Reassessing and expanding the Forage Value Index: native plants and pastoral communities of the Chaco Serrano

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Research

Abstract

Background: The use of ecological indices in ecology is a widely expanded strategy to synthesize and compare complex natural systems by using quantitative variables such as species abundance, diversity, composition, and ecosystem structure. This study proposes a reassessment of the Forage Value Index (FVI) by integrating ethnobotanical criteria to better capture the functional and cultural importance of native forage plants in the Chaco Serrano (northwestern Argentina).

Methods: An enriched Forage Value Index (eFVI) was developed by incorporating locally defined variables, including palatability, abundance, accessibility, seasonal availability, livestock specificity, and plant parts consumed. Data were collected through ethnobotanical fieldwork conducted with rural pastoral communities quantitatively analyzed by relativizing index values to improve comparability across species.

Results: The eFVI integrates ethnobotanical variables to more accurately reflect local forage selection practices in pastoral systems. A total of 129 forage species were documented, among which 26 were identified as key species. The results indicate that forage preference is primarily determined by livestock type, forage quality-palatability, and annual availability. These findings underscore the value of local knowledge in ecosystem management as a foundation for promoting sustainable and autonomous livestock production.

Conclusions: The eFVI constitutes a robust, dynamic, and context-sensitive tool that effectively integrates ecological data with local knowledge. Native species with high index values should be prioritized in the design of management and conservation strategies. Ethnobotanical approaches deepen the understanding of plant and local communities' relationships, thereby supporting biodiversity conservation, autonomous livestock production, and food security in pastoral systems across arid and semi-arid regions.

Keywords: Ethnobotany; Forage plants; Livestock; Rural communities; Catamarca; Argentina

Background

Ethnobotanical studies assessing the relationship between local communities and forage plants used in livestock production have gained increasing relevance worldwide. Local ecological knowledge contributes to the sustainable management of plant resources that support livestock production and rural food systems (Nunes *et al.* 2015, Harun *et al.* 2017, Xie *et al.* 2023). Local practices of selection, use, and management of forage plant species are crucial in socioecological pastoral systems (Galaty & Johnson 1990). For this reason, the central role of plants in complex processes related to peasant economies, livestock production, regional food security, transhumance, and the adaptation and resilience of human communities in diverse environments has been widely discussed (Fernández-Giménez 2000, Ladio & Lozada 2004, Rivera 2014, Volpato & King 2019).

Forage can be defined as any edible and non-harmful part of a plant that has nutritional value, is available, and is accepted for animal consumption (Huss *et al.* 1996, Jiménez-Escobar 2019). However, the parameters used to determine forage quality are not always clearly established and may vary depending on the socioenvironmental context in which the resource is used. In general terms, forage quality is commonly expressed in relation to characteristics such as palatability, temporal availability, consumption level, the type of livestock that consumes it, and digestibility (Roig 2003, Ledesma *et al.* 2017, Marquez *et al.* 2024). Additionally, multiple variables associated with plant type, plant part consumed, phenological stage, and growing season, as well as climatic conditions, soil characteristics, grazing site, stocking rate, and the presence of secondary compounds, among many others, may be incorporated into assessments of forage quality (Lyons *et al.* 2001).

The use of ecological indices in ecology is a widely expanded strategy to synthesize and compare complex natural systems by using quantitative variables such as species abundance, diversity, composition and ecosystem structure (Moreno 2001, Magurran 2004). Over the past few decades, adaptations of these indices have been applied in studies focused on biological and cultural conservation, to evaluate processes of species valuation and prioritization from socioecological perspectives (Reyes-García *et al.* 2006, Rahman *et al.* 2019, Yebouk 2025). However, some authors highlight key methodological difficulties in the use of indices in these contexts, as they are not always accompanied by robust theoretical frameworks (Gaoue *et al.* 2017), or fail to fully capture important dimensions related to the perceptions, uses, and functionality of species in local contexts or in specific ones, such as ethnopharmacological contexts (Leonti 2022). Only when indices are articulated with more qualitative and ethnographic approaches can they serve as reliable indicators or proxies. In this vein, ethnobiology provides an inclusive framework that allows for the incorporation of local ecological knowledge into the formulation of indicators and indices, which enriches their interpretive scope (Toledo & Barrera-Bassols 2014, Berkes 2018). The integration of socioecological variables with local categories not only improves the representation of species functionality but also fosters dialogue between academic and local knowledge systems (Furlan *et al*. 2020). We consider that the integration of ethnobiology and ecology in the formulation of indices is particularly relevant for the study and management of socioecological systems in arid and semi-arid environments worldwide, where environmental variability demands complex adaptive strategies.

To synthesize the available information for the comprehensive assessment of forage resources, Scarpa (2007) proposed the Forage Value Index (FVI), which quantitatively integrates the spatio-temporal availability and quality of wild forage plants used by peasant communities of the semi-arid Chacoan forest in Formosa Province, Argentina. This is an important tool for evaluating the relative importance of plant species within local productive systems. However, its application presents some limitations. Several of its criteria are derived from the literature or from general assessments that do not always capture local variability. Indeed, the author acknowledges that the index was subjectively adjusted based on the annual consumption period, harvestable biomass, and resource accessibility by animals. Integrating locally defined preference criteria and incorporating ethnographic data generated within the communities themselves are therefore essential steps toward improving this index. Moreover, the FVI does not incorporate the relativization of total forage values, which limits comparability across diverse socioecological contexts and restricts its capacity to represent the relative importance of species. These limitations constitute the primary starting point of the present study.

The present study proposes to reassess the FVI with the aim of broadening, refining, and contextualizing the assessment of forage resources through an approach that integrates socioecological variables and local knowledge. To this end, we propose an enriched FVI in which the variables considered are derived from local criteria, that is, variables emerging from the experiences, perceptions, and practices of local communities. In this way, both the analytical categories and the evaluation criteria are grounded in situated knowledge. The objectives of this study are to test the enriched FVI using a case study on forage knowledge from pastoral communities of the Catamarca province (Argentina) and to address three main questions: What local criteria (variable) do local communities highlight to select a forage species? Which native plants are consumed by livestock? and which plant species are most relevant according to the proposed FVI? Finally, we discuss aspects related to local classifications systems and their potential application on the valorization of native plant resources in rural contexts.

