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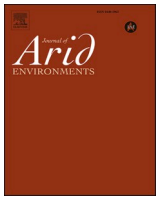

Local ecological knowledge of forage plants for goat farming and perceptions about pollination of tree species in the arid Chaco

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ABSTRACT

Local ecological knowledge (LEK) of forage resources available in the forest is crucial in the sustainability of extensive grazing systems in the arid Chaco region. Here, we document goat farming management strategies of local peasants, assess their LEK about forage plants and evaluate the local perception related to pollination of native tree species. We used semi-structured interviews to obtain ethnoecological information and a cognitive approach to inquire about the plant species considered as fodder and their relative importance. Peasants listed a total of 48 ethnospecies (60 species from 23 botanical families) used as fodder. The most important forage plants in our study were *Neltuma* spp., *Sarcomphalus mistol* and *Castela coccinea*, which provide high quality fruits and also leaves as forage at different moments of the year. Local producers did not identify pollination as a key factor for the production of forage fruits, but they did emphasize the importance of climatic factors for fruit production. This ethnoecological information related to forage plants and factors that determine fruit production is important to understand peasant management systems that sustain local communities and play an important role in forest persistence.

1. Introduction

Ecologists and organizations dedicated to nature conservation recognize the importance of incorporating diverse knowledge from different sources and backgrounds, such as local and indigenous ecological knowledge along with scientific approaches, in management strategies to ensure sustainable ecosystem services provision (Tengo et al., 2014). Traditional or indigenous knowledge provides new insights into the relationship between humans and nature, offering alternative perspectives on environmental management and development (Mazzocchi, 2006). Moreover, the stated goal of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) highlights the importance of the recognition and respect for indigenous and local knowledge and its contribution to the conservation and sustainable use of wild species and ecosystems (IPBES, 2022). There are plenty of studies in the academic literature that promote complementarity across different knowledge systems and advance in the understanding of nature while improving the management of socio-ecological systems (e.g., Albuquerque et al., 2021; IPBES, 2022).

In the driest region of the Chaco forests of central Argentina land use management by peasant communities is retracting due to the growing demand for large-scale silvopastoral systems that have advanced into territories historically occupied by peasants with no formal tenure of the land (Cáceres, 2015). Peasants make multiple uses of the forest, exploiting timber and non-timber resources along with livestock farming, primary goats, that feed mainly on forage fruits, buds, and leaves of native plant species (e.g., Scarpa, 2007; Riat, 2012; Silvetti, 2020). So, forage provision by native plants represents a crucial ecosystem service for local peasant economies. Knowing goat's diet and the survey of local ecological knowledge (LEK) related to forage native plants can improve the efficiency of Chaco forests management and conservation (Jiménez-Escobar, 2019). In this vein, ethnobiology provides an appropriate approach to assess human and nature relations, local knowledge of the environment, and human cognition about nature

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(Wolverton, 2013).

Some of the most iconic and dominant tree species in the arid Chaco, such as *Neltuma* spp. (“Algarrobo”) and *Sarcomphalus mistol* (“Mistol”) are recognized as culturally important plants for local communities as they can be used as fodder, human food, medicine, and firewood as well as for the production of charcoal (e.g., Cavanna et al., 2010; Rueda et al., 2015; Jiménez-Escobar, 2019; Joseau et al., 2023). These trees produce large quantities of fruits with high sugar content, protein and minerals, representing a suitable fodder resource that can meet the grazing requirements of livestock (Cotroneo et al., 2016). These tree species fructify in the summer season (December–February) but the fruits can be stored and used during the winter forage gap (Scarpa, 2007; Quiroga and Trillo, 2022). Importantly enough, fruit production of these trees is highly dependent on insect pollinators, mainly bees, because of their self-incompatibility systems (Aguilar et al., 2012; Cerino et al., 2015). In fact, animal pollinators are responsible for the sexual reproduction of most native plant species, representing a key ecosystem service (Tong et al., 2023). As a result, pollination is crucial to promote the sustainability of socio-ecological systems and their ability to support livelihoods (Rehel et al., 2009). Thus, native forage plants, pollinators, people, and their livestock are irreducibly interrelated.

