# Species of the Poaceae family suitable for Andean livestock farming in the Peruvian Andes reported in GBIF and local studies


**Abstract**

Andean grassland ecosystems are covered by a mega-vascular floristic diversity constituted by families such as: *Poaceae, Rosaceae, Asteraceae, Plantaginaceae, Fabaceae, and Cyperaceae,* among the most important ones that include suitable species for Andean Livestock feeding such as: sheep, cattle, and South American camelids. However, the accelerated degradation of ecosystems and the extinction of several important species, have put it in our interest to know better the spatio-temporal distribution of these species as a starting point for spatio-temporal monitoring. With this purpose, we compiled information on those identified as D species in the Poaceae family, from thesis studies and published scientific articles. We also examined the record and spatial distribution of D species of this family in the Global Biodiversity Information System (GBIF) corresponding to the Sierra region of Peru. Specific geo-processed maps were generated after data curation. It was found that there are 63 D species included in the genus: *Agrostis, Agropirum, Bromus, Calamagrostis, Dissanthelium, Festuca, Hordeum, Muhlenbergia, Nasella, Paspalum, Poa, Stipa, Trisetum* and *Vulpia*, of which only 52 species are registered in GBIF, noting the concentration of records in places of greater tourist interest and with funded research projects such as the Huascaran National Park and others. The few studies on natural grassland species in Peru and the low spatial coverage of the species recorded in GBIF still limit the generation of adequate monitoring strategies.



**Key words**: Poaceae family, suitable species (D), Andean livestock, Andean grassland, GBIF database.


## 1. Introduction


Andean grassland ecosystems are covered by a mega-vascular floristic diversity constituted by families such as: *Poaceae, Rosaceae, Asteraceae, Plantaginaceae, Fabaceae, and Cyperaceae,* among the most important ones that include suitable species for Andean Livestock feeding such as: sheep, cattle, and South American camelids. However, the accelerated degradation of ecosystems and the extinction of several important species, have put it in our interest to know better the spatio-temporal distribution of these species as a starting point for spatio-temporal monitoring.

For this purpose, we compiled information on those identified as D species in the Poaceae family, from thesis studies and published scientific articles. We also examined the record and spatial distribution of D species of this family in the Global Biodiversity Information System (GBIF) corresponding to the Sierra region of Peru.

Specific geo-processed maps were generated after data curation. It was found that there are 63 D species included in the genus: *Agrostis, Agropirum, Bromus, Calamagrostis, Dissanthelium, Festuca, Hordeum, Muhlenbergia, Nasella, Paspalum, Poa, Stipa, Trisetum* and *Vulpia*, of which only 52 species are registered in GBIF, noting the concentration of records in places of greater tourist interest and with funded research projects such as the Huascaran National Park and others. The few studies on natural grassland species in Peru and the low spatial coverage of the species recorded in GBIF still limit the generation of adequate monitoring strategies.

This database is fed by authorized entities and scientists collecting species anywhere in the world under strict codification in accordance with GBIF formats; however, due to some limitations suffered by the responsible entities and the lack of knowledge of the people dedicated to the knowledge and collection of species, this database does not contain the records of many species or, if they are, at least the spatial distribution information is not complete (Qian et al., 2022).

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Andean grassland ecosystems host a mega-diverse floristic composition, with families such as Poaceae, Rosaceae, Asteraceae, Plantaginaceae, Fabaceae, and Cyperaceae among the most significant contributors. These families include species well-suited for feeding Andean livestock such as sheep, cattle, and South American camelids. However, accelerated ecosystem degradation and species extinction highlight the need for better understanding and monitoring of these species' spatio-temporal distribution.

To address this, we compiled information on Poaceae species identified as suitable (D species) from theses and published scientific articles. We also analyzed records and spatial distribution data for these species in the Global Biodiversity Information Facility (GBIF) for the Peruvian Sierra region. After curating the data, we generated geo-processed maps that revealed 63 D species across the genera Agrostis, Agropyrum, Bromus, Calamagrostis, Dissanthelium, Festuca, Hordeum, Muhlenbergia, Nassella, Paspalum, Poa, Stipa, Trisetum, and Vulpia. Notably, only 52 of these species are registered in GBIF, with records concentrated in high-tourist areas and regions supported by research projects, such as Huascarán National Park.

The limited number of studies on natural grassland species in Peru and the low spatial coverage of GBIF records underscore the need for improved monitoring strategies to support conservation and sustainable livestock farming

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Andean grasslands
Livestock feeding
Biodiversity monitoring

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Recent publications on species monitoring from the database globally, were conducted are seen in Panama by Leung et al, (2019), using sightings and retained species datasets, also on Amami-Oshima Island, Tokunoshima Island and northern Okinawa Island by Hirinori et al, (2022) who used the data as a reference for further monitoring of plant diversity of the natural World Heritage site; also Qian et al, (2022) who evaluated the completeness of GBIF-derived fern species lists at a grid scale and at a larger spatial scale, showing that the completeness of GBIF species sampling is low (<40%), this information let us understand that even the global biodiversity database is not complete, both in richness and spatial distribution. Although Darwin Core (DwC) as a TDWG standard has indexed more than 2 billion records from 70,147 datasets, with more than 1561 organizations in 59 countries as of January 2020. Darwin Core is a standardized language that applies unique Internationalized Resource Identifiers (IRIs) to each item assigned as a metadata element, in addition to a tag and definition (Popović et al., 2020).

