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Floristic Composition and Diversity in Plots of Early Post-Agricultural Succession in Four Agroecosystems in the District of Cajatambo, Lima

Composición florística y diversidad en parcelas de sucesión post-agrícola temprana en cuatro agroecosistemas en el distrito de Cajatambo, Lima

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Abstract

In this paper, the floristic composition is studied in plots of early post-agricultural succession induced in four agroecosystems (Ocopata, Rancas, Tupicocha and Ucupi) in the district of Cajatambo, Lima. The plots are located between 2,992 masl and 4,220 masl in three plant formations (agriculture, scrubland and grassland), and the description of the floristic composition was made before and after inducing the succession between 2015 and 2017. The number of determined plants is 78, all of which belong to 30 botanical families, of which the Asteraceae (16 species), Fabaceae (11 species) and Poaceae (8 species) families stand out. Indeed, the only common species among the four agroecosystems is *Medicago polymorpha*; moreover, five species appear in three of the four agroecosystems: *Brassica rapa* subsp. *campestris* and *Verbena litoralis* (Ocopata, Tupicocha and Rancas), *Oenothera rosea* and *Trifolium repens* (Ocopata, Rancas and Ucupi) and *Bidens andicola* (Tupicocha, Rancas and Ucupi).

Keywords: *Vegetation, floristic composition, succession, agriculture, plant diversity*

Resumen

Se estudió la composición florística en parcelas de sucesión post-agrícola temprana inducida en cuatro agroecosistemas (Ocopata, Rancas, Tupicocha y Ucupi) en el distrito de Cajatambo, Lima. Las parcelas se ubicaron entre 2 992 y 4 220 metros sobre el nivel del mar en tres formaciones vegetales (agricultura, matorral y pastizal), y la descripción de la composición florística se hizo antes y después de inducir la sucesión entre los años 2015 y 2017. El número de plantas determinadas fue de 78, pertenecientes a 30 familias botánicas de las cuales destacan las familias Asteraceae (16 especies), Fabaceae (11 especies) y Poaceae (8 especies). Se encontró que la única especie común entre los cuatro agroecosistemas fue *Medicago polymorpha* y que cinco especies aparecieron en tres de los cuatro agroecosistemas: *Brassica rapa* subsp. *campestris* y *Verbena litoralis* (Ocopata, Tupicocha y Rancas); *Oenothera rosea* y *Trifolium repens* (Ocopata, Rancas y Ucupi) y *Bidens andicola* (Tupicocha, Rancas y Ucupi).

Palabras clave: *Vegetación, composición florística, sucesión, agricultura, diversidad vegetal*

Introduction

Ecological succession is a key concept for the sustainable management of agroecosystems, but little is known about its specific role in agricultural systems, particularly in mountain ecosystems (Sarandón & Flores, 2014). It is defined as the process of directed temporal change (linear or cyclic) of vegetation during a specific ecological time, where, usually after a disturbance, changes are observed in the taxonomic composition, three-dimensional structure of the cover and functions of the system. It is also defined as the occupation of an area by organisms involved in an incessant process of action and reaction, which, over time, leads to changes in both the environment and the community (Krebs, 1985; Pickett & Cadenasso, 2005; Pickett & White, 1985).

Agricultural activity takes advantage of these changes to maintain agroecosystems in the initial stages of ecological succession. Therefore, the said system can produce large quantities of harvested material, albeit with unpredictable effects on development and stability processes. By maintaining a mosaic of cultivated and resting plots, farmers have captured the essence of the ecological succession process, which, in essence, is a regeneration process (Gutiérrez, Aguilera & González, 2008). Alternatively, plant succession provides ecological resources and services of interest, such as grazing areas and

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soil fertility, which can be used to implement ecologically sustainable management systems (Espinoza-Bretado & Návar, 2005).

One of the key principles of sustainability is to integrate biological and ecological processes into food production. In this sense, biological diversity is an instrument that, from an ecological management perspective, ensures the design of sustainable agricultural systems, which includes mechanisms for system regulation and recovery. Indeed, this requires knowing the relevant components of the system as well as how they articulate with the aforementioned processes (Pretty, 2008; Sarandón & Flores, 2014).

According to Gliessman (2002), although diversity has been interpreted as the number of different species that make up a community in a given place, the concept of diversity is multidimensional, ranging from genes and species to spatial (horizontal and vertical), functional and temporal diversity. Agricultural activity simplifies ecosystems by replacing multidimensional diversity with minimal species and varieties, which are simultaneously and homogeneously managed (Sarandón & Flores, 2014). In this sense, biological diversity is vital insofar that it provides services that go beyond the production of food, fibre and fuels (Altieri & Nicholls, 2012; Gliessman, 2002). These services include the following: succession, biotic regulation, nutrient recycling, energy flow and water regulation (Sarandón & Flores, 2014).