The pollination process is widely known in scientific fields and taught in formal schools. However, because pollination is a process that occurs at a microscopic level and is difficult to see with the naked eye, only some indigenous or peasant groups with historical ties to fruit production, such as the oasis farmers of the date palm (*Phoenix dactylifera* L.) in Egypt (Roué et al., 2015), identified this process in detail. In fact, according to studies carried out in different regions of the world, farmers often “lack” knowledge about the pollination process and the importance of insect pollinators for fruit and seed production (e.g., Kasina et al., 2009; Mpondo et al., 2021). Studies that evaluate local perceptions related to the pollination ecosystem service consider the production of fruits and their valuation (Cáceres, 2015) or the recognized number of pollinators (Wangchuk et al., 2021) as an approximation of LEK about the pollination process. These indirect valuation measures of the pollination service perception do not consider the interaction between pollinators and plants; that is, the more related variable to the pollination process itself. Most studies about LEK related to pollination have focused on cultivated plants from agricultural landscapes (e.g., Allen-Wardell et al., 2016). No study to our knowledge has assessed the local notions about the dependence of native trees on insect pollination to set fruits that are used as forage for livestock neither in the arid Chaco nor in other regions of the world.

In this study, we aim to document the management strategies of local peasant communities related to goat farming and assess their LEK about the set of native plants used as fodder for goats in the arid Chaco. We aim to answer the following questions: Which are the plant species identified as fodder for goat farming? and What is the relative importance of these species as fodder? We hypothesized that woody plants such as *Neltuma* spp. (“Algarrobo”) and *Sarcomphalus mistol* (“Mistol”) are among the most valuable forage species from local communities. Also, as fruit production of these species is among the main forage resources from local communities, we evaluate local perception related to the insect pollination of these tree species.

2. Materials and methods

2.1. Study area and local people

The study was conducted in a rural area located on the coast of the “Salinas de Ambargasta’’, on the limits between Cordoba and Santiago del Estero provinces (Argentina) between the localities of Lucio V. Mansilla (c.a., 75 km) and San Francisco del Chañar (c.a., 70 km) (Fig. 1). This area belongs to the driest expression of the Great Chaco with a strong hydric deficit due to the combined high mean temperature (34 °C) and low mean annual precipitation (300–500 mm) during the summer growth season, from November through March. The upper layer of the vegetation reaches up to 10 m in height and is constituted by the dominant trees *Aspidosperma quebracho-blanco*, *Neltuma flexuosa*, *Neltuma torquata*, *Sarcomphalus mistol* and the cacti *Stetsonia coryne*. The shrub layer varies between 3 and 4 m in height with *Mimozyganthus carinatus*, *Larrea divaricata*, *Senegalia gilliesii* and *Parkinsonia praecox* as the dominant species (Cabido and Zak, 1999). We will refer to the study area, according to local linguistic ascriptions, as *la costa* (the coast). The inhabitants of *la costa* have no access to basic services such as electric light, natural gas and potable water. The supply of drinking water has always been problematic due to the scarcity and deficiency in water quality in the area. The local peasant communities provide themselves