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On the side of the suitable species (D) for Andean livestock, are those that are highly consumed and (PD) little consumed (Flores E, 2016), being the species of the *Poaceae* family the most important and abundant (Carla., 2021; Onofre M., 2020; Trill F., 2021; Jorge J., 2020; Capuñay K., 2022). Among the *Poaceae* species reported at the level of the main Andean regions of Peru, we have from Carla (2021), who found in the Apas sector of Huancaya-Yauyos, suitable species for alpacas and llamas: *Calamagrostis vicunarum, Jarava ichu, Bromus lanatus, Festuca dolichophylla, Aciachne pulvinata, Muhlenbergia peruviana, Calamagrostis tarmensis, Dissanthelium mathewsii, Calamagrostis glacialis*. Onofre M.I. (2020) in Moyobamba, Canchayllo-Jauja for sheep: *Calamagrostis brevifolia* J. Presl. *Calamagrostis jamesonii* Steud. *Calamagrostis vicunarum* Wedd. In the same district, Trillo F. (2021) conducted revegetation studies with *Festuca dolichophylla* and *F. humilior*, because they are very important species in animal feed; in bofedal de Chacamarca Junín, Galarza P.V and Jorge J.V (2020) found *Poaceae* D and PD species for sheep: *Calamagrostis eminens* (J. Presl) Steud, *Calamagrostis jamesonii* Steud, c (Wedd.) Pilg, *Poa aequigluma* Tovar, Poa spicigera Tovar, *Polypogon interruptus* Kunth. Capuñay K. S. (2022) presented the diet composition of vicuñas in San Cristóbal de la Provincia Lucanas in Ayacucho: *Nassella sp. Jarava pungens, Muhlenbergia peruviana, Festuca rigescens, Aciachne sp, Calamagrostis vicunarum, Poa sp*. However, many studies reported in natural grasslands made little mention of identified D species and in other cases the location of the species was not georeferenced, which hinders adequate geoprocessing to model the spatial distribution (Ivanova and Dhashkov, 2021).

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In this context, the research began by posing the following questions: Do the studies carried out on natural grasslands, which refer to the presence of suitable species (D) of the *Poaceae* family for livestock feeding in the Peruvian Andes, provide sufficient information to model their spatial distribution? Does the database in the Global Biodiversity Information Infrastructure (GBIF) allow modeling the spatial distribution of suitable species (D) of the *Poaceae* family for livestock feeding in the Peruvian Andes? For this reason, and with the intention of mapping the spatial distribution of the most important species in Andean Livestock feed, the following objectives were proposed: Compile the presence of suitable species (D) of the *Poaceae* family for livestock feeding in the Andean region of Peru, based on published theses and research articles. Extract from the Global Biodiversity Information Infrastructure (GBIF) database the suitable species (D) of the *Poaceae* family for livestock feeding in the Peruvian Andes. Geoprocess the data of suitable species (D) for livestock feeding in the Peruvian Andes for its presentation in maps.

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This is my suggestion:
In this context, the research began by posing the following questions: Do studies on natural grasslands, which reference the presence of suitable species (D) of the Poaceae family for livestock feeding in the Peruvian Andes, provide sufficient information to model their spatial distribution? Does the Global Biodiversity Information Facility (GBIF) database support modeling the spatial distribution of suitable species (D) of the Poaceae family for livestock feeding in the Peruvian Andes?

To address these questions and map the spatial distribution of the most important species for Andean livestock feed, the following objectives were proposed:

Compile data on the presence of suitable species (D) of the Poaceae family for livestock feeding in the Andean region of Peru, based on published theses and research articles.
Extract records of suitable species (D) of the Poaceae family for livestock feeding in the Peruvian Andes from the GBIF database.
Geoprocess the data on suitable species (D) for livestock feeding in the Peruvian Andes and present the findings in the form of maps.

## 2. Material and methods

### *2.1* ***Data collection techniques***

The research was carried out using secondary information that reaches the Peruvian Andes, where the Andean grassland ecosystems are located. These ecosystems are made up of plant communities composed mostly of herbaceous species, in others with shrubs and sparsely with trees. They are present in large areas, which, according to the Food and Agriculture Organization of the United Nations - FAO, are mainly used for extensive livestock grazing (Gibson, 2009). From the physiographic point of view, this scenario of the Peruvian Andes is characterized by diverse relief geoforms such as: mountain ranges, mountain slopes, foothills, hollows, plains, hills, valleys, plateaus, cliffs, etc., according to Villota's conception in 1997. These geoforms are related to the characteristics of the soil and climate, and as such predispose the type of vegetation that characterizes each of the geomorphological units (Serrato, 2009).

These ecosystems, due to their bioclimatic characteristics and altitude since the conception of Javier Pulgar Vidal in 1938, are classified as: paramo, those Andean areas ranging from 3000 to 3600 meters altitude, characterized by being very humid and foggy, whose location runs from Piura and Cajamarca in Peru through the mountain ranges of Ecuador to the mountain ranges of Merida in Venezuela and Santa Marta in Colombia (Cuesta et al., 2012); Jalca, part of the mountain ranges of Cajamarca, Lambayeque and Amazonas, which characterizes a state of transition between páramo and puna, with an absence of snow-capped mountains and gently sloping hillsides; Puna, those areas that are located in the mountain ranges between 3800 and 4800 meters altitude, with semi-arid characteristics, due to the low annual rainfall they receive, with areas of plains to steep and steep, which in the forest conception calls it "Andean pajonal" (Ministry of Environment (MINAM), 2015), are located from the Ancash mountain ranges through the central and southern Andes of Peru, Bolivia and Chile (Hofstede et al. , 2014). All of them are characterized by a vegetation cover typical of Andean grasslands, which are the basis of Andean livestock feed (Yaranga, 2019).