The biotic composition of an ecosystem reflects the climate, the nature of the soil, the availability of water and nutrients and anthropic and biotic factors. Vegetation and floristic composition, as the structural basis of the community, are repeated in different areas with similar physical and biological contexts. In spite of this, no two spaces are occupied by identical plant communities, since vegetation type results in different communities of birds, arthropods, microorganisms and other organisms (Matteucci & Colma, 1982; Ramos, Castro & Sánchez, 2015). Therefore, monitoring the dynamics of succession in abandoned plots allows us to obtain information that can be used to design sustainable systems.

Farm spaces represent a special type of secondary succession, as they are continuously disturbed and allow a certain level of regeneration during inactive periods. This favours weeds, which, in natural conditions, are classified as pioneers of succession; they occupy the habitats of those that are normally eradicated, and, therefore, they are considered as invasive (Caamal-Maldonado & Armendariz-Yañez, 2002). Thus, early post-agricultural succession is defined as a form of secondary succession that takes place in fields where agricultural activity has altered original vegetation. When agricultural activity is interrupted or ceases, weeds are ubiquitous and may dominate fields during early succession (Omacini, Tognetti, Trebino & Chaneton, 2005).

Post-agricultural succession studies are indispensable for the success of agroecosystem management activities, as they provide information on how different geographical and climatic areas function and regenerate (Myster, 2008; Sarandón & Flores, 2014). In the Andean region, Omacini et al. (2005) identified the sustained dominance of exotic species 20 years after the interruption of agriculture in the Pampeana region (Argentine); in the same way, Ortuño, Beck and Sarmiento (2006) found minimal changes in the richness and diversity of post-agricultural plots in central Altiplano (Bolivia), which can possibly be attributed to the species adapting to harsh climate conditions, restricted soil conditions and anthropogenic influence. Based on the little information available on succession in high Andean mountain environments, it is necessary to characterise the process in these environments (Krebs, 1985). For example, in the district of Cajatambo, a space in the mountains of the department of Lima that presents a process of abandonment of hillside agriculture and that has a vacuum of biological information (Walsh Perú, 2011).

This research was carried out within the framework of the project, *Determination of criteria for the establishment of environmental quality standards for biological diversity. Case study: Cajatambo District*, financed by the Fondo para la Innovación, Ciencia y Tecnología (FINCyT), with the objective of characterising floristic composition and diversity in early post-agricultural succession plots in four agroecosystems of the Cajatambo District, Lima.

Materials and Methods

The study area was located in the district of Cajatambo, in the province of the same name, to the north–east of the department of Lima in the western part of the Andes, at 10° 28′ 16.65″ SL and 76° 59′ 35.91″ WL, limited by the departments of Ancash, Huánuco and Pasco. The district is located between 2,600 masl and 4,800 masl, and the capital, Cajatambo (Figure 1), is located 3,376 masl (Quinteros, 2009).

The dry season runs from May to October, wherein the days are mostly clear, and the rainy season runs from November to April, with storms usually occurring in the afternoon.

Establishment of permanent plots for monitoring-induced post-agricultural succession

A permanent or long-term plot is one that, once installed, is measured at least three consecutive times. In this type of plot, different variables are measured repeatedly, thereby obtaining a series of data (one in each plot) for the construction of growth models and community dynamics (Gadow, Rojo, Álvarez & Rodríguez, 1999). Three plant formations were selected (agriculture, shrubland and grassland) using an accessibility criterion, that is, plant formations in which the establishment of the plot could be guaranteed in the long term. Therefore, four sites were