Materials and Methods

Study area

The Sierra de Ancasti is in the eastern part of Catamarca province (Fig. 1). It belongs to the Pampean mountain systems, reaching elevations above 1,300 m asl., and is located within the Arid Chaco biogeographic province (Chaco-Serrano district). The study area includes the rural communities of Anquincila, El Taco, Ipizca, Río los Molinos, and Villa de Ancasti, all of which belong administratively to the department of Ancasti (28°23'29.3"S, 65°20'65.4"W). This region presents a warm and humid climate, with a mean annual temperature of 19°C and precipitation ranging from 500 to 1,200 mm per year, concentrated during the summer season (Palmeri *et al.* 2008. The characterized vegetation is represented by dominant species of the Chaco Serrano, including *Lithraea molleoides* (Vell.) Engl., *Geoffroea decorticans* (Gillies ex Hook. & Arn) Burkart., *Parasenegalia visco* (Lorentz ex Griseb.) Seigler & Ebinger, *Ruprechtia apetala* Wedd. and *Zanthoxylum coco* Gillies ex Hook. f. & Arn.) but also includes species characteristic of other environments such as montes, bolsones and yungas forests, including *Anadenanthera colubrina* (Vell.) Brenan, *Erythroxylum argentinum* (O.E. Schulz), and *Xylosma pubescens* (Griseb.)

Figure 1. Location and landscapes of the study area, Sierra de Ancasti, eastern Catamarca Province, Argentina. Figure modified from Jiménez-Escobar (2021).

According to recent data from the National Institute of Statistics and Census (INDEC, 2022), the department of Ancasti accounts for approximately 0.8% of the total provincial population, with 3,302 inhabitants and a population density of 1.7 inhabitants per km². The population has limited access to basic services: only 59% of the population living in private households has access to the public water supply network (INDEC, 2022). Regarding healthcare access, merely 53% of the population has some form of medical coverage (social security, or public or private insurance). The regional economy is primarily associated with the production of three types of livestock: goat (*Capra aegagrus*), sheep (*Ovis orientalis*), and cattle (*Bos taurus*). According to Ramisch *et al.* (2009), cattle production is significant in the region; however, goat and sheep farming predominate. These animals roam in open range and may be raised as a single species or in combination, though always separately, cattle apart from goats and sheep. (Jiménez-Escobar 2019).

Data Analysis

The list of native species follows the taxonomic nomenclature established in the Catalogue of Vascular Plants of the Southern Cone (Zuloaga *et al.* 2019), corroborated with the World Flora Online Plant List (WFO, 2023). Voucher specimens were deposited in the Herbarium of the Botanical Museum (CORD), at the Multidisciplinary Institute of Plant Biology (IMBIV), Universidad Nacional de Córdoba and CONICET, Argentina.

The Forage Value Index (FVI) proposed by Scarpa (2007) qualitatively assesses the relative importance of each wild species as forage, based on its forage quality, estimated according to animal preference (P), and its relative annual supply, estimated according to availability (A). In accordance with our objectives, and to improve comparability and more accurately represent the importance of species in specific socioecological contexts, we incorporated locally defined preference criteria and relativized total values. The enriched index follows the equation:

$$\mathrm{FVI}_{(i,j)} = \frac{Ab_i + Ac_i + Qu_i + Aa_i + Li_{i,j} + Pp_i}{P_{i,j}} \quad (1)$$

$$\mathrm{eFVI}_{(i)} = \frac{\mathrm{FVI}_{(i,j)}}{\max(\mathrm{FVI})} \quad (2)$$

Ab = Abundance - 1 (scarce), 2 (frequent), 3 (abundant)
Ac = Accessibility - 1 (very difficult), 2 (difficult), 3 (easy)
Qu = Quality-Palatability - 1 (coarse/hard), 2 (soft), 3 (very soft)
Aa = Annual availability - 1 (one season), 2 (two seasons), 3 (three or four seasons)
Li = Livestock type - 1 (exclusive to one type), 2 (two types), 3 (three or more types)
Pp = Plant parts consumed - 1 (one part), 2 (two parts), 3 (whole plant or three or more parts)
P = Preference - 1 (primary), 2 (secondary), 3 (tertiary)

Thus, raw FVI ranges from 6/3 = 2 to 18/1 = 18. The eFVI relativizes values to the maximum recorded FVI, yielding a scale from 0 to 1, which allows for comparison across species and socioecological contexts.

During previous ethnobiological fieldwork, we identified local criteria to assess the importance of forage species (see Jiménez-Escobar 2019, Jiménez-Escobar & Martínez 2019). Based on these locally defined valuations, forage preference (P) was classified into three categories: "Primary" forages refer to highly important species, explicitly identified as preferred or actively consumed by animals (index value = 1). "Secondary" forages include species with specific attributes, or those used as emergency resources during periods of scarcity, such as winter or drought (value = 2). "Tertiary" forages include plants with no evident desirable qualities, generally corresponding to plant parts consumed opportunistically, occasionally, or under conditions of extreme scarcity (value = 3).

The translation of local narratives into numerical values followed systematic criteria. For example, statements such as *"un montón, una banda"* ("a lot"), *"hay muchísimo"* ("there is plenty"), and *"crece por todas partes"* ("it grows everywhere") were coded as 3 (abundant); expressions such as *"aquí hay, pero más para el Alto"* ("there are some here, but more for the Alto"), *"se ve"* ("it can be spotted"), and *"se encuentra fácil"* ("it is easy to find") were coded as 2 (frequent); and statements such as *"ahora casi no hay"* ("there is hardly any now"), *"antes se encontraba"* ("it used to be found"), *"ya no se ve más"* ("it can no longer be spotted"), and *"aquí ya no hay"* ("there is none left here") were coded as 1 (scarce). This same procedure was applied to each of the six availability variables, defined as follows: Abundance (Ab): the relative density of a species in the landscape, expressed as "abundant" (3), "frequent" (2), or "scarce" (1). Accessibility (Ac): determined by plant habit (e.g., tree, herb) and habitat (e.g., rupicolous, epiphytic), and scored according to ease of acquisition as "easy" (3), "difficult" (2), or "very difficult" (1). Quality-Palatability (Qu): assessed according to perceived palatability, scored as "very soft" (3), "soft" (2), or "coarse or hard" (1). Annual availability (Aa): based on the number of seasons during which the plant is consumed, scored as three or four seasons (3), two seasons (2), or one season (1). Livestock type (Li): indicating whether the plant is consumed by three or more types of livestock (3), two types (2), or exclusively by one type (1). Plant parts consumed (Pp): scored as the whole plant or three or more distinct parts — including leaves, fruits, flowers, stems, and roots — (3), two parts (2), or a single part (1).

