The Functional Importance of Forbs in Grassland Ecosystems

F. Siebert
North-West University, South Africa

C. Morris
Agricultural Research Council, South Africa

S. Chamane
University of KwaZulu-Natal, South Africa

N. Ntuli
University of Zululand, South Africa

S. J. Siebert
North-West University, South Africa

The functional importance of forbs in grassland ecosystems

Siebert, F*[1]; Morris, C[2]; Chamane, S[3]; Ntuli, N[4]; Siebert, SJ[1]
*[1] Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa;
[2]Agricultural Research Council - Animal Production Institute (ARC-API)
c/o School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, Pietermaritzburg, South Africa;
[3]School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, Pietermaritzburg, South Africa;
[4]Department of Botany, University of Zululand, KwaDlangezwa, South Africa

Key words: rangeland; forage; food and medicinal plants; invertebrates; indicator species

Abstract
Herbaceous vegetation in grassland ecosystems is characterised by grass dominance in a species-rich forb-grass mixture. Forbs (i.e. the non-graminoid herbaceous component) represent the largest proportion of total species- and functional richness, which secure important ecosystem functions. Although grasses remain the most important forage source, certain forb species provide nutritious food sources for herbivores. Moreover, forbs provide food- and habitat sources to enhance invertebrate diversity and hence, agricultural food security through the maintenance of healthy pollinator communities. Important food and medicinal sources for human livelihoods in developing countries are also largely contributed by forbs. However, the dynamics and ecology of forb species are poorly understood in rangeland systems. Increasing global pressures are threatening the hyper-diverse grassland ecosystems (including African savannas) and in particular the diversity of the forb flora. The sub-ordinate role of forbs in savanna and grassland rangeland management practices led us to accumulate evidence of important ecosystem functions and services provided by this diverse life form. In this study, we present results that were obtained from several independent studies in which forb data were collected and analysed as an equally important herbaceous life form, to contribute to our current understanding of the ecology of grassland ecosystems. Our results revealed evidence of forbs as important forage for large African mammalian herbivores, including domestic cattle, during periods when other forage resources are severely limited. However, sustained overgrazing can severely deplete forb populations and diversity. Forbs as grazing indicators have been identified as the basis of a proposed forb-condition scoring method for mesic grasslands. Furthermore, the importance of intermediate disturbances, such as moderate grazing and/or the maintenance of crop field margins were identified for invertebrate community conservation. Studies on useful indigenous plants exposed forbs as an important life form to provide food- and medicinal resources to human livelihoods in African grassland ecosystems.

Introduction
The understanding of herbaceous vegetation ecology stands central to the management of grassland ecosystems globally. Despite their richness and abundance in the herbaceous layer, forbs are weekly represented in grassland management strategies (Siebert and Dreber 2019). In rangeland condition assessments, forbs are often classified as the 'non-grassy, Increaser II' component of the herbaceous layer (Scott-Shaw and Morris 2015) and yet they provide a wide array of important functions and services (Siebert and Dreber 2019). Furthermore, forbs are acknowledged as important forage items to certain African game species, while forb consumption by domestic cattle at certain times of the year is frequently observed and documented (Veblen et al. 2016). Forbs furthermore provide nutritious forage for insects (Siebert and Terblanche 2020) and hence, play an important role in pollination-driven food security. Such evidence is however, loosely defined for 'forbs' as an entire life form group with little reference to species-specific functions. Considering the rich forb flora of grassland ecosystems, species-specific functions and services, and their responses to disturbances, stress and management regimes should be treated equally important as grasses, for which species-specific responses are well documented and clearly defined in grassland ecosystems.

In this study, we aimed to summarise certain functions and services identified from several independent grassland studies from South Africa, in which forb species data were collected and analysed as an equally important life form.

Forb species- and functional diversity

Forbs in grassy ecosystems can contribute up to 80% of the total richness in the herbaceous layer (Siebert and Scogings 2015). Species richness provide trait-based redundancy, as was reported in a semi-arid grassy ecosystem where perennial palatable forb (PPF) and grass species alternated their dominance in response to grazing pressure and rainfall (Van Coller et al. 2018). Thorough floristic surveys of the herbaceous layer can therefore provide valuable insights into ecosystem functioning and resilience.

Forbs have an extensive collection of disturbance tolerant- or avoidance traits that span across the wide array of plant families represented by this life form. In semi-arid and arid grassy biomes, forbs are well equipped to tolerate or avoid the effects of extended dry periods or drought events (Siebert et al. 2020). A variety of underground water and/or carbon storage organs, belowground and soil surface buds to enhance their resprouting capacity (Siebert et al. 2019), and drought avoidance strategies through the maintenance of a viable, dormant seed bank (Siebert et al. 2020), are only some examples how forbs are functionally equipped to withstand natural disturbances. Conversely, certain forb species are strongly dependent on natural disturbances. Post-fire or post-drought phenological traits, and fire- or herbivory-dependent seed germination or dispersal mechanisms (Wigley et al. 2020), explicate the dependency of certain forb taxa on such natural disturbances.