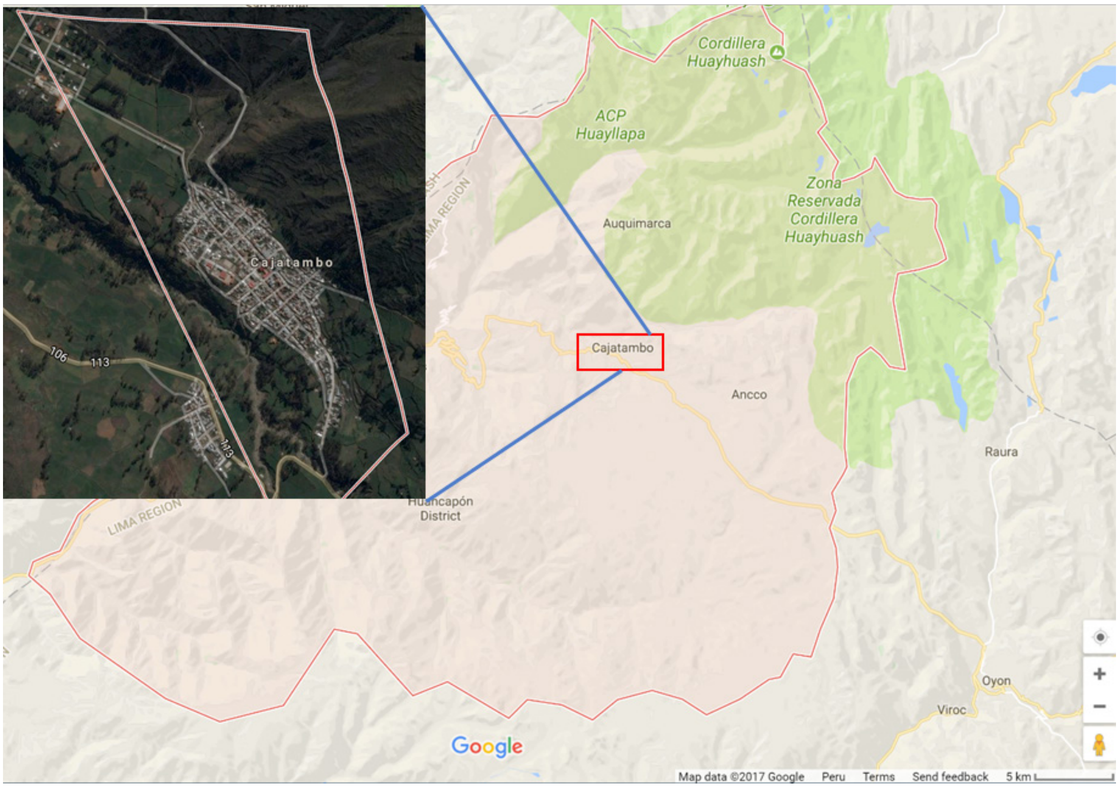

Figure 1: Province and District of Cajatambo. Source: Google Map Data (2017).

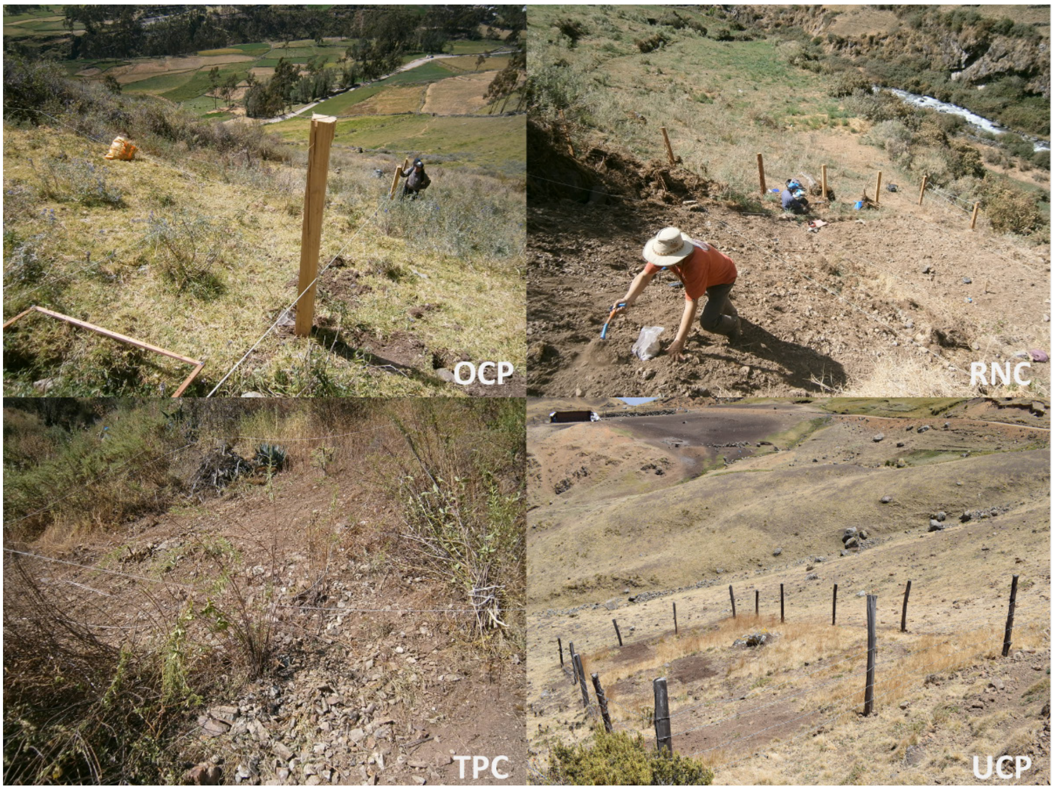

Figure 2. Long-term plots for the monitoring of induced post-agricultural succession.

selected: Ocopata (OCP), corresponding to agriculture; Tupicocha (TPC) and Rancas (RNC), corresponding to shrublands; and Ucupi (UCP), corresponding to grasslands (Figure 2). Three 5 x 5 m plots were installed in each locality and were monitored three times a year during 2015–2017. The OCP, TPC and RNC plots were installed in June 2015, and the UCP plots were installed six months later. The first record of floristic composition was made in June 2015, and, after making the necessary measurements, aerial vegetation coverage was eliminated in the 5 x 5 m squares; in this way, succession was induced. The development of the vegetation was monitored by observing the floristic composition and the number of species in September and December of 2015; April, July and October of 2016; and January, May and October of 2017, thereby covering the dry, rainy and intermediate seasons.