Preference (P) was recorded directly from informants' qualitative assessments (primary, secondary, tertiary) during semi-structured interviews, independently of the variables used to calculate Availability (A). This independence allows for subsequent statistical validation of the relationship between P and the components of A, avoiding circularity in the index construction. To evaluate the relationship between forage preference (P) and availability-related variables (local criteria), a multiple linear regression analysis was performed using preference as the dependent variable and the following predictors: abundance (Ab), accessibility (Ac), quality-palatability Qu), annual availability (Aa), livestock type (Li), and plant parts consumed (Pp). This approach allowed us to assess the relative contribution of each variable while controlling for the effects of the others. Analyses were conducted using PAST statistical software version 4.02 (Hammer et al. 2001), based on a dataset compiled in Microsoft Excel.

Results

Enriched index and highlighted forage variables

To establish the value hierarchy of native plant resources, 117 plant records corresponding to 129 forage species were evaluated (Table 1). The number of species exceeds the number of records because some plants grouped under a single vernacular name by herders may correspond to multiple taxonomic species (e.g., **azahar** a common name that includes at least five species of the genus *Tillandsia*).

Preference (P) indicates that primary forages (those considered of high quality) show lower species richness, comprising 26 species (20% of the total; Fig. 2). In contrast, secondary and tertiary forages, regarded as emergency resources consumed opportunistically, occasionally, or under conditions of scarcity, account for most of the native plant richness (103 spp., 80%). Regarding availability (A), frequent species predominate (47 spp., 36%), and most are easily accessible to livestock (71 spp., 55%). More than one-third of the species exhibit high quality-palatability (54 spp., 42%), and annual availability is concentrated in one or two seasons for 70% of the species. Goats show the highest consumption diversity (89%), followed by cattle (62%) and sheep (55%). Additionally, half of the species (50%) are consumed by at least three types of livestock, and most species are consumed either entirely or through multiple plant parts (72%; Fig. 2).

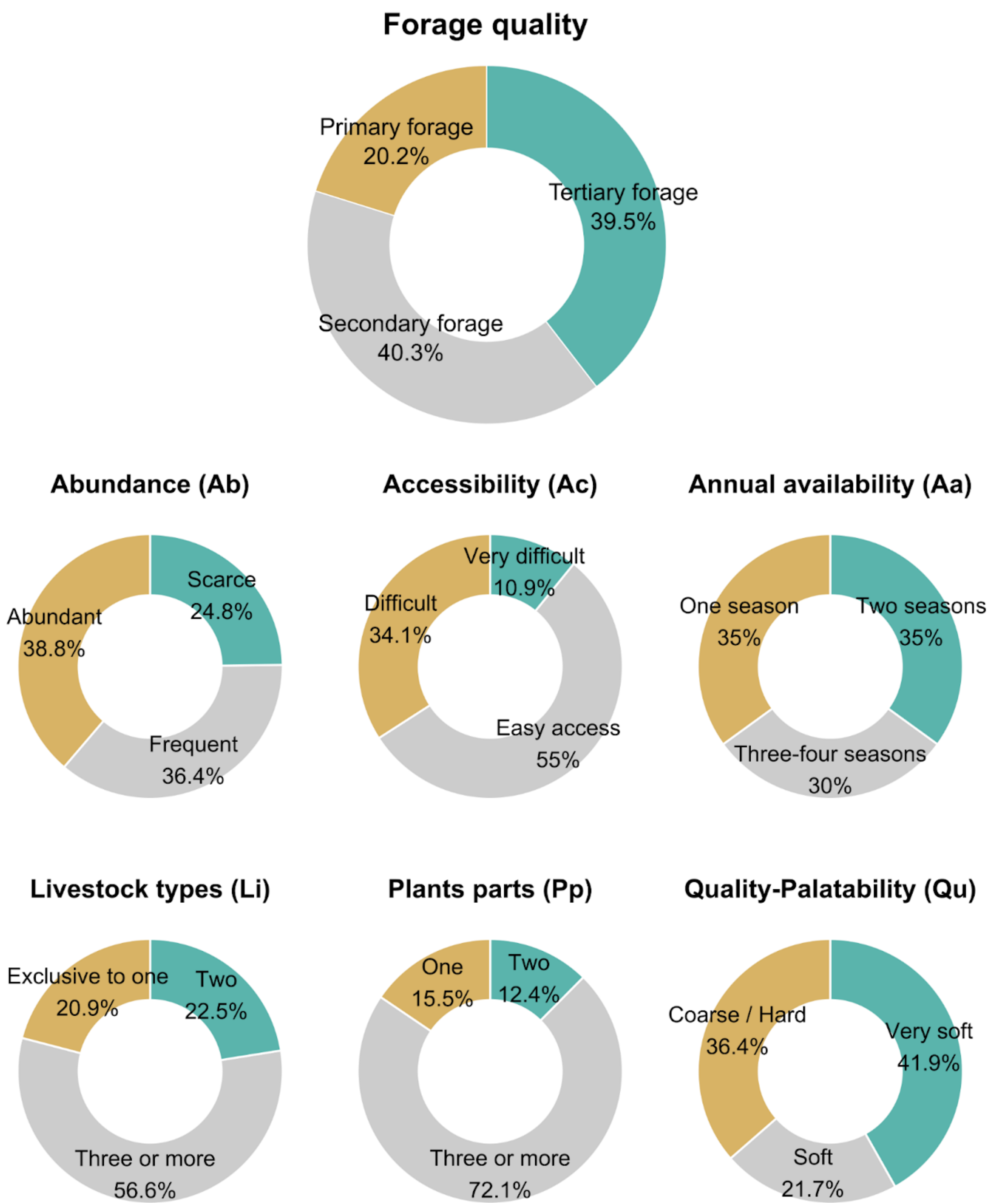

Figure 2. Percentage of species per forage variables evaluated to calculate the Preference (P) and the Availability (A) of native plants of Chaco Serrano, Argentina.

Table 1. Expanded Forage Value Index (eFVI) for native plant species consumed by livestock in pastoral communities of Chaco Serrano, Argentina. Species are arranged according to the Forage Value Index (FVI). Common names; species without common name (NN). A: Availability (Abundance: Ab; Accessibility: Ac; Quality-Palatability: Qu; Annual availability: Aa; Livestock consuming the species: Li; Plant parts consumed: Pp). P: Preference. eFVI: values standardized according to the maximum value.

