. Floristic work recognises forb richness and endemism (Ratnam et al., 2016), and previous studies have identified herbs as the largest group of recorded species (Rawat & Adhikari, 2015). However, Indian grasslands have traditionally been classified by their dominant grass types (Rawat & Adhikari, 2015), and herbs are mostly assessed not for their ecological roles, but their economic values (Rawat & Adhikari, 2015).Globally, forbs are often acknowledged in floristic accounts but rarely become the focus of ecological studies. Whether this holds for India, where grasslands are diverse and forb research has not been assessed systematically, is unknown. We therefore reviewed the Indian grassland literature, asking (1) whether forbs are recognised as a distinct set of functional groups in Indian grassland studies, and (2) how well forbs have been studied compared with grasses.

## 3. Methods

### 3.1 Systematic Review

A structured literature review was conducted using Google Scholar (accessed on 12 July 2026). We narrowed the search to Indian grassland ecology using ten keyword strings: ‘Indian grassland ecology’, ‘Indian grassland biodiversity’, ‘Indian grassland ecosystem function’, ‘Indian grassland restoration’, ‘Indian grassland grazing’, ‘Indian grassland fire ecology’, ‘Indian grassland plant community’, ‘Indian grassland functional traits’, ‘Indian grassland nutrient cycling’, and ‘Indian grassland soil carbon’. These searches were designed to show how far forbs are represented in the existing Indian literature. For each search, we recorded the first 20 results, giving us 200 records in total. We stopped at 20 because results beyond this point were mostly irrelevant or global studies, which indicated that relevant Indian studies had been exhausted.

All 200 records were screened against the inclusion and exclusion criteria above. The studies that met the criteria were then checked for explicit mention of forbs, and only those that explicitly mentioned or described forbs were retained. This left 31 studies that satisfied all criteria, and these formed the dataset for analysis.

Studies were eligible for inclusion in the review if they met the following criteria: (1) published between 2015 and 2025, with older seminal publications included where they provided important ecological or conceptual context; (2) published in peer-reviewed journals; (3) conducted within natural grassland ecosystems in India; and (4) investigated plant communities, biodiversity, ecosystem functioning, ecological restoration, grazing, fire, nutrient cycling, soil ecology, pollination, decomposition, or plant functional traits. Studies were excluded if they focused

exclusively on agricultural or crop production systems, examined forest ecosystems without a natural grassland component, investigated urban lawns or ornamental grasslands, consisted solely of taxonomic descriptions without ecological interpretation, or focused exclusively on molecular biology, genetics, or plant breeding without ecological connotations.

### 3.2 Assessment of Forb Representation

To evaluate how well forbs are represented within Indian grassland ecology, each Indian study was assigned an evidence score based on the level of attention given to forb ecology.

**Table 1: Scoring criteria for assessing the extent of forb-specific focus in grassland ecology studies.**

| Score | Interpretation |
|---|---|
| 5 | Primary focus on forbs; forb traits or ecosystem functions explicitly investigated. |
| 4 | Forbs analysed separately and quantitatively but were not the principal research focus. |
| 3 | Forbs included as a distinct functional group with some results presented. |
| 2 | Forbs mentioned descriptively but not analysed in detail. |
| 1 | No forb-specific data, but the study provided ecological context relevant to understanding forb functions. |
| 0 | No relevance to forb ecology or grassland ecosystem functioning. |

This scoring framework was used to assess the extent to which forbs have been incorporated into Indian grassland research and to identify major gaps in knowledge regarding their ecological roles relative to grasses. The scores were intended as a qualitative measure of research emphasis rather than an assessment of study quality.

## 4. Results

The 31 studies (Supplementary Material S1) were unevenly distributed across India's biogeographic zones. The Western Ghats contributed the most (7 studies, 23%), mainly from the montane shola–grassland mosaics, followed by the Deccan Peninsula (6 studies, 19%), the Himalaya including the Trans-Himalaya (5 studies, 16%) and the Desert zone (4 studies, 13%). The North-East and the Gangetic Plain contributed two studies each (6%), and no studies came from the Coasts or Islands zones. Three studies (10%) were national-scale reviews, and two (6%) covered more than one zone. Two sites, Banni in Kachchh and the Nilgiris in the Western Ghats, together accounted for eight of the 31 studies.