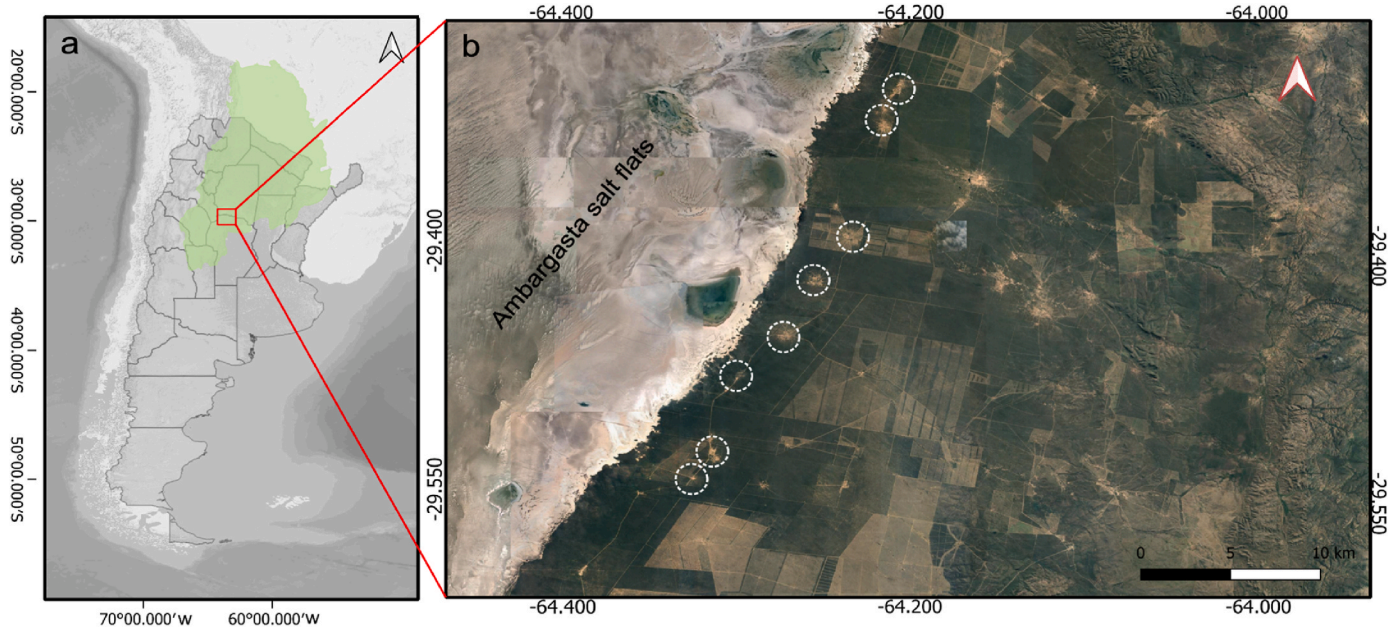

Fig. 1. Spatial location of the study area in the arid Chaco in Argentina (a). The green area in the map represents the Chaco bioregion. The rectangle observed in (a) presents the study area in the buffer zone of Ambargasta salt flat depicted in figure b. White circles indicate the areas where the family houses are located.

and their livestock with rainwater reservoirs (known as *represas*) and wells. These *represas* are non-cemented artificial dams that are filled with rainwater during the rainy months.

2.2. Ethnobiological study design

To obtain the ethnoecological information present in this study we conducted fieldwork from 2018 to 2020. We contacted the collaborators following the snowball method (Johnson, 2014) based on pre-established contacts with members of The Peasant Movement of Córdoba (MCC), a group of rural producers, founded in 2001 that brings together more than 1000 families in the north of Córdoba province. Many of the collaborators' families belong to MCC and call themselves peasants, consequently, this term was selected to qualify local knowledge, taking into account the self-definition of the community. We worked with rural families of diverse composition that live in more or less isolated areas of between 4 and 10 family groups. The group of collaborators consisted of 28 local goat producers older than 18 years old of both sexes. All of these people derive at least part of their family income from livestock farming. We followed the Latin American Society of Ethnobiology Code of Ethics guidelines (SOLAE et al., 2018).

We used semi-structured interviews as the main method to obtain ethnobiological information. We elaborated the semi-structured interviews after informal conversations with key informants and field recognition. The interviews comprised four different sections aiming to assess different aspects of peasant life and complete the objectives of the study. The first section was related to the personal information of the collaborators (age, occupation, family history, etc.). The second section aimed to assess topics related to goat management, i.e.: How are the goats managed, and what activities are carried out daily? Do you collect or store any plants to give to the goats in the pen? Do you do it every year? What period of the year do goats need the most care? Do you have a livestock guardian dog? When is a good year for goats? why? Finally, in the third section we assessed local perceptions about *Neltuma* spp. and *S. mistol* forage fruit production dependance on insect pollinators using relational questions: Do plants benefit from bees? or Do bees benefit from plants? Encounters were documented with different methodologies: videos, voice recordings, and notes in field notebooks.

To inquire about the plant species considered as fodder for goat farming and their relative importance, we used a cognitive approach and estimated their cognitive salience (Ross and Revilla-Minaya, 2011). This can be defined as the place occupied by different elements of nature (in our case forage plants) in human cognition and is generally obtained through the analysis of a set of free listings made from a motor question (e.g., Sutrop, 2001). The position in which the elements appear in the free listing is closely related to the salience: more salient elements appear first in the free listing. However, the cognitive salience that a community has about the elements of their environment, including forage plant species, depends on many factors such as their usefulness, abundance, size, conspicuousness and other cultural values (Zamudio and Hilgert, 2018). The motor question delimits the domain and guides the direction of the inquiry; it is possible to assume that the criteria determining the order of the items refer to forage importance for goats. However, this needs to be corroborated afterward. In our case, the free listings were made under the question "What plants do the goats eat in the forest?". After obtaining the first list, we asked again, "Any other that comes to your mind?". This approach did not imply a structured and fixed task, but rather it was developed within the framework of a dialogue in which other issues and referents related to goat farming and forage plants could be derived. With the set of individual lists, overall cognitive salience (CS) was calculated as: CS=F/(N mP); where F = Frequency of appearance of the item in the listings; mP = Average position of the item in all the lists; and N = total collaborators (Sutrop, 2001). This results in a unique list of ethnospecies (i.e., local plant species entities identified by local people with a vernacular name) that were ordered from highest to lowest cognitive salience, which varies between 0 (the least salience items) and 1 (the most salience items) and gives us an idea about the relative importance of the mentioned plants.