The collection of information was carried out in three phases:

- As a first phase, we searched for publications on the desirability of natural grassland species for Andean livestock: South American camelids, sheep and cattle, reported in the repositories of universities in Peru and academic Google. The information obtained was systematized in a table, selecting those publications that report on the identity of suitable species (D) for Andean domestic animals. Based on this information, a second table was constructed containing a) the identity of the species, b) the place where the research work was carried out, c) the geographic coordinates of the work site, and d) the altitude of the site.
- Secondly, the database was accessed by Elsevier, Crossref, Science Direct and others to download scientific articles published in the various indexed journals containing the information referred to in the first phase, which served to complement the information in the tables referred to.
- Thirdly, the information was downloaded from the Darwin Core database of the Global Biodiversity Information Infrastructure - GBIF (Mahapatra et al., 2022), taking into consideration the genus of natural grasses identified as suitable.

### *2.2 Data processing techniques*

The procedure for data processing was:

- The data obtained and recorded in the tables were validated for their relevance to the organized structure of the data, eliminating those that did not comply at least with the identity of the suitable species and location of the research conducted.
- From the data downloaded from the Darwin Core of the GBIF, curator ship processes were carried out using the Rstudio vs 4.1.2 software, considering: a) species D, eliminating all those that did not correspond to the species identified as suitable, b) duplicity, eliminating duplicate location points, and c) geospatial, eliminating those points whose coordinates were located outside the Andean area (Karasti, et al., 2006).
- For the elaboration of the distribution map of the location points of the D species, a table was generated with validated data mainly consisting of: D species, UTM 18S coordinates and altitude. These data were uploaded to ArcGis Pro vs 3.2.0 using the command "Geoprocessing >XY Table to Point", then converted to an SHP vector layer using the command "Geoprocessing >Feature class to Feature class >parameters". The base map that helped visualize the location of the points was the "World Topographic Map" and "World Hillshade", in addition to a layer of the national boundary of Peru that remained active during the mapping of all species.

## 3. Results

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Suggestion:
The collection of information was carried out in three phases:

1.First Phase:
Publications on the suitability of natural grassland species for Andean livestock—South American camelids, sheep, and cattle—were searched in the repositories of Peruvian universities and Google Scholar. The collected information was organized into a table, selecting publications that reported the identity of suitable species (D) for Andean domestic animals. Based on this information, a second table was created, containing:
a) the identity of the species,
b) the location of the research work,
c) the geographic coordinates of the study site, and
d) the altitude of the site.

2.Second Phase:
Databases such as Elsevier, CrossRef, and ScienceDirect were accessed to download scientific articles published in various indexed journals. These articles provided additional data to complement the tables created in the first phase.

3.Third Phase:
Information was downloaded from the Darwin Core database of the Global Biodiversity Information Facility (GBIF) (Mahapatra et al., 2022). This phase focused on the genera of natural grasses identified in the previous phases

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***3.1 Suitable species (D) identified for the 5 types of Andean livestock.***

Sixty-three species D of the *Poaceae* family were compiled as suitable species in Andean livestock feed, including 4 species of the genus *Agrostis*, 1 of *Agropirum*, 3 of *Bromus*, 17 of *Calamagrostis*, 4 of *Disanthelium*, 12 of *Festuca*, 1 of *Hordeum*, 3 of *Muhlenbergia*, 1 of *Nassella*, 1 of *Paspalum*, 7 of *Poa*, 7 of *Stipa*, 1 of *Trisetum* and 1 of *Vulpia* (Table 1); which have differences in their suitability against the 5 Andean livestock species: Sheep, cattle, domesticated alpaca (Lama pacos), domesticated llama (Lama glama) and wild vicuña (Vicugna vicugna). It was observed that only 5 species of grasses were suitable for all the referred livestock. Of the total number of species identified as D species, 29% are suitable for cattle, 27% for alpacas, 25% for sheep, 15% for llamas, and only 4% for vicuñas.

**Table 1**. Species D of the Poaceae family suitable for Andean livestock

| N° | Species D | Cattle | Sheep | Alpacas | Vicuñas | Llamas |
|---|---|---|---|---|---|---|
| 1 | *Agrostis breviculmis* | | D | D | D | |
| 2 | *Agrostis sp* | | D | D | | |
| 3 | *Agrostis foliata* | D | D | D | | |
| 4 | *Agrostis haenkeana* | | | D | | |
| 5 | *Agropirum breviaristatum* | D | D | D | | |
| 6 | *Bromus catharticus* | D | D | D | D | D |
| 7 | *Bromus lanatus* | D | D | D | D | D |
| 8 | *Bromus pitensis* | D | D | D | D | D |
| 9 | *Calamagrostis antoniana* | D | D | D | | |
| 10 | *Calamagrgostis brevifolia* | D | | | | |
| 11 | *Calamagrostis curvula* | D | | D | | D |
| 12 | *Calamagrostis chrysanta* | D | | | | D |
| 13 | *Calamagrsotis densiflora* | | | D | | |
| 14 | *Calamagrostis heterophylla* | D | D | D | | |
| 15 | *Calamagrostis intermedia* | D | | | | D |
| 16 | *Calamagrostis jamesoni* | D | | | | D |
| 17 | *Calamagrostis ovata* | D | | | | D |
| 18 | *Calamagrostis recta* | | | D | | |
| 19 | *Calamagrostis rigescens* | D | | | | D |
| 20 | *Calamagrostis rigida* | D | | | | D |
| 21 | *Calamagrostis spiciformis* | D | | | | D |
| 22 | *Calamagrostis sp* | | | | | D |
| 23 | *Calamagrostis tarmensis* | D | | D | | |
| 24 | *Calamagrostis violacea* | | D | D | | |
| 25 | *Calamagrostis vicunarum* | | D | D | | |
| 26 | *Dissanthelium calicynum* | | D | D | | |
| 27 | *Dissanthelium rahuii* | | D | D | | |
| 28 | *Dissanthelium semitectum* | | D | D | | |
| 29 | *Dissanthelium sp* | D | D | D | | |
| 30 | *Festuca casapaltensis* | D | D | D | | |
| 31 | *Festuca dolichophylla* | D | D | D | | D |
| 32 | *Festuca distichovaginata* | D | | | | |
| 33 | *Festuca huamachusesis* | D | D | D | | |
| 34 | *Festuca inarticulada* | D | | | | |
| 35 | *Festuca peruviana* | D | D | D | | |
| 36 | *Festuca rigidifolia* | D | D | D | | |
| 37 | *Festuca rigescens* | D | D | | | D |
| 38 | *Festuca sedifolia* | D | | | | |
| 39 | *Festuca tarmensis* | | | D | | |
| 40 | *Festuca tenuiculmis* | | D | D | | |
| 41 | *Festuca weberbaueri* | D | | | | |
| 42 | *Hordeum muticum* | D | D | D | D | D |
| 43 | *Muhlenbergia fastigiata* | | D | D | | |
| 44 | *Muhlenbergia ligularis* | | D | D | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 45 | *Muhlenbergia peruviana* | | D | D | | |
| 46 | *Nassella brachyphylla* | | D | | D | D |
| 47 | *Paspalum penicillatum* | | D | D | | |
| 48 | *Poa aequigluma* | D | | | | |
| 49 | *Poa annua* | D | | | | |
| 50 | *Poa asperiflora* | D | | | | |
| 51 | *Poa gymnantha* | D | D | D | | |
| 52 | *Poa perligulata* | D | D | D | | D |
| 53 | *Poa pardoana* | D | D | D | | |
| 54 | *Poa spicigera* | D | D | D | | |
| 55 | *Stipa brachyphylla* | D | D | D | | D |
| 56 | *Stipa hans-meyerii* | D | D | D | | D |
| 57 | *Stipa huallancaensis* | D | D | D | | |
| 58 | *Stipa ichu* | D | | | | D |
| 59 | *Stipa mucronata* | D | D | D | | D |
| 60 | *Stipa obtusa* | D | | | | D |
| 61 | *Stipa vargasii* | D | D | D | | |
| 62 | *Trisetum spicatum* | D | D | D | | |
| 63 | *Vulpia megalura* | D | D | D | D | D |