Each study was scored from 0 to 5 for how much it focused on forbs, using the criteria in Table 1 (Fig. 2). The mean score was 1.7 out of 5. Nine studies (29%) contained no forb-specific information and scored 0; they were retained as grassland studies that address the herbaceous or whole-vegetation layer (see Methods). Twelve studies (39%) scored 1 or 2, seven (23%) scored 3, and only three (10%) scored 4, the highest score reached. No study scored 5.

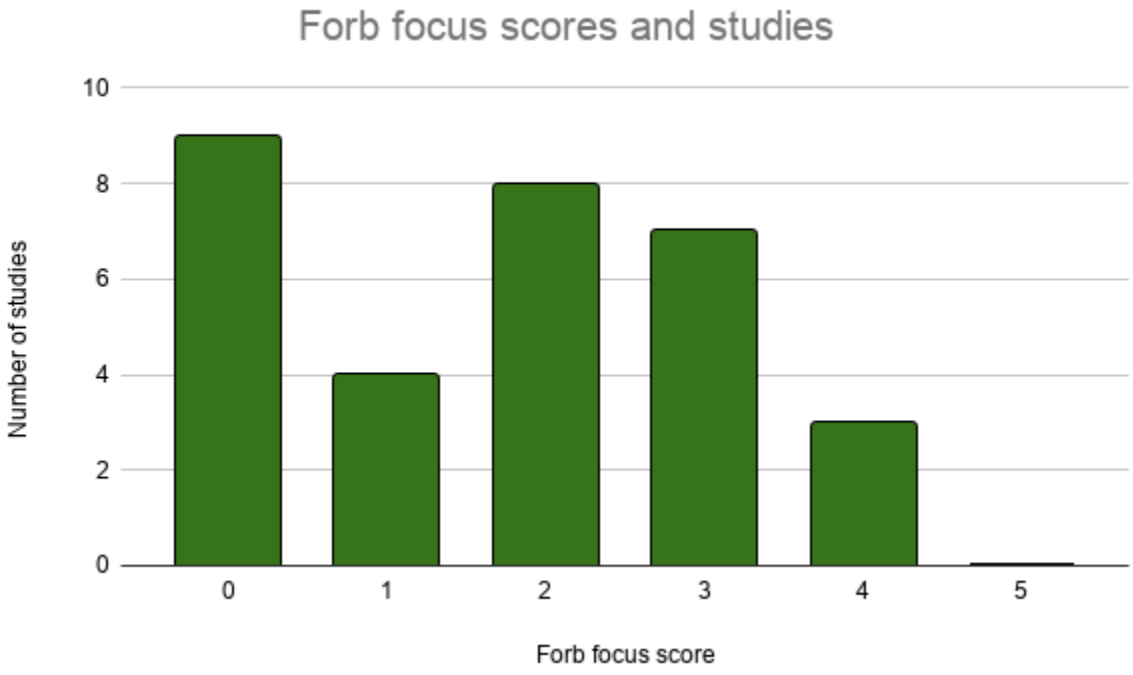



Fig 2.Forb-focus scores (0–5; Table 1) of the 31 Indian grassland studies reviewed.

Methodologically, the studies were predominantly descriptive. Observational field surveys of floristic composition, diversity, community structure, phenology or invasion were the most common (12 studies, 39%), followed by reviews and syntheses (8 studies, 26%) and spatial, remote-sensing and modelling approaches (4 studies, 13%). Manipulative field experiments, including active restoration and experimental warming, drought, nutrient enrichment or grazing, accounted for three studies (10%). Comparative designs (fenced versus grazed plots, restoration chronosequences) and process-based measurements of carbon cycling and soil microbial function contributed two studies each (6%).

Across the 31 studies, forbs were seldom treated as a distinct set of functional groups. Only eight studies (26%) analysed forbs separately, for example distinguishing annual and perennial forbs or leguminous forbs, or comparing forbs with grasses under nitrogen addition. Twelve studies (39%) distinguished herbs or non-grasses from grasses or listed individual forb species but pooled them as herbaceous vegetation. The remaining 11 studies (35%) did not separate forbs at

all, treating vegetation collectively or focusing on grasses. Overall, 74% of studies did not analyse forbs as a distinct set of functional groups, and the term "forb" was frequently absent from the literature, with authors instead using words like "herbs" or "non-grasses".