To corroborate the underlying criteria of the order given to the items in the previous free list, in another question section we asked the collaborators: "Which are the three **most important plants** for goat feeding?", "Can you please place them in order of importance?". We obtained a ranking list of three plants in order of importance and we calculated the cognitive salience of each one. We then evaluated the relationship between the cognitive salience of the plants obtained by free listing and the plants present in the ranking list using Pearson correlation coefficient. We did not include ethnospecies that were mentioned less than three times in this analysis because these species are considered of low consensus. This is a more rigorous criterion than the one commonly used (Benz et al., 1994), where only unique appointments are eliminated.

We identified the vernacular names that were synonymous and unified some ethnospecies, which according to our criteria and some of the consulted collaborators, corresponded to the same plant. The correspondence between the ethnospecies (i.e., according to the local classification) and the botanical species was carried out in conjunction with the collaborators by doing ethnobotanical walks to recognize species mentioned during the interviews (Albuquerque et al., 2014). Thus, for the generic local categories such as "Grasses" (Poaceae), "Jume'' (Chenopodioideae) and "Algarrobo" (*Neltuma* spp.) the scientific names of all related species present in the study area were included. When possible, we collected plants in their reproductive stage and deposited them in the Herbarium of the Botanical Museum (CORD) of the National University of Córdoba. All the identified species were linked to a voucher specimen available in the Herbarium of Botanical Museum or an observation in iNaturalist (https://www.inaturalist.org/), as proposed by Greene et al., 2023. When the plant specimens were not collected by us during field work the species was associated with a herbarium voucher of a specimen collected in the nearest place to the study area (see Table S1). The nomenclature and taxonomy of the recorded plant species and their categorization in different life forms (herbs, shrubs, and trees) were based on Flora Argentina (http://www.floraargentina.edu.ar/).

3. Results

3.1. Management strategies and livestock knowledge

Local peasants informed that livestock farming in the salt flats is family-based and the animals roam in the open field. Goat farming is carried out extensively on land that is under common use by several families or by the community. The common use of the territory is not always linked to land ownership and can be extended to private lands, as fences are not usually obstacles for the goats. In this area it is not a widespread practice to buy fodder, such as alfalfa (*Medicago sativa*) and corn (*Zea mays*), to feed the goats. Production is mainly oriented to *cabritos* (kids between 4 and 9 kg) destined for family consumption only (41% of the collaborators), family consumption and local sale (36%), and only local sale (23%). The commercialization of *cabritos* in local towns and cities is mediated by the *cabritero*, a man who frequents the study area with a truck looking for *cabritos* to buy or exchange (e.g., medicines, furniture) and then re-sells them.

The goats herd is composed mostly of female goats and one or two male goats (*chivos*). The herd is released in the morning for daily grazing in the forest, they are accompanied by a livestock mongrel guardian dog, known as *cabrero* (Fig. 2a). The great majority of the collaborators (74 %) have at least one livestock guardian dog in their pen. The *cabreros* are important in preventing attacks from the Puma (*Puma concolor*) and other animals, and thus they help to mitigate the conflicts between peasants and wildlife in *la costa*. Before nightfall, the herd of goats returns to the pen, and if they do not return, they have to be fetched, a task that is mainly carried out by men.

Fig. 2. Practices and management strategies associated with goat farming in the arid Chaco of central Argentina. a) Livestock mongrel guardian dog known as *cabrero*; b) Goats pen; c) Burlap bags with "Algarrobo" (*Neltuma* spp.) fruits; d) Structure known as *troja* used by local peasants to store algarrobo fruits (Pictures: Fernando Zamudio).

Goats have two kidding periods during the year, the first period takes place in winter (May–June) and the second one in the summer season (November–January). Winter kidding is the period of the year in which the goats need the most care, therefore, the activities related to goat rearing increase. For example, it is important to milk the goats before they go to the *monte* (forest) to avoid mastitis, identifying the goats that are near kidding and the *cabritos* that are not accepted by their mothers (i.e., *guachos*). The latter have to be fed by other goats or by giving them milk with baby bottles.