Characterisation of the floristic composition and plant diversity in permanent plots for the monitoring of induced post-agricultural succession

The botanical material was collected in the long-term plots according to the direct collection technique (INBio, 2008; Mesa & Bernal, 2005; Cámara & Díaz, 2013); processing was carried out at the collection site and at the Augusto Weberbauer Herbarium of La Molina National Agrarian University. The classification system of the flowering plants proposed by Angiosperm Phylogeny Group IV (APG et al., 2016) was used. The scientific names follow the guidelines of the *Catalogue of Gymnosperms and Angiosperms of the Peruvian Flora* (Brako & Zarucchi, 1993) and the TROPICOS database of the Missouri Botanical Garden (www.tropicos.org). Using species richness data for each agroecosystem, a general description of alpha diversity and its changes over time was made through the Shannon–Weaver and Simpson indices, using PAST 3.25 software (Hammer, Harper & Ryan, 2001). With this information, a list of species, botanical families and life forms was created for plants that are registered in the four agroecosystems represented by the long-term exclusion plots.

Results and Discussion

Characterisation of permanent plots for the monitoring of induced post-agricultural succession

According to Tovar (2007) and Quinteros (2009), as well as the altitude of the plots, the plot of TPC corresponds to the lower part of the basin, between 2,600 masl and 3,000 masl; the climate is dry and semi-cold, with scarce precipitations, and the average temperature is between 12°C and 16°C. The plot of OCP, between 3,200 masl and 3,600 masl, corresponds to a semi-humid and semi-cold climate, with moderate rainfall in summer and moderate drought throughout the rest of the year as well as temperatures ranging between 8°C and 12°C. The RNC plot, between 3,600 masl and 3,900 masl, presents a slightly humid and semi-cold climate, with temperatures below 10°C and the presence of frost between June and August. Finally, the plot of UCP corresponds to heights above 3,900 masl, where the climate is moderately humid and cold, with abundant rainfall in summer, mild drought the rest of the year and temperatures between 5°C and 8°C, falling to 0°C at night.

According to the information provided by the owners of the plots, three of the four selected agroecosystems have exhibited agricultural activity that subsequently (for various reasons) ceased. In OCP, the main crop was maize, which was rotated with beans, ollucos and tarwi during breaks, the last of which was prolonged and thus allowed shrub development of the tarwi and favouring the entrance of the kikuyo. This is the reason why it remained in rest 8 years ago; currently, it is used for the grazing of cattle since it is near a water canal. In TPC, the main crop was maize; however, due to its remoteness and the lack of water irrigation, agricultural activity was abandoned 20 years ago. In RNC, the main crop was potato; however, due to the reduction of agricultural activities in the area and the change to livestock, agricultural activity was abandoned 10 years ago. In UCP, the main activity was sheep grazing, which is still being used today.

The soil texture varies from sandy clay loam (OCP), to sandy loam (TPC and RNC) and loam (UCP). OCP has the highest organic matter content, as shown in Table 1. Precipitation data obtained from the Cajatambo Conventional Weather Station (CWS) (Figure 3) for 2015–2017 indicates that the rainy months were concentrated between December and April, with maximum values reached in February; the dry months were between June and August. Indeed, sporadic rain occurred throughout the year, which characterises them as intermediate months. Precipitation for 2015 was 560 mm, 317 mm for 2016 and 770 mm for 2017 (Figure 4).

Table 1. Main characteristics of the four agroecosystems evaluated in Cajatambo, Lima.

Plot	Ocopata (OCP)	Tupicocha (TPC)	Rancas (RNC)	Ucupi (UCP)
Plant formation	Agriculture	Shrubland	Shrubland	Grassland
Geographic coordinates	77°00’2.5” W.L 10°28’39.4” S.L	77°01’27.9” W.L 10°27’25.3” S.L	77°00’21.8” W.L 10°25’42.4” S.L	76°56’36.5” W.L 10°29’54.3” S.L
Height (masl)	3,505	2,992	3,635	4,220
Climate	Semi-humid and semi-cold	Dry and semi-cold	Wet and semi-cold	Wet and cold
Temperature (°C)	8 to 12	12 to 16	<10	5 to 8
Slope (°)	40	30	30	20
Orientation	N	N	NE	S
Soil texture	Sandy clay loam	Sandy loam	Sandy loam	Loam
O.M. (%)	10	5	8	8
Last sowing	12 years	20 years	15 years	-