Family	**Species**	**Common name**	**Voucher No.**	**Ab**	**Ac**	**Qu**	**Aa**	**Li**	**Pp**	**P**	**FVI (A/P)**	**eFVI**
Loranthaceae	*Ligaria cuneifolia* (Ruiz & Pav.) Tiegh.	liga	NDJ 2281	3	2	3	3	3	3	1	17,0	1,00
Loranthaceae	*Struthanthus uraguensis* (Hook. & Arn.) G. Don	liga	GJM 1241	3	2	3	3	3	3	1	17,0	1,00
Poacea	*Bothriochloa springfieldii* (Gould) Parodi	pasto	GJM 1271	2	3	3	2	3	3	1	16,0	0,94
Poacea	*Cenchrus pilcomayensis* (Mez) Morrone	pasto simbol	NDJ 2259	2	3	3	2	3	3	1	16,0	0,94
Fabaceae	*Mimosa farinosa* Griseb.	shinqui	NDJ 2023	3	2	3	2	3	3	1	16,0	0,94
Bromeliaceae	*Tillandsia argentina* C.H. Wright	azahar	NDJ 2000	3	3	1	3	3	3	1	16,0	0,94
Bromeliaceae	*Tillandsia duratii* Vis.	azahar	NDJ 2021	3	3	1	3	3	3	1	16,0	0,94
Bromeliaceae	*Tillandsia ixioides* Griseb.	azahar	NDJ 1983	3	3	1	3	3	3	1	16,0	0,94
Bromeliaceae	*Tillandsia lorentziana* Griseb.	azahar	GJM 1050	3	3	1	3	3	3	1	16,0	0,94
Bromeliaceae	*Tillandsia xiphioides* Ker Gawl.	azahar	NC	3	3	1	3	3	3	1	16,0	0,94
Fabaceae	*Vachellia aroma* (Gillies ex Hook. & Arn.) Seigler & Ebinger	algarrobilla, tusca, tusquilla	NDJ 2014	3	2	3	3	3	2	1	16,0	0,94
Fabaceae	*Vachellia caven* (Molina) Seigler & Ebinger	churqui	GJM 871	3	2	3	3	3	2	1	16,0	0,94
Rhamnaceae	*Condalia buxifolia* Reissek	piquillín	GJM 881	3	2	3	2	2	3	1	15,0	0,88
Rhamnaceae	*Condalia microphylla* Cav.	piquillín	GJM 1285	3	2	3	2	2	3	1	15,0	0,88
Rhamnaceae	*Condalia montana* A. Cast.	piquillín	GJM 1290	3	2	3	2	2	3	1	15,0	0,88
Fabaceae	*Neltuma alba* (Griseb.) C.E. Hughes & G.P. Lewis	algarrobo	GJM 1166	2	2	3	3	3	2	1	15,0	0,88
Fabaceae	*Neltuma nigra* (Griseb.) C.E. Hughes & G.P. Lewis	algarrobo	GJM 1216	2	2	3	3	3	2	1	15,0	0,88
Poacea	*Paspalum notatum* Flüggé	grama colorada, gramilla	NDJ 2234	1	3	3	2	3	3	1	15,0	0,88
Amaranthaceae	*Amaranthus spinosus* L.	ataco	GJM 931	3	1	3	1	3	3	1	14,0	0,82
Poacea	*Bromus catharticus* Vahl	cebadilla	NDJ 2372	2	2	2	2	3	3	1	14,0	0,82
Fabaceae	*Geoffroea decorticans* (Gillies ex Hook. & Arn.) Burkart	chañar	NDJ 2219	3	2	3	2	3	1	1	14,0	0,82
Poacea	*Hordeum stenostachys* Godr.	cebadilla	NDJ 2385	2	2	2	2	3	3	1	14,0	0,82
Poacea	*Jarava leptostachya* (Griseb.) F. Rojas	paja	NDJ 2306	1	3	3	1	3	3	1	14,0	0,82

Rhamnaceae	*Sarcomphalus mistol* (Griseb.) Hauenschild	mistol	GJM 944	2	2	3	2	3	2	1	14,0	0,82
Poacea	*Leptochloa fusca* (L.) Kunth	pasto	GJM 2241	2	3	2	1	2	3	1	13,0	0,76
Poacea	*Poa calchaquiensis* Hack.	pasto	NDJ 2272	1	3	3	1	2	3	1	13,0	0,76
Cactaceae	*Cereus forbesii* Otto ex C.F. Först.	ucle, cacto de san Juan	NDJ 2300	3	2	3	3	3	3	2	8,5	0,50
Poacea	*Setaria* Ach. ex Michx. sp.1	pasto	GJM 1270	3	3	3	1	3	3	2	8,5	0,50
Bromeliaceae	*Tillandsia capillaris* Ruiz & Pav.	azahar pispito, clavel del aire	NDJ 2010	3	2	3	3	3	3	2	8,5	0,50
Bromeliaceae	*Tillandsia minutiflora* Donadío	azahar pispito, clavel del aire	NDJ 2017	3	2	3	3	3	3	2	8,5	0,50
Sapindaceae	*Allophylus edulis* (A. St.-Hil., A. Juss. & Cambess.) Hieron. ex Niederl.	chal-chal	GJM 899	3	3	3	3	3	1	2	8,0	0,47
Scrophulariaceae	*Buddleja mendozensis* Benth.	salvia blanca	NDJ 2247	2	3	3	2	3	3	2	8,0	0,47
Poacea	*Cenchrus spinifex* Cav.	roseta	NDJ 2283	2	3	3	2	3	3	2	8,0	0,47
Poacea	*Eragrostis orthoclada* Hack.	pasto	NDJ 2305	2	3	3	2	3	3	2	8,0	0,47
Poacea	*Jarava ichu* Ruiz & Pav.	paja (brava, de techar, dura, gruesa)	NDJ 2228	3	3	2	2	3	3	2	8,0	0,47
Poacea	*Jarava pseudoichu* (Caro) F. Rojas	paja (brava, de techar, dura, gruesa)	NDJ 2380	3	3	2	2	3	3	2	8,0	0,47
Myrtaceae	*Myrcianthes cisplatensis* (Cambess.) O. Berg	huil, mato huil	GJM 895	3	2	2	3	3	3	2	8,0	0,47
Cactaceae	*Opuntia sulphurea* Gillies ex Salm-Dyck	quiscaludo, quishcaloro	NC	3	1	3	3	3	3	2	8,0	0,47
Poacea	*Setaria lachnea* (Nees) Kunth	pasto	NDJ 2358	2	3	3	2	3	3	2	8,0	0,47
Poacea	*Sporobolus phleoides* Hack.	pasto	NDJ 2384	3	3	2	2	3	3	2	8,0	0,47
Fabaceae	*Anadenanthera colubrina* (Vell.) Brenan	cébil	NDJ 2341	3	2	3	2	3	2	2	7,5	0,44
Poacea	*Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn.	cortadera	NDJ 2242	2	3	3	2	2	3	2	7,5	0,44
Ephedraceae	*Ephedra tweediana* Fisch. & C.A. Mey. emend. J.H. Hunz.	tramontana	NDJ 1987	3	2	1	3	3	3	2	7,5	0,44
Poacea	*Eustachys retusa* (Lag.) Kunth	pasto ¨tipo¨gramilla	NDJ 2278	2	3	3	1	3	3	2	7,5	0,44
Verbenaceae	*Lippia junelliana* (Moldenke) Tronc.	salvia de campo, salvia	NDJ 2260	3	3	3	2	3	1	2	7,5	0,44
Fabaceae	*Parasenegalia visco* (Lorentz ex Griseb.) Seigler & Ebinger	viscote, viscote negro	NDJ 2277	3	2	3	2	3	2	2	7,5	0,44