**Source**: Fundo Ayaracra (Pasco) -Identified by Nancy Refulio (2002), ZEE Ayacucho (2011); Laboratory of pasture utilization (2008) UNALM mentioned by Alegria, Fiorella (2013) - Pasco; Florez (2005), Mamani (2001), Huerta (2001), Miranda (1991); Pineda (1996); Zegarra (1999); Flores (1995) reported by Irma Rovera Velásquez, report 1st grassland evaluation Shullcas (2011)
Native domestic animal species: Lama guanicoe (alpaca), Lama glama (Llama), Vicugna vicugna (Vicuña).

### *3.2 Publications that identified the presence of suitable species for Andean livestock in the Peruvian Andes.*

Twenty-three publications have been found that have reported the identity of D species of the *Poaceae* family in the Andes of Peru (Table 2). The department of Junín had the largest number of studies were made with 30.44% of the publications made in 7 places, followed by the departments of Pasco with 13.04% in 3 places, then Tacna, Puno, Cusco and Ancash with 8.70% in 2 places in each department, and finally the remaining 4 regions have 17.39% of publications made in only one place per department. The most reported natural grass species were: *Calamagrostis vicunarum* in 17% of studies, *Festuca dolichophylla* in 8.57%, and *Bromus lanatus* in 7.61%. The details of the table are shown in the appendix (Table 5).

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Suggestion:
**3.2 Publications Identifying Suitable Species for Andean Livestock in the Peruvian Andes**
Twenty-three publications have reported the identity of suitable (D) species of the Poaceae family in the Peruvian Andes (Table 2). The department of Junín accounted for the largest proportion of studies, with 30.44% of the publications conducted across seven locations. This was followed by the department of Pasco, which contributed 13.04% of the studies in three locations. The departments of Tacna, Puno, Cusco, and Ancash each accounted for 8.70% of the studies, conducted in two locations per department. Finally, the remaining four regions contributed 17.39% of the publications, with one location studied per department. The most frequently reported natural grass species were Calamagrostis vicunarum, found in 17% of the studies; Festuca dolichophylla, reported in 8.57%; and Bromus lanatus, identified in 7.61% of the publications. Further details can be found in the appendix (Table 5).

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**Table 2.** Regions and places where studies on species D of the family *Poaceae* were carried out.

| Study source regions | N° Publications | Places where studies were conducted |
|---|---|---|
| Huancavelica | 1 | Lachocc |
| Huánuco | 1 | Lauricocha |
| Apurimac | 1 | Ocrabamba |
| Tacna | 2 | Ancomarca, Palca |
| Puno | 2 | Chila, Carolina |
| Junín | 7 | Acopalca (2), Canchayllo (2), Lomo Largo, Vista Alegre, Quero |
| Cusco | 2 | Marampaqui, Pinaya |
| Ancash | 2 | Cordillera Blanca, Canray Grande |
| Arequipa | 1 | Pampa Cañahuas |
| Pasco | 3 | Rancas, Conocancha, Ninacaca |
| Lima | 1 | Tomas |

### *3.3 Suitable species (D) of the ~~family~~ Poaceae family recorded in the GBIF database.*

T~~In t~~he GBIF database contained~~,~~ 8,352 records across ~~were found in~~ 11 genera of the Poacea family~~us~~. Among these,~~,~~ ~~of which~~ 1,844 records were identified as suitable ~~of~~ D species, accounting for ~~s were found, corresponding to~~ 22% of the total ~~number of~~ records (Table 3). After curating data to remove ~~Once the~~ duplicates and records lacking ~~and those without~~ coordinate information, ~~were curated,~~ 1,149 valid records were obtained, representing ~~equivalent to~~ 14% of the total number of records. T~~Species of t~~he genus *Poa* had the highest number of valid records

(20%), followed by *Sipa* (18%), *Calamagrostis* (15%), and *Bromus* (14%), making these~~m~~ the most prominent genera~~important genus~~ within the database.