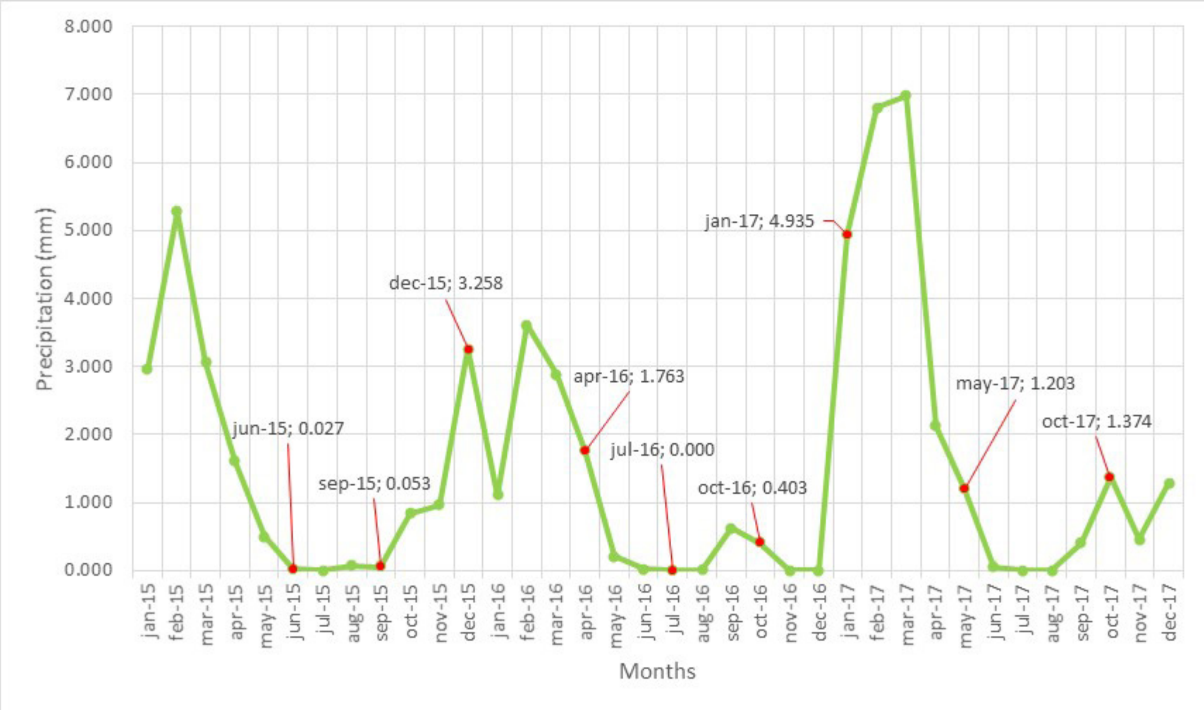

Figure 3. Evolution of average monthly precipitation (mm) from January 2015 to December 2017. Source: Cajatambo CWS, SENAMHI.

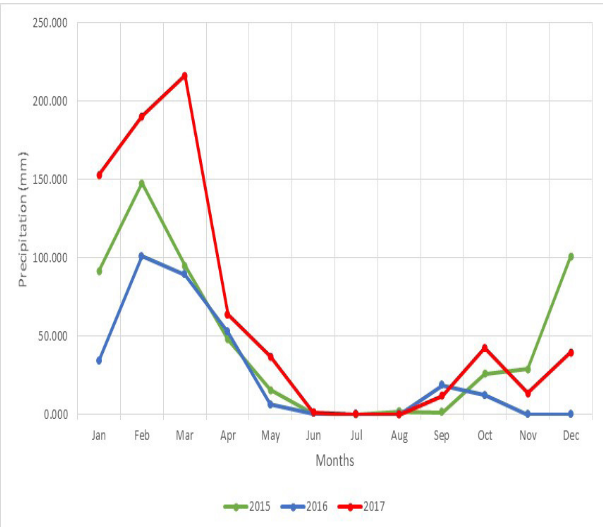

Figure 4. Comparison of accumulated monthly precipitation (mm) from 2015 to 2017. Source: Cajatambo CWS, SENAMHI.

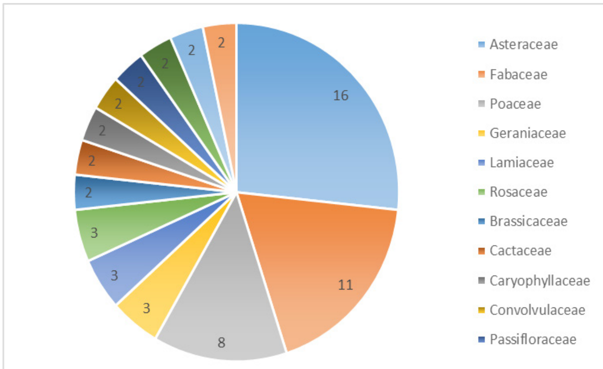

Figure 5. Main plant families and their richness recorded in the plots of early post-agricultural succession in Cajatambo, Lima (2015 to 2017).