## 5. Discussion

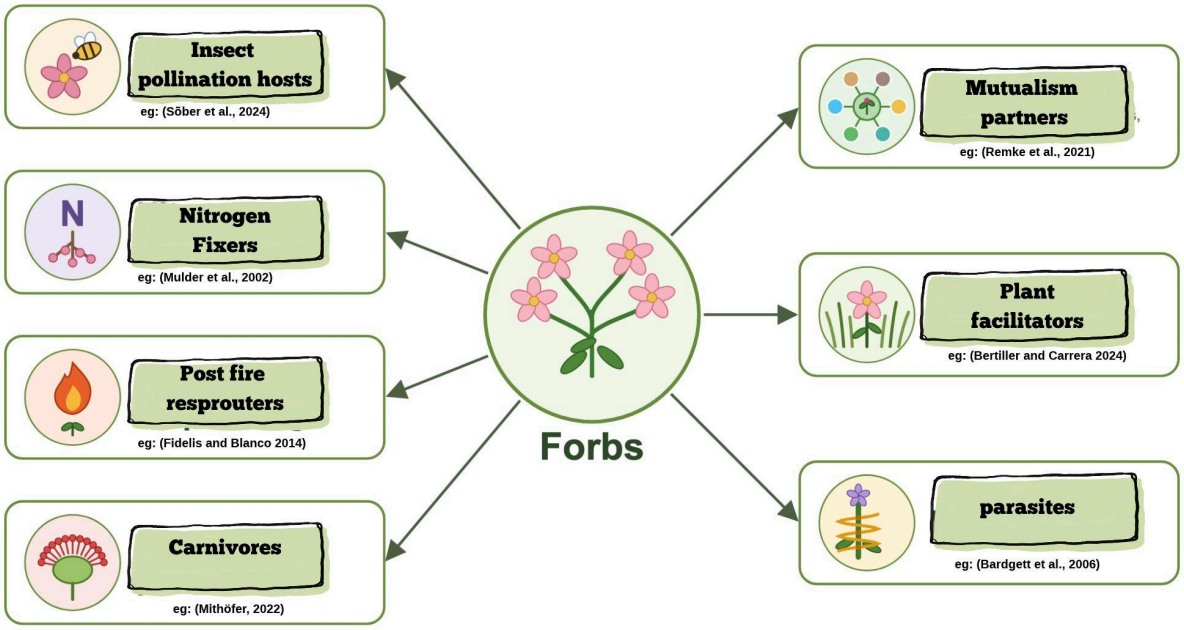



Fig 3. Multiple functional roles of forbs in grassland ecosystems.

Our structured literature review revealed that, despite receiving research focus globally, forbs remain a largely invisible component of Indian grassland research: described but seldom studied as distinct functional groups. Thus, little is known about the contribution of forbs to the ecosystem functioning of grasslands, or how forbs will respond to local and global environmental change or policy and management interventions.

Of the 31 studies that described or mentioned forbs or the herbaceous layer, research effort was strongly concentrated in a few regions, principally the semi-arid belt of western and peninsular India, the Western Ghats and the western Himalaya. Consequently, the central Himalaya, the eastern Himalaya, the Terai and the Eastern Ghats remain largely unstudied, as did the grasslands of the northeastern plains and non-Himalayan hills such as the Shillong Plateau.

The Indian literature was predominantly descriptive. Observational surveys, reviews and remote-sensing or modelling approaches made up most studies (n = 24, 77%), whereas manipulative experiments, comparative designs and process-based measurements were rare (n =

7, 23%). Forbs were also seldom analysed as distinct functional groups: only eight studies (26%) treated them separately from grasses, while the remaining 74% either pooled them within the herbaceous layer or did not separate them at all. The term “forb” itself was largely absent, with authors instead using “herbs” or “non-grasses”.