Forbs as foraged items for large herbivores

Forbs are known as nutritious food items for mixed feeders and domestic cattle, although species-specific selection, palatability and digestibility is less known (Siebert and Dreber 2019). Similar to trees and shrubs, browsed forb species, such as *Blepharis integrifolia*, may adapt their growth form from erect (in the absence of herbivores) to a prostrate form producing abundant flowers armed with spiny bracts that also cover the nutritious leaves.

The role of forbs in providing alternative nutritious food resources when grasses are depleted, e.g. during a drought or in overgrazed rangelands, are not well documented. Preliminary results from a DNA metabarcoding study identified forb species from the Convolvulaceae and Malvaceae plant families as important forb forage items in the diet of native African mixed feeders and domestic cattle during a dry season (Siebert et al. unpublished data).

Mesic forbs as grazing indicators

Herbaceous forb species far outnumber (5-6 x) grasses in the densely tufted, productive, mesic grasslands in the summer rainfall regions of South Africa (> 650 mm a^{-1}). Many of the mesic grassland forbs are geophytes possessing underground bud and energy storage organs (USOs) - ranging from woody rootstocks and rhizomes to more substantial corms and bulbs - that enable them to tolerate recurrent frost, dormant-season fire, and dry spring periods (Bond and Parr 2010). Despite having most of their biomass ostensibly protected underground, mesic forbs are vulnerable to herbivory (Scott-Shaw and Morris 2015; Chamane et al. 2017), with chronic heavy stocking with livestock markedly reducing forb species abundance by up to 85% (from 50–55 to 10–20 species per 100 m^2). Certain mesic forbs are particularly sensitive, declining with sustained herbivory, whereas mostly non-native ruderals along with only a few indigenous forbs benefit from sustained overgrazing. The former species have been classified as Decreaser (that decline with overgrazing), and the latter as Increaser (that increase with overgrazing) grazing indicator species for use in assessing the impact of grazing on the ecological condition and plant species diversity of mesic grassland (Morris and Scott-Shaw 2019).

Decreaser indicator forbs decline because of leaf and shoot damage by trampling and/or grazing (Chamane et al. 2017). Forbs with erect growth form are most sensitive, and prostrate forbs are most resistant, to herbivory (Chamane et al. 2017; Morris and Scott-Shaw 2018; Chamane et al. 2019). Most erect species are Decreasers, whereas prostrate species are typically Increasers because they tend to escape extensive leaf and bud damage (Figure 1). Frequent loss of leaf tissue during the growing season can diminish the USOs of mesic forbs, thereby reducing their regrowth potential and probable long-term survival in overgrazed mesic grassland (C Morris, unpublished data; Chamane et al. 2019).