Floristic composition and plant diversity in long-term plots for the monitoring of induced post-agricultural succession

Initial richness is defined as the number of different species present in a defined geographical space (Colín, Maeda & Muñoz, 2006). In the four agroecosystems evaluated, a total richness of 78 species belonging to 30 botanical families was determined, of which the Asteraceae (16 species), Fabaceae (11 species), Poaceae (8 species), Geraniaceae (3 species), Lamiaceae (3 species) and Rosaceae (3 species) stood out (Figure 5). The list of 78 species, their form of life, botanical family and agroecosystems are shown in Table 2.

The total diversity of identified families and the total abundance of species for the main families in the four agroecosystems evaluated between 2015 and 2017 are consistent with previous studies conducted in the valleys of the Lima Region, where the Asteraceae, Fabaceae and Poaceae families are dominant. According to Huamán, Chávez, Arias and Zegarra (2007), 68 families are registered for the province of Barranca (0 masl to 484 masl), including Poaceae (37 species) and Fabaceae (32 species); 56 families are registered for Quinteros (2009) in the district of Cajatambo (2,600 masl to 4,800 masl), including Asteraceae (55 species) and Solanaceae (18 species). According to Paulino, La Torre and Huamán (2015) for the province of Oyón (2,500 masl to 4,300 masl), 40 families are registered, of which Asteraceae (65 species) and Poaceae (23 species) stand out. Moreover, according to Gonzáles, Navarro, La Torre and Cano (2015), 77 families are registered for the province of Canta

Table 2. List of 78 species found indicating their presence (1) or absence (0) at OCP, TPC, RNC and UCP in Cajatambo, Lima during 2015–2017.

N°	Scientific name	Families	Life form	Location			
				OCP	TPC	RNC	UCP
1	*Achyrocline alata* DC.	Asteraceae	Herbaceous broadleaf	0	1	0	0
2	*Agave cordillerensis* Lodé & Pino	Agavaceae	Leaf succulent	1	1	0	0
3	*Ageratina sternbergiana* (DC.) R.M. King & H. Rob.	Asteraceae	Herbaceous broadleaf	0	1	1	0
4	*Aldama helianthoides* (Rich.) E.E.Schill. & Panero	Asteraceae	Herbaceous broadleaf	0	1	0	0
5	*Ambrosia arborescens* Mill.	Asteraceae	Perennial broadleaf	0	1	1	0
6	*Astragalus garbancillo* Cav.	Fabaceae	Herbaceous broadleaf	0	0	0	1
7	*Austrocylindropuntia floccosa* (Salm-Dyck) F. Ritter	Cactaceae	Stem succulent	0	0	0	1
8	*Austrocylindropuntia subulata* (Muehlenpf.) Backeb.	Cactaceae	Stem succulent	1	0	0	0
9	*Avena sterilis* L.	Poaceae	Grass	1	1	0	0
10	*Baccharis pentlandii* DC.	Asteraceae	Perennial broadleaf	0	0	1	0
11	*Berberis lutea* Ruiz & Pav.	Berberidaceae	Perennial broadleaf	0	0	1	0
12	*Bidens andicola* Kunth	Asteraceae	Herbaceous broadleaf	0	1	1	1
13	*Bidens pilosa* L.	Asteraceae	Herbaceous broadleaf	1	1	0	0
14	*Bomarea dulcis* (Hook.) Beauverd	Alstroemeriaceae	Herbaceous broadleaf	0	1	0	0
15	*Brassica rapa* subsp. *campestris* (L.) Clapham	Brassicaceae	Herbaceous broadleaf	1	1	1	0
16	*Bromus catharticus* Vahl	Poaceae	Herbaceous broadleaf	0	0	1	0
17	*Bromus* sp.	Poaceae	Grass	0	1	0	1
18	*Caiophora cirsiifolia* C. Presl	Loasaceae	Herbaceous broadleaf	0	0	1	0
19	*Calamagrostis vicunarum* (Wedd.) Pilg.	Poaceae	Grass	0	0	0	1
20	*Calceolaria cuneiformis* Ruiz & Pav.	Calceolariaceae	Herbaceous broadleaf	0	0	1	0
21	*Cestrum auriculatum* L'Hér.	Solanaceae	Perennial broadleaf	0	1	0	0
22	*Chuquiraga spinosa* Less.	Asteraceae	Perennial broadleaf	0	0	0	1
23	*Citharexylum* cf. *dentatum* Tafalla ex D. Don	Verbenaceae	Deciduous broadleaf	0	1	0	0
24	*Croton ruizianus* Müll. Arg.	Euphorbiaceae	Perennial broadleaf	0	1	0	0
25	*Cuscuta odorata* Ruiz & Pav.	Convolvulaceae	Parasite	1	0	0	0
26	*Dalea exilis* DC	Fabaceae	Herbaceous broadleaf	0	1	0	0
27	*Desmodium molliculum* Kunth	Fabaceae	Herbaceous broadleaf	1	0	0	0
28	*Dichondra microcalyx* (Hallier f.) Fabris	Convolvulaceae	Herbaceous broadleaf	0	0	1	0
29	*Dicliptera* cf. *montana* Lindau	Acanthaceae	Herbaceous broadleaf	0	1	0	0
30	*Eragrostis* sp.	Poaceae	Grass	0	1	1	0
31	*Erodium cicutarium* (L.) L'Hér. ex Aiton	Geraniaceae	Herbaceous broadleaf	0	1	1	0
32	*Festuca* sp.	Poaceae	Grass	0	1	0	0
33	*Fuertesimalva peruviana* (L.) Fryxell	Malvaceae	Herbaceous broadleaf	0	1	0	0
34	*Galium* sp.	Rubiaceae	Herbaceous broadleaf	0	0	1	0
35	*Geranium matucanense* R. Knuth	Geraniaceae	Herbaceous broadleaf	0	1	0	0
36	*Geranium sessiliflorum* Cav.	Geraniaceae	Herbaceous broadleaf	0	0	1	1
37	*Gomphrena globosa* L.	Amaranthaceae	Herbaceous broadleaf	0	0	1	0
38	*Hesperomeles cuneata* Lindl.	Rosaceae	Perennial broadleaf	0	0	1	0
39	*Hypochaeris brevicaulis* Phil.	Asteraceae	Herbaceous broadleaf	0	0	1	1
40	*Lachemilla pinnata* (Ruiz & Pav.) Rothm.	Rosaceae	Herbaceous broadleaf	0	0	1	1
41	*Lepidium bipinnatifidum* Desv.	Brassicaceae	Herbaceous broadleaf	0	0	1	0
42	*Lupinus ballianus* C.P.Sm.	Fabaceae	Perennial broadleaf	1	0	1	0