Collaborators mentioned that a good fruiting season from "Algarrobos" (*Neltuma* spp.) and "Mistol" (*Sarcomphalus mistol*) trees during the summer allows the goats to get by through the winter fatter and stronger. They mentioned that fruits of these species are important forage sources for livestock during the summer season, and also during the winter gap, as they can be stored and used as emergency forage (Fig. 2). More than half of the collaborators (57%) collect fruits of "Algarrobo" and "Mistol" to give to the goats in the pen. Even more, some of them collect these native fruits to sell them to large livestock producers in the area. The fruits are preserved in burlap bags and placed on a *troja*, a wooden structure that holds them up, and then covered with a plastic bag to prevent them from getting wet (Fig. 2). To prevent bugs from attacking the fruits, peasants keep the bags separated with a layer of "Atamisqui" (*Atamisquea emarginata*) and ash. Producers unanimously ensured that a rainy year (i.e., above annual average) is a good year for goats, as "the forest remains green for a longer period". It is also important that the rainy season starts earlier (October), and thus rainwater is available to be consumed by the goats.

3.2. Forages and plants consumed by goats

At the beginning of this section of the interviews, most of the collaborators answered that "goats eat all kinds of monte (forest)". However, when we asked for further information about this topic, collaborators reported a total of 48 forage ethnospecies corresponding to 60 species from 23 botanical families, consumed by goats in the arid Chaco forest (Table S1). Non-exact equivalence between ethnospecies and species is a typical pattern due in part to the fact that an ethnospecies could correspond to more than one biological species or due to locally used generic categories such as "grasses". Poaceae and Fabaceae were the families that presented the highest number of botanical species (11 each), followed by Cactaceae (6). Trees represented 20 % of the total species, shrubs 40 %, and herbs 40 %. Most plant species were native (49 species), 8 were endemic to Argentina, and 3 species were exotic and belonged to the Poaceae (*Cenchrus ciliaris* and *Megathyrsus maximus*) and Cactaceae family (*Opuntia ficus-indica*). This last species, known as "Tuna" or "Penca", was the most frequently mentioned cactus. Collaborators mentioned that it is highly palatable as goats "love it" and they have to fence the "Tunas" to avoid goats from eating them. This introduced species resists the arid conditions of the region and is planted near the houses or pens. It is widely used as forage for livestock (fruits and cladodes) and also for human consumption and production of *arrope* and jams.

The cognitive salience values (S) found by free listing were highly correlated with cognitive salience values obtained by the ranking question ($r\,(11) = 0.97$, $p < 0.001$), meaning that the cognitive salience of the free list items was explained by forage or feeding importance to the goats. The ranking, which was established as a hierarchy of the value of native forage plants, highlights the importance of 11 ethnospecies (22 % of the total). The highest values of cognitive importance were "Algarrobo", "Mistol" and "Mistollillo" (*Castela coccinea*) (Table 1; Fig. 1S.).

The importance of green forage was mentioned by some collaborators by its availability throughout the year; "Buds and leaves are as important as fruits, the fruits are seasonal, whereas the forest offers resources all the year round, dry or green but it persists". Collaborators frequently mentioned the importance of green forage of "Algarrobo" and "Mistol" especially in winter. Goats prefer "Mistol" and "Algarrobo" leaves in winter and they even eat them from the ground. Other ethnospecies were widely recognized as good forage for goats because they have specific properties used during the breeding season, such as the epiphytes "Liga" (*Struthanthus uraguensis*) and the "Azahar" (*Tillandsia duratii*), which appear to "make the goats produce more milk". Also, halophyte vegetation near the salt flats was mentioned as an important

Table 1
Value of cognitive salience of the most important ethnospecies mentioned in the free listing and the ranking list in the arid Chaco of central Argentina. Ethnospecies correspondences to biological species are shown in Table 1S.

Ethnospecies	Ranking	Free listing
Algarrobo	0.754	0.31
Mistol	0.746	0.26
Mistolillo	0.254	0.12
Grasses	0.2	0.1
Garabato	0.152	0.1
Lata	0.111	0.11
Liga	0.019	0.034
Chañar	0.019	0.032
Tusca	0.019	0.031
Albarilla	0.019	0.03
Tintitaco	0.019	0.024

resource, especially during the forage gap. Collaborators mentioned that in winter goats usually go near the salt flats to find something to eat. Some of the mentioned forage plants only grow in areas surrounding the salt flats and represent the dominant plant species from halophyte shrublands, such as the shrubby "Jumes" (*Allenrolfea patagonica* and *Heterostachys ritteriana*) and the endemic grass "Pasto Guanaco" (*Distichlis acerosa*).

3.3. Pollination perception

When we asked about perceptions related to insect pollination dependance of native trees (*Neltuma* spp. and *S. mistol*) to set fruits we found that 56 % of the collaborators believe that only bees benefit from the interaction with the plants, whereas 44 % answered that both plants and bees benefit from the interaction and no collaborator mentioned that only plants benefit.