***Table 3***. Sequence of information on the total number of species recorded in GBIF and result of the curation: D species, duplicate records and others with incomplete information such as coordinates.

| **Genus** | **GBIF Records** | **Species D** | **% Species D** | **Duplicate records** | **Incomplete information*** | **Valid records** | **% Sp-valid** |
|---|---|---|---|---|---|---|---|
| *Agrostis* | 352 | 80 | 23% | 9 | 4 | 67 | 6% |
| *Bromus* | 501 | 228 | 46% | 62 | 8 | 158 | 14% |
| *Calamagrostis* | 1243 | 318 | 26% | 143 | 1 | 174 | 15% |
| *Festuca* | 1012 | 167 | 17% | 58 | 1 | 108 | 9% |
| *Hordeum* | 2020 | 33 | 2% | 10 | 1 | 22 | 2% |
| *Nassella* | 645 | 145 | 22% | 51 | 3 | 91 | 8% |
| *Paspalum* | 544 | 49 | 9% | 11 | 5 | 33 | 3% |
| *Poa* | 1426 | 441 | 31% | 204 | 7 | 230 | 20% |
| *Stipa* | 458 | 312 | 68% | 100 | 7 | 205 | 18% |
| *Trisetum* | 131 | 64 | 49% | 10 | 0 | 54 | 5% |
| *Vulpia* | 20 | 7 | 35% | 0 | 0 | 7 | 1% |
| **Total** | **8352** | **1844** | **22%** | **658** | **37** | **1149** | **14%** |

** The records do not have geospatial coordinates information*

The record of the genus *Dissanthelium* is not very specific, as it is only registered as "*Dissanthelium trim*" and accepted as *Poa* L; also, the genus *Muhlenbergia* is reported as "*Bromus*", likewise the species *Vulpia megalura* is not registered for the Peruvian Andes, so they were not taken into consideration in Table 3.

***3.4 Spatial distribution of the main D species according to genus in the Peruvian Andes***

**Figure 1.** Spatial distribution of suitable species for Andean Livestock recorded in GBIF, in the Andean area of Peru.

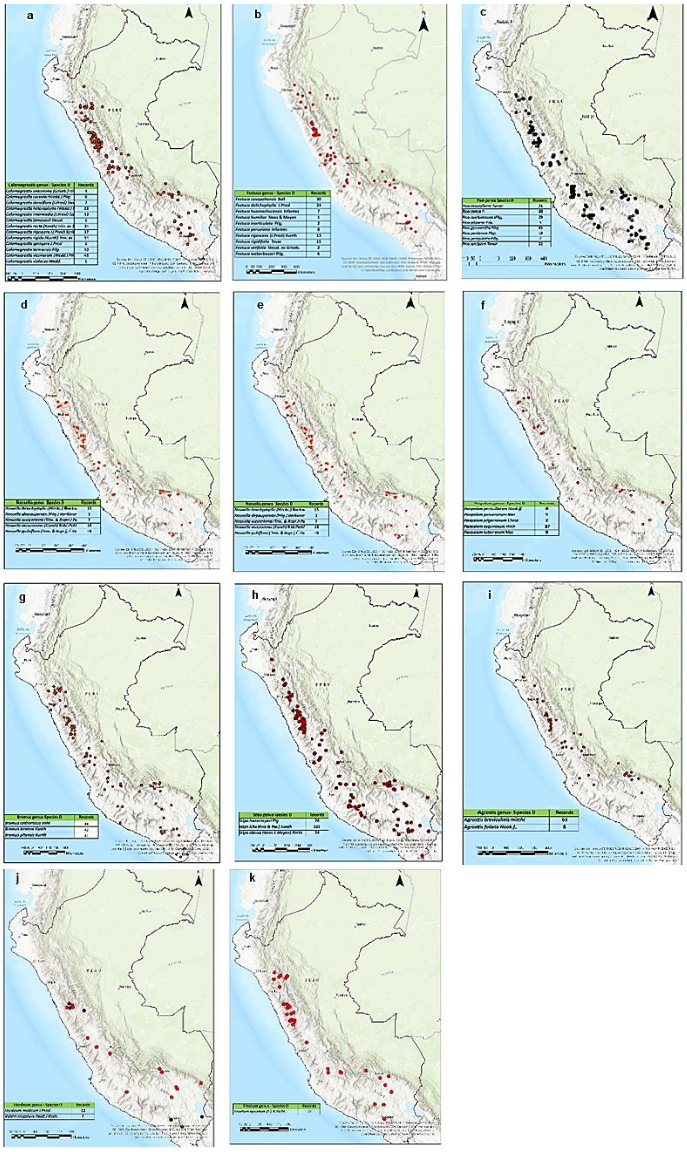


Fig:1Spatial distribution of suitable species for Andean Livestock recorded in GBIF, in the Andean area of Peru.
Source: GBIF.org (01 August 2023) GBIF Occurrence downloaded from https://doi.org/10.15468/dl.hqme3u

Of the 11 genus of natural grasses corresponding to the suitable species (D) of the *Poaceae* family for Andean livestock, the genus *Calamagrostis* (Figure 1 a) was the most reported, with 13 species whose names are shown in Table 4, distributed in the Andean region, showing the highest number of reports in the departments of: Cajamarca, Ancash (Cordillera

Blanca), Lima, Junín, Cusco, and Arequipa, with the species *Calamagrostis vicunarum* (Wedd) Pilg being the most reported. The genus *Festuca* is reported with 10 species (Figure 1 b), with reports concentrated in the department of Ancash and fewer reports in Lima, Huancavelica and Arequipa, with *Festuca dolychophylla* Pilg being the most reported. The genus *Poa* is reported with 8 species, with the most reported in Ancash, Cajamarca, Huancavelica, Ayacucho, Junín, Cusco, and Arequipa, with the species *Poa gymnantha* Pilg being the most reported (Figure 1 c).