Cyperaceae	*Rhynchospora* cf. *rugosa* (Vahl) Gale	pasto	NDJ 2273	1	3	2	1	3	3	2	7,5	0,44
Rhamnaceae	*Colletia spinosissima* J.F. Gmel.	tola, tola-tola	NDJ 2007	2	2	2	2	3	3	2	7,0	0,41
Poacea	*Festuca hieronymi* Hack.	paja	NDJ 2376	1	2	2	3	3	3	2	7,0	0,41
Poacea	*Jarava plumosa* (Spreng.) S.W.L. Jacobs & J. Everett	pasto	NDJ 2381	1	3	2	2	3	3	2	7,0	0,41
Anacardiaceae	*Lithraea molleoides* (Vell.) Engl.	molle (cordobés, de beber)	GJM 883	3	2	1	3	3	2	2	7,0	0,41
Poacea	*Nassella argentinensis* (Speg.) Peñailillo	cebadilla	NDJ 2383	2	3	2	1	3	3	2	7,0	0,41
Poacea	*Nassella catamarcensis* Torres	cebadilla	NDJ 2018	2	3	2	1	3	3	2	7,0	0,41
Fabaceae	*Parapiptadenia excelsa* (Griseb.) Burkart	viscote colorado	GJM 1057	3	2	3	2	2	2	2	7,0	0,41
Poacea	*Paspalum malacophyllum* Trin.	pasto	NDJ 2274	2	3	2	1	3	3	2	7,0	0,41
Salicaceae	*Salix humboldtiana* Willd.	sauce, sauce llorón	GJM 929	2	2	3	2	3	2	2	7,0	0,41
Poacea	*Setaria cordobensis* R.A.W. Herrm.	pasto	GJM 1272	1	3	2	1	3	3	2	7,0	0,41
Loranthaceae	*Tripodanthus acutifolius* (Ruiz & Pav.) Tiegh.	corpo, corpus	NDJ 2284	3	2	2	3	1	3	2	7,0	0,41
Cannaceae	*Canna indica* L.	achera	NC	2	3	3	2	1	2	2	6,5	0,38
Malvaceae	*Ceiba chodatii* (Hassl.) Ravenna	palo borracho	NDJ 2296	1	3	2	2	3	2	2	6,5	0,38
Cyperaceae	*Cyperus corymbosus* Rottb.	pasto colorado	NDJ 1991	1	3	2	1	3	3	2	6,5	0,38
Cyperaceae	*Cyperus haspan* L.	pasto	NDJ 2236	1	3	2	1	3	3	2	6,5	0,38
Cyperaceae	*Cyperus niger* Ruiz & Pav.	paja	NDJ 2251	1	3	2	1	3	3	2	6,5	0,38
Juglandaceae	*Juglans australis* Griseb.	nogal, nogal cimarrón	NDJ 2020	2	2	3	2	3	1	2	6,5	0,38
Poacea	*Nassella* cf. *tenuissima* (Trin.) Barkworth	cebadilla	NDJ 2374	1	3	2	1	3	3	2	6,5	0,38
Anacardiaceae	*Schinus fasciculata* (Griseb.) I.M. Johnst.	molle (incienso, pispo, sonso, tonto)	GJM 1263	3	2	1	3	2	2	2	6,5	0,38
Cannabaceae	*Celtis pallida* Torr.	horco tala, tala macho	NDJ 2249	2	2	1	1	3	3	2	6,0	0,35
Cannabaceae	*Celtis tala* Gillies ex Planch.	tala (hembra, pispito, solito)	NDJ 2295	2	2	1	1	3	3	2	6,0	0,35
Poacea	*Gouinia latifolia* (Griseb.) Vasey	cebadilla	NDJ 2356	2	3	2	2	1	2	2	6,0	0,35
Zygophyllaceae	*Porlieria microphylla* (Baill.) Descole, O´Donell & Lourteig	caspicuchara, frutilla negra, monte crespo, pan de cata	GJM 934	3	2	1	3	2	1	2	6,0	0,35
Cactaceae	*Echinopsis aurea* Britton & Rose	machocorota, machocorote	NDJ 2280	3	3	3	3	2	3	3	5,7	0,33