Collaborators mentioned three decisive climatic factors for fruit production: precipitation, wind, and strong insolation (Fig. 3). They mentioned that scarce fruit production of "Algarrobo" and "Mistol" was related to the alteration in the precipitation regime, either a decrease in precipitation or changes in the rainy season. For example, one producer mentioned that "fruit production increases when precipitation does not exceed 20 or 30 mm". He mentioned that the problem is not the drought itself because these trees are adapted to arid conditions, the problem is when it does not rain frequently, and thus the fruits "burn", meaning that fruits in the trees do not reach maturity due to dehydration and have no forage value. In the same vein, another collaborator told us that it is important that the precipitations continue across the summer to prevent the fruits from "burning". This means that it is not only relevant how much it rains, but also when it rains. Furthermore, collaborators mentioned that "if it rains when the trees are flowering, the rain washes the flowers and fruits do not form". For them, it has to rain before and after the flowering peak for adequate fruit formation (see Fig. 3). Finally, another important factor that determines fruit production according to local people is the wind as it causes flowers to fall from the trees compromising fruit production.

4. Discussion

In this study, we assessed management practices related to goat farming, LEK about native forage plants and pollination of native trees. Our results contribute to understanding the importance of LEK in arid environments such as the arid Chaco of central Argentina for sustainable livestock management. Native forage plants used as fodder were diverse, and as we hypothesized, "Algarrobo" (*Neltuma* spp.) and "Mistol" (*S. mistol*) trees were the most important forage species in the area.

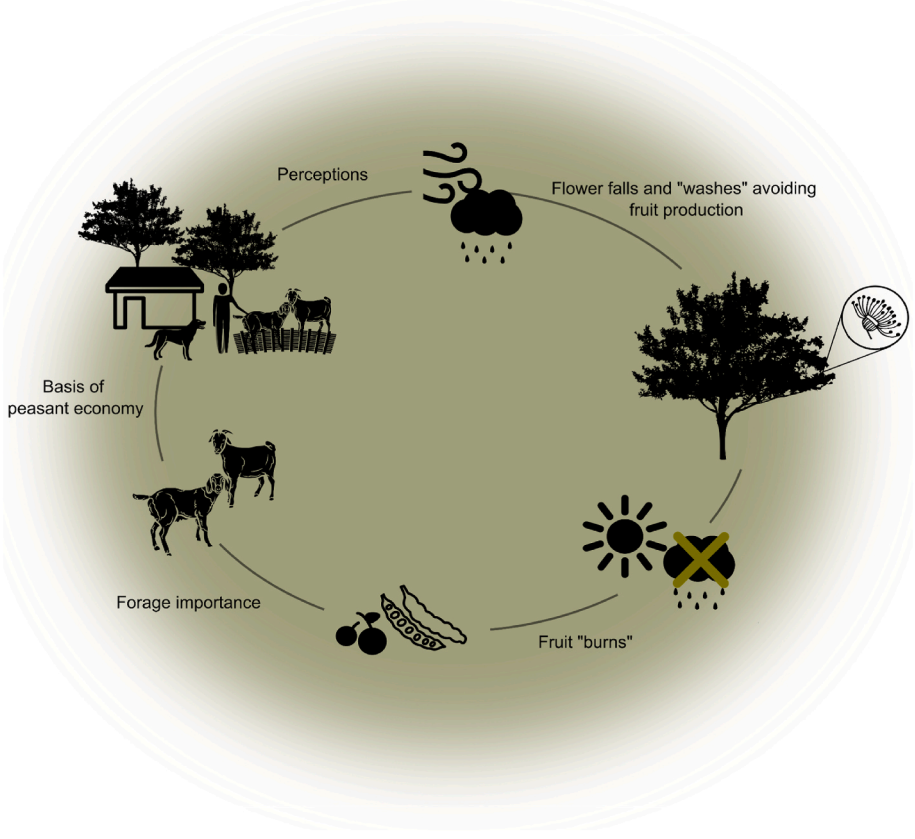

Fig. 3. Local perceptions related to factors that determine fruit production in native plant species of the arid Chaco of central Argentina. The diagram shows the relations between climate factors, fruit production of native species (*Neltuma* spp. and *S. mistol*), goats, and peasant management. Icons are from the Noun Project (https://thenounproject.com) credits in Supplementary material).

However, contrary to what we expected, the importance of these species is not only based on fruit production but also on green forage provision. In general, pollination was not perceived by local producers as beneficial for these tree forage plants, but climatic variables were mentioned as determinant factors for fruit production in this goat-farming area.