The genus *Nassella* is reported in 5 species, with the most reported spatially in Ancash, Cajamarca, Lima and Cusco (Figure 1 d), with the species Nassella pubiflora (Trin. & Rupr.) E. Desv is the most reported. The genus *Paspalum* with 5 species is most reported in the departments of Ancash, Cajamarca, and Cusco (Figure 1 e), with the species *Paspalum pygmaeum* Hack as the most reported. The genus *Bromus* has 3 species reported in the departments of Cajamarca, Ancash, Lima, Huancavelica, Ayacucho, Cusco, Arequipa, Moquegua, and Tacna (Figure 1 f), with the species *Bromus catharticus* Vahl being the most reported; the genus *Stipa* has 3 species reported in Ancash, La Libertad, Cusco, Ayacucho, and Arequipa (Figure 1 g) with the species *Stipa ichu* (Ruiz & Pav. ) Kunth as the most reported; the genus *Agrostis* with 2 species with the most reported in the departments of Ancash, Lima, and Cusco; the species *Agrostis breviculmis* Hitch as the most reported; and finally the genus *Hordeum*, Trisetum and Vulpia with only one species each (Figure 1 j k).

**Table 4**. *Poaceae* suitable species for Andean Livestock and number of records by genus found in GBIF

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| **Calamagrostis genus - Species D** | **Records** | **Festuca genus - Species D** | **Records** |
|---|---|---|---|
| *Calamagrostis antoniana* (Griseb.) Hitchc | 4 | *Festuca casapaltensis* Ball | 30 |
| *Calamagrostis curvula* (Wedd.) Pilg | 6 | *Festuca dolichophylla* J.Presl | 24 |
| *Calamagrostis densiflora* (J.Presl) Steud. | 7 | *Festuca huamachucensis* Infantes | 7 |
| *Calamagrostis heterophylla* (Wedd.) Pilg | 23 | *Festuca humilior* Nees & Meyen | 1 |
| *Calamagrostis intermedia* (J.Presl) Steud | 13 | *Festuca inarticulata* Pilg | 2 |
| *Calamagrostis jamesonii* Steud | 1 | *Festuca peruviana* Infantes | 8 |
| *Calamagrostis recta* (Kunth) Trin. ex Steud | 34 | *Festuca rigescens* (J.Presl) Kunth | 13 |
| *Calamagrostis rigescens* (J.Presl) Scribn | 17 | *Festuca rigidifolia* Tovar | 15 |
| *Calamagrostis rigida* (Kunth) Trin. ex Steud | 14 | *Festuca setifolia* Steud. ex Griseb | 2 |
| *Calamagrostis spicigera* J.Presl | 1 | *Festuca weberbaueri* Pilg | 6 |
| *Calamagrostis tarmensis* Pilg | 10 | **Nassella genus- Species D** | **Records** |
| *Calamagrostis vicunarum* (Wedd.) Pilg | 43 | *Nassella brachyphylla* (Hitchc.) Barkworth | 15 |
| *Calamagrostis violacea* Wedd | 1 | *Nassella depauperata* (Pilg.) Barkworth | 3 |
| **Poa genus-Species D** | **Records** | *Nassella meyeniana* (Trin. & Rupr.) Parodi | 7 |
| *Poa aequigluma* Tovar | 31 | *Nassella mucronata* (Kunth) R.W.Pohl | 16 |
| *Poa annua* L | 40 | *Nassella pubiflora* (Trin. & Rupr.) É.Desv | 48 |
| *Poa candamoana* Pilg | 29 | **Paspalum genus- Species D** | **Records** |
| *Poa gilgiana Pilg* | 5 | *Paspalum penicillatum* Hook.f | 8 |
| *Poa gymnantha* Pilg | 85 | *Paspalum peruvianum* Mez | 1 |
| *Poa pardoana* Pilg | 10 | *Paspalum pilgerianum* Chase | 2 |
| *Poa perligulata* Pilg | 7 | *Paspalum pygmaeum* Hack | 17 |
| *Poa spicigera* Tovar | 22 | *Paspalum tuberosum* Mez | 5 |
| **Bromus genus-Species D** | **Records** | **Agrostis genus- Species D** | **Records** |
| *Bromus catharticus* Vahl | 66 | *Agrostis breviculmis* Hitchc | 63 |
| *Bromus lanatus* Kunth | 62 | *Agrostis foliata* Hook.f. | 8 |
| *Bromus pitensis* Kunth | 24 | **Hordeum genus - Species D** | **Records** |
| **Stipa genus-Species D** | **Records** | *Hordeum muticum* J.Presl | 22 |

| | | | |
|---|---|---|---|
| *Stipa hans-meyeri* Pilg | 70 | *Vulpia megalura (Nutt.)* Rydb | 7 |
| *Stipa ichu* (Ruiz & Pav.) Kunth | 101 | **Trisetum genus - Species D** | **Records** |
| *Stipa obtusa* (Nees & Meyen) Hitchc | 34 | *Trisetum spicatum* (L.) K.Richt | 51 |

Comparing the number of records found in the GBIF database with 1,141 and those compiled from studies carried out in Peru and published in theses and scientific articles with 105 records, the difference observed is very wide. On the other hand, at least 17 species were not identified or reported in the local studies: *Agrostis foliata* Hook.f, *Calamagrostis antoniana* (Griseb.) Hitchc, *Calamagrostis densiflora* (J. Presl) Steud, *Calamagrostis intermedia* (J.Presl) Steud, *Calamagrostis spicigera* J. Presl, *Festuca casapaltensis* Ball, *Festuca inarticulata* Pilg, *Festuca setifolia* Steud. Ex Griseb. *Festuca weberbaueri* Pilg, *Nassella mucronata* (Kunth) R.W. Pohl, *Nassella pubiflora* (Trin. & Rupr.) É. Desv. *Paspalum penicillatum* Hook.f, *Paspalum peruvianum* Mez, *Paspalum tuberosum* Mez. *Poa pardoana* Pilg, *Poa spicigera* Tovar, *Stipa obtusa* (Nees & Meyen) Hitchc and *Vulpia megalura* (Nutt.) Rydb.