The evidence indicates that forbs are acknowledged in Indian grassland literature only implicitly. Wherever forbs appear, they are typically subsumed within the broader categories of "herbs" or "non-grasses" rather than being treated as an independent set of functional groups. This prevents the assessment of their contributions to diversity, productivity and ecosystem processes (Siebert & Dreber, 2019; Siebert et al., 2024). This treatment contrasts with the sustained attention given to grasses, which dominate the literature around Indian grassland composition, management and ecology (Thomas & Palmer, 2007; Rawat & Adhikari, 2015; Datar, 2016; Sharma et al., 2024; Siddabathula et al., 2025; Lahiri et al., 2023). The few studies that treated forbs as distinct functional groups were mostly single-site and single-driver in design such as forb responses to nitrogen addition (Yadav et al., 2024), flowering phenology (Shrotri et al., 2025) or restoration outcomes (Nerlekar et al., 2022; Nerlekar et al., 2024). No study had yet examined why forbs respond as they do. The forb-specific studies measured patterns, mainly species composition, diversity, cover and biomass, but none tested the mechanisms behind them: functional traits (e.g. leaf or root traits), demography (e.g. recruitment, survival and reproduction) or belowground processes (e.g. root and soil microbial interactions and nutrient cycling). The combination of geographic concentration, descriptive methodology and the treatment of forbs as part of “herbs” or “non-grasses”, rather than as distinct functional groups, suggests that forb research in India lags behind the recognition forbs receive globally.

Treating forbs as a single category masks functional variation within the herbaceous layer (Craine et al., 2002). Many forbs with underground storage organs resprout rapidly after fire and can trigger a pulse of post-fire flowering (Pilon et al., 2021), so forb identity acts as a fire-response trait (Pausas et al., 2018). Insect-pollinated, short-lived, seed-reproducing species are the first to decline as grasslands overgrow, which can erode pollination even as vegetation cover increases (Sõber et al., 2024). Herbaceous legumes fix nitrogen that supports both grasses and non-leguminous forbs (Mulder et al., 2002). Forbs thus play many distinct roles in grasslands (Fig. 3), none of which can be inferred from a grass–forb split.

These roles have been documented mainly outside India, yet India’s open natural ecosystems span a wide range of climates, soils and management systems, so patterns from other regions may not hold here. Subcontinental-scale work on Indian grasses shows that this breadth produces structured, zone-specific lineage sorting rather than a simple increase in richness (Mande et al., 2025). Most climate–richness relationships match those reported elsewhere, but not all: C4 grass richness increases with moisture, counter to the expectation that C4 grasses are favoured in warm, dry climates (Edwards et al., 2010; Osborne, 2008). Mande et al. (2025) attribute this partly to the dominance of Panicoideae, a lineage typical of warm, moist habitats, among India’s

C4 species, so regional richness depends on which lineages make up the local flora and not only on climate. The scarcity of forb studies in India therefore reflects a gap in research effort, not lower ecological importance. It leaves open the question whether what is known about forbs elsewhere is general or idiosyncratic to the regions where forbs have been studied.

**Our work and future directions**

Our work provides the first systematic assessment of how forbs are represented in Indian grassland research and quantifies the extent to which they have been overlooked as a set of functional groups distinct from grasses. Future research should move beyond documenting species composition and address the functional ecology of forbs, quantifying the roles of forbs in nutrient cycling, decomposition, pollination, soil carbon storage and ecosystem resilience. It should also identify the traits that mediate forb responses to grazing, fire, drought and climate change. Finally, plant-soil-microbial interactions involving forbs should be examined within a mechanistic framework (Siebert & Dreber, 2019; Bråthen et al., 2021; Siebert et al., 2024). Long-term monitoring programmes that explicitly track forb abundance, diversity and phenology, and deliberate incorporation of forb functional diversity into restoration planning and conservation strategy, are equally important. Forbs underpin grassland function far beyond their share of biomass. As a diverse component of grassland vegetation, forbs provide floral resources and forage for pollinators and herbivores and thus contribute to grassland functioning. If these priorities are not addressed, forb communities will continue to decline unmonitored under global and local changes such as intensifying grazing, fire suppression and woody encroachment. Grassland restoration in India will then recover grass cover without the functional diversity of native forbs, undermining pollination networks, food webs, biodiversity, ecosystem services and the resilience of some of the country's most threatened ecosystems.

## Conflict of interest statement

The authors declare that this study was carried out without any commercial or financial relationships that might represent a conflict of interest.

## Author Contribution

AR: Conceptualization, Data curation, Formal analysis, Methodology, Investigation, Visualization, Writing – original draft; Writing – review and editing; AP: Methodology, Investigation, Writing – review and editing; SP: Investigation, Writing – review and editing

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