Poacea	*Disakisperma dubium* (Kunth) P.M. Peterson & N.W. Snow	pasto	NDJ 2321	1	3	1	2	1	3	2	5,5	0,32
Amaranthaceae	*Gomphrena haenkeana* Mart.	NN	NDJ 2315	1	1	3	1	2	3	2	5,5	0,32
Poacea	*Setaria parviflora* (Poir.) Kerguélen	pasto	NDJ 2240	1	1	3	1	2	3	2	5,5	0,32
Cactaceae	*Trichocereus terscheckii* (J. Parm. ex Pfeiff.) Britton & Rose	achuma, cardón	NDJ 2301	3	1	1	3	2	1	2	5,5	0,32
Convolvulaceae	*Ipomoea* L. sp. 1	porotillo, suspiro	NDJ 2354	3	3	3	1	3	3	3	5,3	0,31
Convolvulaceae	*Ipomoea purpurea* (L.) Roth	porotillo, suspiro	NDJ 2232	3	3	3	1	3	3	3	5,3	0,31
Verbenaceae	*Aloysia gratissima* (Gillies & Hook. ex Hook.) Tronc.	palo amarillo, poleo del campo	GJM 878	3	1	3	2	3	3	3	5,0	0,29
Euphorbiaceae	*Croton lachnostachyus* Baill.	tinajera	NDJ 2256	3	1	3	3	2	3	3	5,0	0,29
Bromeliaceae	*Dyckia floribunda* Griseb.	chaguar	NC	1	3	1	1	3	1	2	5,0	0,29
Bromeliaceae	*Dyckia longipetala* Baker	chaguar	NDJ 2322	1	3	1	1	3	1	2	5,0	0,29
Araliaceae	*Hydrocotyle ranunculoides* L. f.	arandela del agua, redondo del agua	NDJ 2015	2	3	1	3	3	3	3	5,0	0,29
Asteraceae	*Pseudognaphalium* Kirp. sp.1	salvia blanca	NDJ 2311	2	3	3	2	2	3	3	5,0	0,29
Bromeliaceae	*Puya spathacea* (Griseb.) Mez	chaguar	NDJ 1992	1	3	1	1	3	1	2	5,0	0,29
Polygonaceae	*Ruprechtia apetala* Wedd.	chicharra, chuluca, churrusca	GJM 865	2	2	1	2	2	1	2	5,0	0,29
Asteraceae	*Schkuhria pinnata* (Lam.) Kuntze ex Thell.	canchalagua, matapulgas	GJM 860	3	2	3	3	1	3	3	5,0	0,29
Asteraceae	*Achyrocline satureioides* (Lam.) DC.	salvia silvestre	GJM 1284	3	1	3	3	1	3	3	4,7	0,27
Malpighiaceae	*Heteropterys dumetorum* (Griseb.) Nied.	loconte amarillo	GJM 1202	3	3	2	2	1	3	3	4,7	0,27
Poacea	*Setaria macrostachya* Kunth	cadillo	NDJ 2264	2	3	1	2	3	3	3	4,7	0,27
Solanaceae	*Solanum chacoense* Bitter	papilla	NDJ 2266	3	3	3	3	1	1	3	4,7	0,27
Urticaceae	*Urtica circularis* (Hicken) Sorarú	rupachico, ortiga	GJM 1314	2	3	2	1	3	3	3	4,7	0,27
Asteraceae	*Acanthospermum hispidum* DC.	orquetilla	NDJ 2292	2	2	3	1	2	3	3	4,3	0,25
Poacea	*Bouteloua megapotamica* (Spreng.) Kuntze	pasto, paja fina	NDJ 2289	2	3	1	1	3	3	3	4,3	0,25
Euphorbiaceae	*Cnidoscolus tubulosus* (Müll. Arg.) I.M. Johnst.	ya te veo	GJM 885	3	2	3	3	1	1	3	4,3	0,25
Apiaceae	*Eryngium ebracteatum* Lam.	escorcera, escorsonera	NDJ 2233	2	3	3	1	2	2	3	4,3	0,25
Asteraceae	*Gaillardia megapotamica* (Spreng.) Baker	botón de oro, topasaire	NDJ 2254	2	3	1	2	2	3	3	4,3	0,25

Verbenaceae	*Glandularia peruviana* (L.) Small	sangre de Cristo	GJM 857	3	1	3	2	1	3	3	4,3	0,25
Cactaceae	*Harrisia pomanensis* (F.A.C. Weber ex K. Schum.) Britton & Rose	ulva	GJM 1104	3	1	2	3	2	2	3	4,3	0,25
Solanaceae	*Petunia axillaris* (Lam.) Britton, Stern & Poggenb.	bocinita, pepinia del campo	NDJ 2290	3	3	1	1	2	3	3	4,3	0,25
Solanaceae	*Solanum argentinum* Bitter & Lillo	malfato	GJM 951	2	3	1	3	1	3	3	4,3	0,25
Malvaceae	*Sphaeralcea bonariensis* (Cav.) Griseb.	malva, malva blanca	GJM 854	3	3	1	2	3	1	3	4,3	0,25
Anemiaceae	*Anemia tomentosa* (Savigny) Sw.	doradilla	GJM 877	2	3	1	2	1	3	3	4,0	0,24
Salviniaceae	*Azolla filiculoides* Lam.	cresta de gallo	NDJ 2022	2	3	1	2	1	3	3	4,0	0,24
Asteraceae	*Baccharis flabellata* Hook. & Arn.	clavillo	NDJ 2245	2	3	1	2	3	1	3	4,0	0,24
Asteraceae	*Baccharis ulicina* Hook. & Arn.	yerba oveja	NDJ 2268	3	2	1	2	1	3	3	4,0	0,24
Lamiaceae	*Hedeoma multiflora* Benth.	tomillo	GJM 1257	2	2	2	2	1	3	3	4,0	0,24
Lytraceae	*Heimia salicifolia* Link	arupaco, quiebraarado	NDJ 2258	1	3	1	2	2	3	3	4,0	0,24
Rosaceae	*Margyricarpus pinnatus* (Lam.) Kuntze	huevito de la perdiz, manzanita, perlita	GJM 866	1	3	1	1	3	3	3	4,0	0,24
Oxalidaceae	*Oxalis conorrhiza* Jacq.	saladillo, vinagrillo	NDJ 2252	1	3	2	1	2	3	3	4,0	0,24
Asteraceae	*Pectis odorata* Griseb.	manzanilla (del campo, dulce)	NDJ 2320	1	3	2	1	2	3	3	4,0	0,24
Asteraceae	*Zinnia peruviana* (L.) L.	chinita	NDJ 2248	2	3	1	1	2	3	3	4,0	0,24
Fabaceae	*Adesmia muricata* (Jacq.) DC.	boca de pato	NDJ 2004	1	2	1	1	3	3	3	3,7	0,22
Ranunculaceae	*Anemone decapetala* Ard.	cebolla del zorro	NDJ 1989	1	3	1	1	2	3	3	3,7	0,22
Poacea	*Aristida adscensionis* L.	pasto, pasto flecha	NDJ 2293	2	3	1	1	1	3	3	3,7	0,22
Cactaceae	*Cleistocactus smaragdiflorus* (F.A.C. Weber) Britton & Rose	alaba, cola de zorro	NC	1	2	1	3	3	1	3	3,7	0,22
Pteridaceae	*Doryopteris triphylla* (Lam.) Christ	helecho negrillo, negrillo	GJM 1277	1	3	1	2	1	3	3	3,7	0,22
Amaranthaceae	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	paico	GJM 947	2	3	1	1	1	3	3	3,7	0,22
Araceae	*Lemna gibba* L.	rojilla	NDJ 2016	2	3	1	1	1	3	3	3,7	0,22
Solanaceae	*Nicotiana longiflora* Cav.	flor de sapo, yerba de sapo	GJM 1045	2	3	1	1	1	3	3	3,7	0,22
Cactaceae	*Opuntia salmiana* J. Parm. ex Pfeiff.	cola de león	NDJ 2296	2	2	1	3	2	1	3	3,7	0,22
Asteraceae	*Parthenium hysterophorus* L.	altamisa	NDJ 2291	2	3	1	1	1	3	3	3,7	0,22