**Commented [MOU11]:** Improve.

Suggestion:
Comparing the number of records found in the GBIF database (1,141) with those compiled from studies conducted in Peru and published in theses and scientific articles (105 records), a significant disparity is observed. Furthermore, at least 17 species were not identified or reported in the local studies. These species include:

- Agrostis foliata Hook.f
- Calamagrostis antoniana (Griseb.) Hitchc
- Calamagrostis densiflora (J. Presl) Steud
- Calamagrostis intermedia (J.Presl) Steud
- Calamagrostis spicigera J. Presl
- Festuca casapaltensis Ball
- Festuca inarticulata Pilg
- Festuca setifolia Steud. ex Griseb.
- Festuca weberbaueri Pilg
- Nassella mucronata (Kunth) R.W. Pohl
- Nassella pubiflora (Trin. & Rupr.) É. Desv.
- Paspalum penicillatum Hook.f
- Paspalum peruvianum Mez
- Paspalum tuberosum Mez
- Poa pardoana Pilg
- Poa spicigera Tovar
- Stipa obtusa (Nees & Meyen) Hitchc
- Vulpia megalura (Nutt.) Rydb.

## 4. Discussion

### *4.1 Poacae family species*

Natural grass species of the *Poaceae* family are the most successful among other herbaceous plants on the planet and are found in all climatic environments, including subalpine, xerophytic, aquatic and geographic environments in the Andes and high elevation regions, covering about 20% of the planet's land surface, making them ecological hegemons as an essential ecological resource and a staple diet for herbivores (Flores, 2016; Scrivanti & Anton, 2021; Mageed et al., 2022; Jamil et al., 2022). They also contribute to the production and maintenance of soil texture, continuously providing humus to the soil, satisfying nutrient needs and increasing primary production (Scrivanti & Anton, 2020; Mageed et al., 2022). *Poaceae* species, especially *Calamagrostis* and *Festuca*, have the anatomical features of roots that are adapted to drought or flooding (Yamauchi et al., 2021), in addition to the involute leaves and hollow stems that are adapted to restrict plant transpiration, through which they have greater capacity to adapt to the divergent conditions of the mountain range, despite the transformation that they have been suffering due to the effects of agriculture, overgrazing and mining (Yaranga et al., 2019; Sirimarco et al., 2023); however, some species such as *Festuca dolichophylla* present moderate vegetation cover in the upper and middle zones of the microbasin and low vegetation cover in the lower altitude zone due to soil, temperature and altitude conditions (Scrivanti & Anton, 2020; Paz et al., 2022).

**Commented [MOU12]:** The sentence is very long. Try to make shorter sentences.

### *4.2 Characteristics of suitable species (D) for Andean livestock*

It has been observed that, not all families or species have been reported as suitable for Andean livestock (Table 1), due to the diversity in the preference they have based on the anatomical adaptation in the mouth to ingest natural grasses (Flores, 2016), the ecological interaction of the animal with the morphology and tissue structure of grasses and the nutrient content that are key factors in the feeding behavior of grazing animals (Dias-Silva & Filho, 2020; Molnár et al., 2020; Bakhshi et al., 2020); likewise, grass height, forage mass per unit volume, leaf lamina fibrosity, spatial arrangement of preferred plant tissues, presence of defoliation barriers and dry matter content play an important role in intake preference (Dias-Silva & Filho, 2020; Scrivanti & Anton, 2021).

**Commented [MOU13]:** Rephrase your first sentence. And avoid long sentences as it can cause confusion to the readers

### *4.3 Local publications on species D*

While it is true that there are many studies and publications related to natural grasslands, both in composition, floristic diversity and grazing in the Andean region of Peru and neighboring countries, there are very few (Table 2) that have ventured into the issue of species identification in relation to their suitability for livestock (Carla, 2021; Onofre, 2020; Trillo, 2021; Galarza and Jorge, 2020; Capuñay, 2022); in others, they only studied some species in particular, such as *Festuca dolichophylla*, due to its importance in livestock feeding (Paz et al. , 2022). There are few publications related to research carried out by universities with professional careers involved in the management of grasslands with Andean livestock grazing: cattle, sheep, alpacas, llamas and vicuñas (Yaranga, 2019), in which most of the data were not georeferenced, leaving a deep gap in the possibilities of geographic modeling or ecological niches (Ivanova and Dhashkov, 2021). Meanwhile, the GBIF database has numerous species recorded (Table 3) due to the report made on the species identified by various sources such as: research entities, museums and citizen science, which is why there are many duplicate data and with invalid georeferencing and others without this detail, as well as many records with ambiguous or unclear identity, which confirm that the completeness of the sample is less than 40%, i.e. low (Leung et al, 2019; Popović et al., 2020; Hirinori et al., 2022) i.e. the information stored in the GBIF is not yet complete (Qian et al., 2022), as mentioned in a footnote to Table 3. However, this database is increasingly used to initiate processes of geographic reconnaissance and local environmental conditions, as a basis for species-specific habitat analysis that allows modeling ecological niches. This requirement is important for the Puna region of Peru, where it is necessary to reinforce the approach of entities that propose restoration projects for degraded grassland ecosystems with livestock interest (Mosquera et al., 2022; Vásquez et al., 2023; Young et al., 2023).