4.1. Management strategies and livestock knowledge

In contrast with local communities of other arid areas of central Argentina, such as the Sierra de Ancasti and the Salinas Grandes from Catamarca, the purchase of alfalfa and corn as forage for goats is not an extended practice in our study area (Quiroga and Trillo, 2022; Califano, 2020; Jiménez-Escobar, 2019; Cavanna et al., 2010; Scarpa, 2007). The absence of this practice, which facilitates goat farming in arid conditions (Quiroga and Trillo, 2022), could be related to the difficult access to the area (the nearest town is 70 km away through a dirt road), but also to the continuity of native fruit harvesting practices. Fruit forage harvesting is possible because of the persistence of native forests in the area. Precisely, the northwest of Córdoba hosts the largest remaining tracts of native forest in the province, although none of them are in pristine conditions (Zeballos et al., 2023). In contrast, in the northeast of Córdoba province, local communities have progressively abandoned native forage fruit harvesting due to high land-use changes and deforestation, leading to decreased tree cover (Silvetti, 2011). What is more, the populations settled in deforested areas are the rural sectors with the highest levels of Unsatisfied Basic Needs in the province of Córdoba (Paz, 2016). Native forests and their species persistence are intrinsically related to peasant life and production (Silvetti, 2020). As a consequence, peasants will be more affected than any other social sector by practices that favor the degradation of the environment (Silvetti, 2011).

As a current management practice, the harvesting and storage of fruits of *Neltuma* spp. and *S. mistol* is a widespread strategy in different arid ecosystems of Argentina and the structures known as *trojas* have been reported in other studies (Quiroga and Trillo, 2022; Scarpa, 2007) as well as the use of "Atamisqui" (*Atamisquea emarginata*) as an insect repellent to preserve the fruits (Karlin et al., 1994). What is more, *Prosopis* s. l. (including *Neltuma* spp.) are important species in arid zones across the world. These nitrogen-fixing trees are well adapted to long drought seasons and salinity, and they provide food for many species of wild animals that feed on their nectar, pollen, leaves, and pods (Ruiz--Nieto et al., 2020). Fruits of *Neltuma* spp. and *S. mistol* are nutritious with a high percentage of carbohydrates and proteins (Ruiz-Nieto et al., 2020; Cittadini et al., 2021) that provides an important nutritional contribution to goats in critical periods of forage gap, improving winter kidding conditions (Carballo, 1999). Fruits of some *Neltuma* species contain a higher percentage of protein than corn grain (Silva et al., 2000) and have been proposed as a good alternative of fodder provision to livestock (Freyre et al., 2003).

4.2. 2 Forages and plants consumed by goats

We found a high richness of plant species considered by local peasants as forage for goats. Goats have great flexibility in their diet composition, especially in arid areas, where they consume a greater variety of plant species (De Gea et al., 2005). It is important to mention that 37 % of the forage ehtnospecies were mentioned less than three times (e.g., *Aspidosperma quebracho blanco*) so they can be considered of low consensus in the community. Further inquiries are necessary to understand their importance as forages in this ecosystem. Except for "Grasses", all of the forage plants that appeared in the ranking list were woody species that depend, to different degrees, on animal pollination for the fructification and persistence of their native populations (Tong et al., 2023). The results emphasize the high preference of goats for woody species and the importance of pollination conservation to ensure native forage provision (Rehel et al., 2009). The high forage importance found for *Neltuma* spp., and *S. mistol* coincides with the results found in other arid areas of Argentina such as Santiago del Estero (Riat, 2012), Catamarca (Jiménez-Escobar, 2019), and northeastern Córdoba (Silvetti, 2020). It also coincides with the high importance given to fruit production of these species in determining a good year for goats. The cognitive salience of the free list items was explained by forage or feeding importance to the goats. However, as *Neltuma* spp. and *S. mistol* trees are dominant species in the study area, their abundance could also be playing an important role in the cognitive importance of local inhabitants.

The most important forage plants in our study ("Algarrobo", "Mistol" and "Mistolillo") can provide high-quality fruits and also leaves as forage at different moments of the year. They provided fruits during the summer season, and also in winter when collected, and with leaves during the rest of the year. Leaves are especially important and preferred by the goats towards the end of winter and the beginning of spring, a critical moment in which the general fodder supply of the ecosystem is lowest, so this resource is especially appreciated by the peasants. Forage provided by the leaves is important due to the marked seasonality of fruit availability, allowing peasants to stagger the forage resources to make them available throughout the year. This has been reported in other arid regions of Argentina, where leaves and fallen leaves of *N. flexulosa* are consumed by goats in autumn and winter (Allegretti et al., 2012). Other woody legume species such as *Senegalia gilliesii* ("Garabato") and *Mimozyganthus carinatus* ("Lata") based their importance on the provision of green forage. Their fruits are consumed by goats when they are green, however, the amount of fruits produced and the fruits themselves are small, dry, and not of high nutritional value (Ledesma et al., 2017).