Polygonaceae	*Polygonum acuminatum* Kunth	duraznillo, ruibarbo	NDJ 2237	2	2	1	2	1	3	3	3,7	0,22
Solanaceae	*Vassobia breviflora* (Sendtn.) Hunz.	piscoyuyo, piscoyuyo blanco	GJM 926	1	1	3	1	2	3	3	3,7	0,22
Nygtaginaceae	*Bougainvillea stipitata* Griseb.	espinillo	GJM 896	2	1	3	2	1	1	3	3,3	0,20
Cactaceae	*Cleistocactus baumannii* (Lem.) Lem.	bola de gato, huevo de gato	GJM 1088	1	1	1	3	1	3	3	3,3	0,20
Orchidaceae	*Gomesa bifolia* (Sims) M.W. Chase & N.H. Williams	margarita	NDJ 2299	1	1	1	2	2	3	3	3,3	0,20
Fabaceae	*Prosopis sericantha* Gillies ex Hook. & Arn.	albardón	GJM 1217	1	3	1	1	1	1	3	2,7	0,16
Simaroubaceae	*Castela coccinea* Griseb.	mistolillo	GJM 1167	1	2	1	1	1	1	3	2,3	0,14
Solanaceae	*Lycium cestroides* Schltdl.	piscoyuyo	NDJ 2267	1	2	1	1	1	1	3	2,3	0,14

Multiple linear regression analysis revealed that forage preference (P) was significantly explained by livestock type ($\beta = -0.433 \pm 0.070$, $p < 0.001$), quality-palatability ($\beta = -0.197 \pm 0.068$, $p = 0.004$), and annual availability ($\beta = -0.179 \pm 0.086$, $p = 0.040$). In contrast, abundance ($\beta = -0.002 \pm 0.085$, $p = 0.978$), accessibility ($\beta = -0.047 \pm 0.088$, $p = 0.597$), and plant parts consumed ($\beta = -0.041 \pm 0.074$, $p = 0.581$) showed no significant effects. These results indicate that forage selection in the Chaco Serrano is primarily driven by perceived quality and availability, as well as by the type of livestock consuming them (Fig. 3).

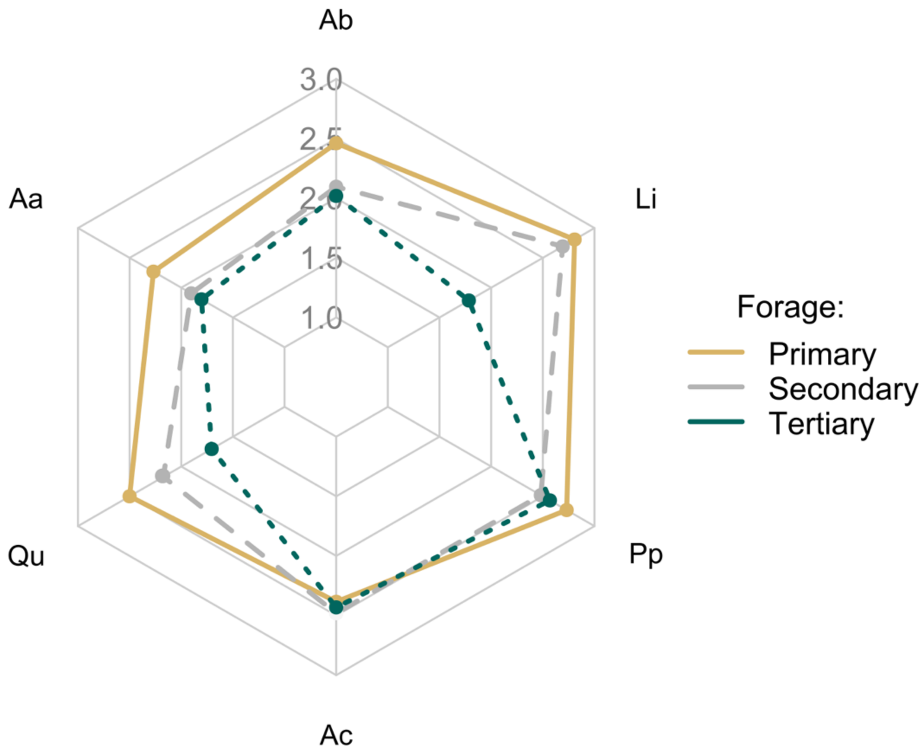

Figure 3. Mean values of the variables of the availability (A) according to forage preference (primary, secondary, tertiary).

Native plants consumed by livestock

The reported native plant species (Fig. 4), belong to 41 families and 95 botanical genera. The family Poaceae showed the highest species richness (30), followed by Fabaceae (11), Asteraceae (10), Bromeliaceae (10), and Cactaceae (8). The genus with the greatest number of species was *Tillandsia* (7), followed by *Setaria* (5), *Jarava* (4), *Condalia* (3), *Cyperus* (3), and *Nassella* (3). When species were grouped by growth form, herbaceous plants were the most representative biological form (57%), followed by shrubs and subshrubs (27%), trees (14%), and vines (2%).

Most relevant forage species

The species from the Sierra de Ancasti that achieved the highest forage relevance values according to the eFVI are two hemiparasitic plants, both locally known as **ligas** (*Ligaria cuneifolia* and *Struthanthus uraguensis*) which reached the maximum reference value of the index (1.00) (Table 1). Other native species that ranked highly under the eFVI include herbaceous species such as *Bothriochloa springfieldii* and *Cenchrus pilcomayensis*, epiphytes such as *Tillandsia* spp., and woody species including *Mimosa farinosa*, *Neltuma* spp., *Vachellia aroma,* and *Vachellia caven*. Only 20% of the recorded species are classified as highly important or of high forage relevance (eFVI values > 0.75), whereas the remaining 80% are considered of medium to low importance.

Figure 4. Native plants consumed by farm animals in the Sierra de Ancasti, Chaco Serrano, Argentina. A) shepherdess with her sheep. B) **azahar** (*Tillandsia ixioides*). C) **achuma** (*Trichocereus terscheckii*). D) **shinqui** (*Mimosa farinosa*). E) **corpo** (*Tripodanthus acutifolius*). F) **palo de borracho** (*Ceiba chodatii*). G) **pasto** (*Paspalum notatum*). H) **chal-chal** (*Allophylus edulis*). I) **salvia de campo** (*Lippia junelliana*). Photos: N.D. Jiménez-Escobar.

Discussion

In this study, we propose and test the enriched forage value index (eFVI) as a context-sensitive tool that incorporates local pastoral knowledge and practices to evaluate the importance of plant resources used as forage. The eFVI incorporates key variables from an ethnobiological perspective —such as forage quality and palatability, seasonal availability, abundance, accessibility, livestock type, and plant parts consumed— integrating locally defined criteria and relativizing the obtained forage values, thereby improving its capacity to reflect the forage selection criteria in specific socioecological contexts. In Argentina, where livestock farming holds an important historical, cultural, and economic significance, the identification of forage species and the assessment of their differential management are crucial (see Califano 2020), as they not only optimize livestock feeding, but also reduce dependence on external inputs, thereby supporting autonomous livestock production in contexts of high environmental variability.