N°	Scientific name	Families	Life form	Location			
				OCP	TPC	RNC	UCP
43	*Lupinus microphyllus* Desvaux	Fabaceae	Perennial broadleaf	0	0	0	1
44	*Marrubium vulgare* L.	Lamiaceae	Herbaceous broadleaf	0	0	1	0
45	*Medicago polymorpha* L.	Fabaceae	Herbaceous broadleaf	1	1	1	1
46	*Medicago sativa* L.	Fabaceae	Herbaceous broadleaf	1	0	0	0
47	*Melilotus* sp.	Fabaceae	Herbaceous broadleaf	0	1	0	0
48	*Minthostachys mollis* Griseb.	Lamiaceae	Perennial broadleaf	0	1	1	0
49	*Muehlenbeckia volcanica* (Benth.) Endl.	Polygonaceae	Herbaceous broadleaf	1	0	0	0
50	*Oenothera rosea* L'Hér. ex Aiton	Onagraceae	Herbaceous broadleaf	1	0	1	1
51	*Ophryosporus peruvianus* (J. Gmel.) R.M. & H. Rob.	Asteraceae	Herbaceous broadleaf	0	1	0	0
52	*Otholobium pubescens* (Poir.) J.W.Grimes	Fabaceae	Perennial broadleaf	1	0	0	0
53	*Oxalis peduncularis* Kunth	Oxalidaceae	Herbaceous broadleaf	0	0	1	0
54	*Paranephelius uniflorus* Poepp. & Endl.	Asteraceae	Herbaceous broadleaf	0	0	0	1
55	*Paronychia andina* A. Gray	Caryophyllaceae	Herbaceous broadleaf	0	0	0	1
56	*Paspalum* sp.	Poaceae	Grass	1	0	1	0
57	*Passiflora trifoliata* Cav.	Passifloraceae	Climbing	0	0	1	0
58	*Passiflora tripartita* var. *mollissima* (Kunth) Holm-Niels. & Jørgensen	Passifloraceae	Climbing	0	1	0	0
59	*Pennisetum clandestinum* Hochst. ex Chiov.	Poaceae	Grass	1	1	0	0
60	*Perezia coerulescens* Wedd.	Asteraceae	Herbaceous broadleaf	0	0	0	1
61	*Plantago lanceolata* L.	Plantaginaceae	Herbaceous broadleaf	1	0	1	0
62	*Ranunculus praeomorsus* Kunth ex DC.	Ranunculaceae	Perennial broadleaf	0	0	1	0
63	*Salvia sagittata* Ruiz & Pav.	Lamiaceae	Herbaceous broadleaf	1	0	0	0
64	*Senecio nutans* Sch. Bip.	Asteraceae	Herbaceous broadleaf	0	0	1	0
65	*Siphocampylus tupaeformis* Zahlbr.	Campanulaceae	Herbaceous broadleaf	0	0	1	0
66	*Solanum acaule* Bitter	Solanaceae	Herbaceous broadleaf	0	0	1	1
67	*Stellaria* cf. *weddellii* Pedersen	Caryophyllaceae	Herbaceous broadleaf	0	0	0	1
68	*Tagetes multiflora* Kunth	Asteraceae	Herbaceous broadleaf	1	1	0	0
69	*Taraxacum officinale* Weber in Wigg.	Asteraceae	Herbaceous broadleaf	1	0	1	0
70	*Tecoma stans* (L.) Juss. ex Kunth	Bignoniaceae	Perennial broadleaf	0	1	0	0
71	*Tetraglochin cristatum* (Britton) Rothm.	Rosaceae	Perennial broadleaf	0	0	0	1
72	*Trifolium repens* L.	Fabaceae	Herbaceous broadleaf	1	0	1	1
73	*Ullucus tuberosus* Caldas	Basellaceae	Herbaceous broadleaf	0	0	1	0
74	*Urtica leptophylla* Kunth	Urticaceae	Herbaceous broadleaf	0	1	1	0
75	*Verbena litoralis* Kunth	Verbenaceae	Herbaceous broadleaf	1	1	1	0
76	*Veronica persica* Poir.	Plantaginaceae	Herbaceous broadleaf	1	0	1	0
77	*Vicia andicola* Kunth	Fabaceae	Herbaceous broadleaf	0	0	1	0
78	*Werneria pygmaea* Gillies ex Hook. & Arn.	Asteraceae	Herbaceous broadleaf	0	0	0	1