The importance of "Grasses" is mainly based on their provision of green forage and their high palatability (Ledesma et al., 2017). The broad category of "Grasses" includes native species such as *Gouinia paraguayensis, Sporlobolus pyramidatus, Setaria hunzikeri* that have a high to medium palatability and also exotic megatermic grasses such as *Megathyrsus maximus* and *Cenchrus ciliaris,* introduced by large cattle farmers in silvopastoral systems within the area. These exotic grasses have higher levels of palatability and productivity than native grasses, however forage quality is generally higher in native grasses (Cotroneo et al., 2016). *Cenchrus ciliaris* is mainly consumed in the summer, but *Megathyrsus maximus* remains green in autumn and winter and can be consumed throughout the year (Ledesma et al., 2017). Grassess consumption by goats could imply conflicts with large farmers that argue that trampling and droppings of goats have negative effects on the quality of pastures destined for cattle ranching (Silvetti, 2020). However, the high representativeness of woody species in forage plants considered as important for goats by local producers suggests that the diet overlapping between goats and cattle is minimal. The replacement of native vegetation with pastures severely affects the woody stratum, which provides multiple ecosystem services (e.g., forage provision, water regulation, soil nutrients availability, provision of habitat and resources for pollinators and seed dispersal) essential for the subsistence of the local peasant producers (Cotroneo et al., 2016). Apart from fruit production and green forage provision, other characteristics such as favoring milk production, as in the epiphyte "Ligas", seem to play a relevant role for livestock in the arid Chaco.

4.3. Pollination perception

Local peasants easily identified the relevance of *Neltuma* spp. and *S. mistol* for bees, as many bees are easily observed in these trees during flowering periods. A previous study conducted in the area showed that the category of "bees" is, for local habitants, an exact reference to honey bee *Apis mellifera* (see Furlan et al., 2020). Thus, our result could be related to honey bee production through beekeeping activities. Although it is not a widespread activity in the study area, almost all collaborators have had some contact with beekeeping. Thus, they know that bees visit flowers to produce honey to feed the hive. Almost half of

the collaborators identified that the interaction between bees and plants is beneficial for both, and bees could assist plants in producing fruits and seeds. However, the direct and positive effects of insect pollinators on fruit production did not translate into an intentional understanding by local people of this phenomenon. Local peasants did not perceive pollination as a crucial factor that determines fruit production. All of the collaborators emphasized that climatic factors, such as precipitation, insolation, and wind were the most determinant factors for fruit production. In the adverse scenario of no access to basic services, such as drinking water, climatic factors become very important, shaping LEK on both ecological processes and local management strategies. This is why precipitation also appears as a crucial factor that determines whether a year is good or bad for goats, either because it ensures the availability of water for animal consumption or the production of native forage.

We conclude that the LEK of rural communities about native forage plants is important to manage their immediate environment and is in general more intuitive and holistic than the analytical and reductionist knowledge of disciplines such as ecology (Iaccarino, 2003). What is more, conventional ecological studies have limitations in understanding slow processes in landscapes and ecosystems, such as climate factors during the year (Roué et al., 2015). Climate factors should be taken into account in the studies about the reproductive success of plants in the arid Chaco and LEK could guide the formulation of adequately contextualized ecological hypotheses. Our conclusions can not be entirely extrapolated to populations from different cultural and socio-ecological systems. Even so, it does not mean that the information present in our study is not useful to assess and understand similar topics in other populations. Comparison is as important as extrapolation in scientific knowledge, especially in social sciences (Peirano, 2019). The complementarity across this ethnoecological information and the ecological scientific knowledge about insect pollination dependence of native plants could improve the sustainability of goat farming that sustains local communities and plays an important role in forest persistence.

CRediT authorship contribution statement

Victoria Marquez: Writing – original draft, Investigation, Conceptualization, Data curation, Formal analysis. **Lucas M. Carbone:** Writing – review & editing, Investigation, Data curation, Conceptualization. **N. David Jiménez-Escobar:** Writing – review & editing, Methodology, Conceptualization. **Andrés Horacio Britos:** Writing – original draft, Methodology, Conceptualization, Investigation. **Ramiro Aguilar:** Conceptualization, Funding acquisition, Investigation, Project administration, Writing – review & editing. **Fernando Zamudio:** Investigation, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaridenv.2024.105167.

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