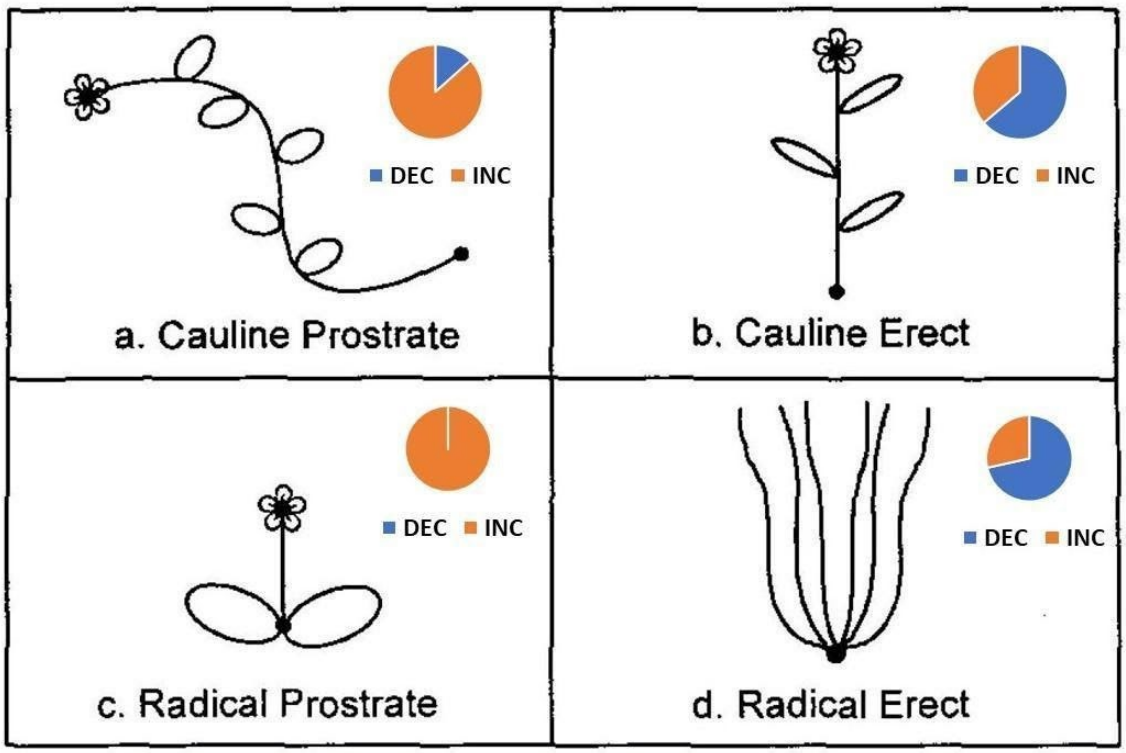

Figure 1: The distribution of mesic grassland forb growth forms across Decreaser (DEC) and Increaser (INC) grazing indicator species (data from Morris and Scott-Shaw 2019; Chamane et al. 2017). Point of leaf emergence is either cauline (from stem) or radical (at or below ground) and plant orientation is either erect or prostrate.

Forbs as insect hosts plants

Large-scale cultivation, mining and urbanisation lead to plant diversity decreases in grassland and savanna ecosystems as a result of habitat loss and land transformation (Muller et al. 2021). As forb species provide important provisioning and regulating services which are important to maintain arthropod biodiversity in these altered habitats and vice versa (Potts et al. 2010), forb loss has a cascading effect in higher trophic levels involving insects. Forbs species from wildlife conservation areas have proven to be specific hosts for butterfly larva and this interaction is delicately maintained by megaherbivores that suppress the grass layer (Siebert and Terblanche 2020). The interactions of forbs and insects are not always positive and some disservices are well known. Some forbs act as refuges for pest species during unfavourable conditions (Moolman et al. 2014) or displace grasses which provide important habitat structure for predacious arthropods such as spiders (Botha et al. 2017). It is therefore important to consider which arthropods need to be enhanced or restricted in an ecosystem when forbs are managed within a landscape. Managing for specific plant genera or families may therefore benefit specific arthropod trait groups at the expense of others (Skaldina 2020).

Grassland forbs with food and medicinal properties

Wild leafy vegetables are commonly herbaceous plants, whose leaves, tender shoots, flowers, fruits, seeds and sometimes roots are edible (Ntuli 2019). They are fortified with carbohydrates, micro- and macronutrients, vitamins and proteins that are essential for human health (Tanor et al. 2020). Such vegetables include both annual and perennial forbs that occur in grasslands and savanna vegetation, as well as in cultivated areas or fallow fields (Ntuli et al. 2012, Mncwango et al. 2020). The growth forms range from erect, decumbent to climbing (Ntuli et al. 2012). Leaves and shoot tips are the commonly consumed parts in leafy vegetables, with the inclusion of flowers, fruits and seeds to a lesser extent. Some forb species provide multiple services. For instance, *Amaranthus thunbergii*, a leafy vegetable forb species, is also used as livestock fodder (Eshete et al. 2016) and as a medicinal infusion taken orally as a vermifuge and to cleanse blood (Moteetee and Van Wyk 2011).

Conclusions

The growing awareness of the crucial ecological role that forbs play in grassland requires that management of these grasslands be aimed not just at maximising productivity of grasses in the sward, but also at maintaining the diverse grassland forb populations that provide a myriad of goods and services. Forb traits and indices should also be included in the assessment and monitoring of the functional integrity of grassland ecosystems. Considering that our current understanding of grassland ecology has been built upon solid foundations of species-specific research on grasses, similar fundamental species-specific research on forbs are envisaged to contribute to an improved understanding of grassland ecology and hence its restoration, conservation and management for long-term sustainability in the face of complex global change.

References

Bond, W.J. and Parr, C.L. 2010. Beyond the forest edge: ecology, diversity and conservation of the grassy biomes. *Biol. Conserv.*, 143: 2395-2404.

Botha, M., Siebert, S.J. and Van den Berg, J. 2017. Grass abundance maintains positive plant–arthropod diversity relationships in maize fields and margins in South Africa. *Agric. For. Entomol.*, 19: 154–162.

Chamane, S.C., Kirkman, K.P., Morris, C.D. and O'Connor, T.G. 2017. Does high-density stocking affect perennial forbs in mesic grassland? *Afr. J. Range For. Sci.*, 34: 133–142.