### *4.4 Geographical distribution of suitable species*

The geographic distribution of species D of the *Poaceae* family (Figure 1) is widespread in the Puna region, with a greater concentration of records in some places closely related to ecotourism activity, such as the Cordillera Blanca del Huascarán in the department of Ancash, others in Cajamarca, Cusco, Huancavelica, Ayacucho, and Arequipa, with very little information in places with little Andean tourist attraction such as: Puno, Apurímac, Junín, Cerro de Pasco, La Libertad, Piura, and others (GBIF. org, 2022). However, all the species of interest in this study are located in the Puna region of the Andean Cordillera, due to their adaptation to climatic, edaphic and anthropogenic effects (Scrivanti & Anton, 2021; Waheed et al., 2022), influenced by topography and elevation (Scrivanti & Anton, 2021; Lemmer et al., 2021), to the complex and rugged topographic factor, coupled with significant latitudinal and altitudinal gradients with physical and chemical soil properties of low agro-ecological value and low nitrogen availability (Huarcaya, 2020; Kaltrina, 2020; Zhang et al., 2021; Zhang et al., 2023).

The greater diversity of species shown by the genus *Calamagrostis* and *Festuca* is due to the fact that these genus have species of wide diversity in their morphological structure with growth heights ranging from a few centimeters to the presence of tall species with abundant bushes whose heights can exceed 100 cm; these characteristics give them a better ability to adapt to the very heterogeneous environmental conditions of the Andean Cordillera (Yaranga et al., 2021); whereas, the genus with few species are less heterogeneous in their morphological structure and plant size, which also restrict their habitat to sites with a certain environmental homogeneity, thus their presence in more specific habitats (Christmann et al., 2020; Huarcaya, et al., 2020¸Yaranga et al., 2021).

## 5. Conclusions

The Poaceae family of natural grasses in the Andean region has the largest number of suitable species that make up the basic diet of Andean livestock, in addition to contributing to the production and maintenance of soil texture, humus and nutrients. However, local information from studies carried out at different universities on the identification of suitable species in the *Poaceae* family of Andean natural grasses is very scarce, barely reaching 105 records, and most of them were not georeferenced, which does not allow geoprocessing to identify specific habitats and ecological niches for each species of interest. Not all the species cataloged as suitable for cattle are preferred by the four Andean cattle species, but each one shows a particular preference for some species.

Although it is true that there is a huge amount of data recorded in the GBIF, very few species of this family are suitable for livestock feed, so only an average of 22% of the species recorded in the GBIF fall into this category, many of them with duplicate records or with invalid geographic positioning information, an aspect that highlights the low completeness of the record in natural grasslands. The geospatial distribution of D species is mostly concentrated in places of major tourist attractions such as the Cordillera Blanca of Ancash and others such as Cajamarca, Cusco, and Arequipa, which leads to urgent tasks of identification and registration of species in the Darwin Core of GBIF, to contribute to the expansion of the database to facilitate modeling work of ecological niches for each species in particular and build spatial information for sustainable restoration programs of degraded areas.

**Commented [MOU14]:** Improved your conclusion. This part should clearly summarize the important findings in the study.

Here is my suggestion
5. Conclusions
The Poaceae family of natural grasses in the Andean region provides the largest number of suitable species that form the basic diet of Andean livestock. Beyond their role in livestock nutrition, these grasses also contribute significantly to soil texture, humus formation, and nutrient cycling. However, local information from studies conducted by various universities on identifying suitable species within the Poaceae family is scarce, with only 105 records available. Moreover, most of these records lack georeferencing, which limits the ability to geoprocess data and identify specific habitats and ecological niches for species of interest. It is also worth noting that not all species cataloged as suitable for livestock are equally preferred by the four Andean livestock species, as each exhibits specific preferences for certain species.

While the GBIF database contains a large volume of records, only a small subset—approximately 22%—represents species suitable for livestock feed. Many of these records are duplicates or lack valid geographic positioning information, underscoring the low completeness and reliability of the current records for natural grasslands. The geospatial distribution of suitable species (D species) is predominantly concentrated in areas of major tourist interest, such as the Cordillera Blanca in Ancash, as well as regions like Cajamarca, Cusco, and Arequipa.

This situation highlights the urgent need for comprehensive identification and registration of species in the Darwin Core standard of GBIF. Expanding the database is essential to facilitate ecological niche modeling for each species and to develop spatial information for sustainable restoration programs aimed at rehabilitating degraded areas.

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**Table 5.** *Species D of the family Poaceae identified in local studies carried out in the Andean Cordillera of Peru.*

| N° | Species identified | Department | Place | N | E | Year | Author | Title of publication | Source |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *Festuca dolychopyla, Calamagrostis vicunarum, Calamagrostis rigescens, Muhlenberigia ligularis* | Huancavelica | Lachocc | 8857256 | 317506 | 2021 | Guillen Héctor | | Revista de Investigación Científica Siglo XXI |
| 2 | *Agrostis breviculmis, Calamagrostis curvula, Calamagrostis rigescens, Muhlenbergia ligularis,* | Huánuco | Lauricocha | 8453278 | 810219 | 2005 | Salvador F., Alonso M. y Rios S. | Avance sobre los pastos de turberas en los Andes Centrales Peruanos | Producciones Agroganaderas |
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| 7 | *Calamagrostis vicunarum, Hordeum muticum, Paspalum pygmaeum, Bromus catharticus, Poa pratensis, Festuca dolichophylla, Bromus pitensis, Bromus unioloides, Muhlenbergia ligularis, Calamagrostis curvula, Stipa sp* | Cusco | Marampaqui | | | 2000 | Farfan R., San Martin F. y Durand A. | Recuperación de praderas degradas port medio de clausuras temporales | Rev. Inv. Vet. Perú |
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