Unlike the original FVI (Scarpa 2007), where Availability was a value containing some subjective ecological criteria, our eFVI operationalizes Availability as the sum of six locally-defined variables, each assessed on a three-point Likert scale. This operationalization enhances replicability by providing explicit coding criteria for translating local narratives into numerical values. Furthermore, the independence of Preference (P) from the components of Availability allows for statistical validation of the relationships between these dimensions, strengthening the index's empirical grounding.

What local criteria do local communities highlight to select a forage species?

We found that preference (P) is primarily explained by livestock type, forage quality and availability. These results suggest that forage selection in the pastoral systems of the Chaco Serrano is not determined exclusively by the population, morphological, or structural characteristics of plants (e.g., abundance, growth form, or plant parts consumed), but is instead shaped by the relationships among livestock, and plants, as well as by locally defined ecological evaluation criteria and locally recognized attributes linked to resource quality and reliability (e.g., presence during specific seasons). Similar patterns have been documented in pastoral communities of other arid and semi-arid regions. For example, in Pakistan and China, forage selection incorporates local ecological knowledge related to nutritional value, seasonal persistence, and livestock productive response (Harun *et al.* 2017, Xie *et al.* 2023). In this regard, the results can be interpreted within the framework of biocultural memory, in which accumulated environmental knowledge allows for the optimization of resource use in variable or restrictive environments, such as arid and semi-arid systems worldwide (Toledo & Barrera-Bassols 2014).

Which native plants are consumed by livestock?

The number of species recorded as forage plants in this study (129) represents more than a quarter of those documented for the region in recent reviews of the Argentine ethnoflora (Palchetti *et al.* 2023) and in specific studies of the Arid Chaco of Córdoba (Marquez *et al.* 2025). This highlights the floristic richness of the Chaco serrano and the extent of ecological knowledge held by local pastoral communities of the region. Compared to other studies conducted in arid and semi-arid regions of the country, this richness can be considered high (Scarpa 2007, Muiño 2010, Quiroga-Mendiola 2011). The assessment of this diversity constitutes a fundamental baseline for the design of livestock management strategies in pastoral communities, since greater species richness implies a broader resource supply, promotes diversification of animal diet, and helps mitigate risks associated with critical periods, such as droughts or harsh winters, as well as socioeconomic vulnerability contexts.

Which plant species are most relevant according to the proposed FVI?

According to the proposed FVI we identify 26 relevant forage species, distinguished by their high eFVI values (between 1 and 0.76). These species exhibit distinct characteristics and may be associated with forage gaps; for instance, summer fruit-producing species (*Condalia* spp., *Geoffroea decorticans*, and *Sarcomphalus mistol*), arboreal and shrub legumes (*Mimosa farinosa*, *Neltuma* spp., *Vachellia aroma*, and *V. caven*), epiphytic forage plants (*Tillandsia* spp.), hemiparasitic plants (*Ligaria cuneifolia* and *Struthanthus uraguensis*), and native pastures (*Bothriochloa springfieldi*, *Bromus catharticus*, *Cenchrus pilcomayensis*, etc). The valuation of the so-called emergency forages, species used under adverse environmental conditions, is fundamental for understanding local strategies, since, although they do not constitute the basis of sustainable livestock systems (Díaz 2007), they structure practices such as searching, gathering, harvesting, and storage, evidencing their relevance in the organization of rural life (Jiménez-Escobar 2015, Quiroga & Trillo 2022).

As originally proposed by Scarpa (2007), the calculation of the FVI through ratios assigns proportionally lower values to secondary and tertiary forages relative to primary forages, which may generate a certain overestimation of species considered to be of higher quality. For this reason, it is also worth noting the role of cacti species used during dry periods, such as *Cereus forbesii*, *Opuntia sulphurea*, and *Trichocereus terscheckii*, which, although not included among the 26 most relevant species, also showed high eFVI values. At the same time, the index may underestimate relevant species that are rarely mentioned, as is the case with various grasses locally grouped under the category of "pastizales" (grasslands). These local classification units encompass a high diversity of Poaceae, which are fundamental in animal feeding, whose low mention frequency may be related to morphological similarities among species and taxonomic ambiguities related to local processes of ethnobotanical grouping, similarly to what has been documented in silvopastoral communities of the Semi-arid Chaco (Roger, 2020).

Finally, the hierarchical assessment of native forage plants, as proposed in this study, can be understood as the capacity to maintain autonomous productive systems that secure the nutritional base of livestock and, by extension, peasant livelihoods (Altieri & Toledo 2011, Vía Campesina 2018). This reinforces the idea that livestock farming constitutes a structural axis of the social and cultural organization of Chaco Serrano communities. Consequently, the knowledge associated with forage plants can be interpreted as a fundamental biocultural mechanism for sustaining not only livestock production, but also social reproduction of peasant life.

Conclusion

The values estimated through the enriched Forage Value Index should be interpreted as dynamic and context-sensitive estimates, subject to temporal variation and conditioned by environmental, climatic, ecological, and social factors that influence plant use and management. Native plant species with high index values emerge as priorities for the design of management and conservation strategies, as well as for the assessment of their population status and nutritional contribution. Particularly emergency forages can be key for local contexts characterized by long seasons of very low food availability and therefore deserve attention in arid and semi-arid environments. The application of quantitative indices constitutes a valuable methodological tool for integrating academic frameworks with local knowledge systems. In this regard, the ethnobotanical approach enables a deeper understanding of the relationships between communities and plant resources, by integrating ecological, functional, and cultural dimensions that sustain livestock production in arid and semi-arid environments. Recognizing and valuing local knowledge not only contributes to biodiversity conservation, but also fosters productive autonomy, food sovereignty, territorial belonging, and sustainable rural development.

Declarations

List of abbreviations: FVI - Forage Value Index; eFVI - enriched Forage Value Index; A - Availability; P - Preference; Aa - Annual availability; Ab - Abundance; Ac - Accessibility; Li - Livestock types; Pp - Plants parts; Qu - Quality-Palatability; Species without common name - NN.

Ethics approval and consent to participate: The study was conducted following ethical guidelines for research on traditional knowledge. Municipal authorities of the department of Ancasti were informed about the research project and its objectives. A research agreement was established with the Secretariat of Environment and Sustainable Development of Catamarca Province (File No. 28950/15). Verbal informed consent was obtained from all participating shepherds in the Sierra de Ancasti prior data collection. Participation was voluntary, and all information was documented with respect for confidentiality and cultural sensitivity.

Consent for publication: Not applicable.

Availability of data and materials: The dataset analyzed during this study is available from the corresponding author on reasonable request.

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