Chamane, S.C., Kirkman, K.P., Morris, C.D. and O'Connor, T.G. 2019. Response of three mesic South African perennial grassland forbs to defoliation and competition. *Afr. J. Range For. Sci.*, 36: 191–195.

Eshete, M.A., Afsaw, Z. and Kelbessa, E. 2016. A review on taxonomic and use diversity of the family Amaranthaceae in Ethiopia. *J. Med. Plants Stud.*, 4(2): 185–194.

Mncwango, N.C., Mavengahama, S., Ntuli, N.R. and Van Jaarsveld, C.M. 2020. Diversity, consumption dynamics and ethnomedical claims of traditional leafy vegetables consumed by a rural community in the KwaMbonambi area, northern KwaZulu-Natal, South Africa. *Biodiversitas*, 21(3): 1201–1207.

Moolman, H.J., Van den Berg, J., Conlong, D., Cugala, D., Siebert, S.J. and Le Ru, B.P. 2014. Species diversity and distribution of lepidopteran stem borers in South Africa and Mozambique. *J. Appl. Entomol.*, 138: 52–66.

Morris, C.D. and Scott-Shaw, R. 2019. Potential grazing indicator forbs for two mesic grasslands in South Africa. *Ecol. Indic.*, 107: 105611.

Moteetee, A. and Van Wyk, B-E. 2011. The medicinal ethnobotany of Lesotho: a review. *Bothalia*, 41(1): 209–228.

Muller, M., Siebert, S.J., Ntloko, B.R. and Siebert, F. 2021. A floristic assessment of grassland diversity loss in South Africa. *Bothalia* 51(1), a11.

Ntuli, N.R. 2019. Nutrient content of scarcely known wild leafy vegetables from northern KwaZulu-Natal, South Africa. *S. Afr. J. Bot.*, 127: 19–24.

Ntuli, N.R., Zobolo, A.M., Siebert, S.J. and Madakadze, R.M. 2012. Traditional vegetables of northern KwaZulu-Natal, South Africa: Has indigenous knowledge expanded the menu? *Afr. J. Agric. Res.*, 7(45): 6027–6034.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O. and Kunin, W.E. 2010. Global pollinator declines: Trends, impacts and drivers. *Trends Ecol. Evol.*, 25: 345–353.

Scott-Shaw, R. and Morris, C.D. 2015. Grazing depletes forb species diversity in the mesic grasslands of KwaZulu-Natal, South Africa. *Afr. J. Range For. Sci.*, 32: 21–31.

Siebert, F. and Scogings, P. 2015. Browsing intensity of herbaceous forbs across a semi-arid savanna catenal sequence. *S. Afr. J. Bot.*, 100: 69–74.

Siebert F, and Dreber N. 2019. Forb ecology research in dry savannas: knowledge, gaps and future perspectives. *Ecol. Evol.*, 9(13): 7875–7891.

Siebert, F., Bertolosi Bombo, A., Archibald, S., Greve, M. and Fidelis, A. 2019. Introducing bud bank and belowground plant organ research to South Africa: report-back on a workshop and the way forward. *S. Afr. J. Sci.*, 115(11-12): 1–2.

Siebert, F., Klem, J. and Van Coller, H. 2020. Forb community responses to an extensive drought in two contrasting land-use types of a semi-arid Lowveld savanna. *Afr. J. Range For. Sci.*, 37(1): 53-64.

Siebert, F. and Terblanche, R. 2020. Surprise green feasts. *Veld & Flora*, 106: 20–23.

Skaldina, O. 2020. Insects associated with sweet fennel: beneficial visitors attracted by a generalist plant. *Arthropod Plant Interact.*, 14: 399-407.

Van Coller, H., Siebert, F., Scogings, P. and Ellis, S. 2018. Herbaceous responses to herbivory, fire and rainfall variability differ between grasses and forbs. *S. Afr. J. Bot.*, 119: 91–103.

Veblen, K.E., Porensky, L.M., Riginos, C. and Young, T.P. 2016. Are cattle surrogate wildlife? Savanna plant community composition explained by total herbivory more than herbivore type. *Ecol. Appl.*, 26(6): 1610–1623.

Wigley, B.J., Charles-Dominique, T., Hempson, G.P., Stevens, N., TeBeest, M., Archibald, S., Bond, W.J., Bunney, K., Coetsee, C., Donaldson, D., Fidelis, A., Go, X., Gignoux, G., Lehmann, C., Massad, C.J., Midgley, J.J., Millan, M., Schwilk, D., Siebert, F., Solofondranohatra, C., Staver, A.C., Zhou, Y. and Kruger, L.M. 2020. A handbook for the standardised sampling of plant functional traits in disturbance-prone ecosystems, with a focus on open ecosystems. *Aus. J. Bot.*, 68(8): 473–531.