(550 masl to 3,200 masl), of which Asteraceae (66 species) and Poaceae (41 species) stand out. According to Gonzáles (2016), the Asteraceae family has a great richness of species within Peruvian flora, being these plants often dominant elements that give the physiognomic aspect to several plant formations in the region of Lima.

Eight life forms were found using the modified Küchler and Zonneveld classification (1988) (Figure 6). Plant habit, also known as plant life form, is the characteristic appearance of a plant species, which includes growth size, configuration and orientation. It develops from specific genetic growth patterns in combination with environmental factors. According to Matteucci and Colma (1982), life forms have an adaptive connotation as species adapt to physical parameters and the biota within the community; therefore, natural selection favours the development of specialised characteristics that allow the species to

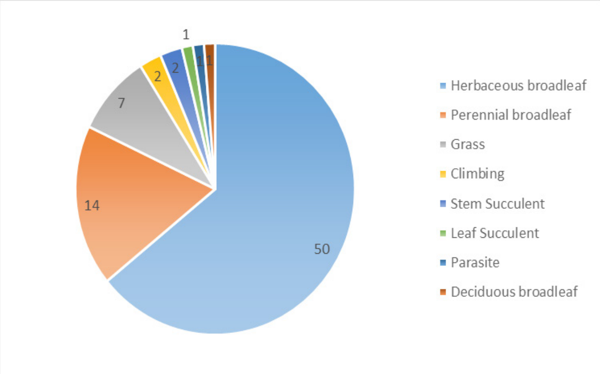

Figure 6. Number of species according to the life forms recorded in the plots of early post-agricultural succession in Cajatambo, Lima (2015 to 2017).

uniquely exploit the environment and evolve over time. The analysis of life forms suggests a general tendency in the four agroecosystems to maintain the broadleaf herbaceous weed lifestyle. However, each agroecosystem has a different dynamic due to the predominance of certain species. Of the 78 species that were recorded in the four agroecosystems, 50 were broadleaf herbaceous, which, in this study, is the most dominant species.

Finally, using initial richness data from each agroecosystem, a general description of alpha diversity (and its changes over time) was obtained using the Shannon–Weaver and Simpson indices. Herein, diversity is defined as 'the relationship between the number of species and the relative abundance of each of them in a given community' (Margalef, 1980). Among the levels of diversity, alpha diversity (or diversity within a habitat) is determined by the ecological interactions, evolutionary history and biogeographic of the area in question (Halffter & Moreno, 2005). This can be measured through several diversity indices. The Shannon–Weaver index is widely used, which is derived from information theory and provides a measure of structure as a result of ecosystem interactions. This is expressed in bits/individual, and its values increase as the richness and uniformity of the community increases (Margalef, 1980; Magurran, 2004). In addition, the Simpson index is often used, which is sensitive to the abundance of the most dominant species a community; accordingly, it is a measure of dominance, varies from zero to one and lacks units (Magurran, 2004).

Table 3 shows that, in the OCP plot, the initial richness is nine species, which decreases to two species affected after the induction of the succession. In 2016, a richness value of eight species was reached, and the sampling ends with ten species. In this temporal evolution, it is evident that, on average, diversity is 1.87 bits/individual; moreover, there is no dominance in any season.

In TPC, the initial richness is 28 species, which decreases to one species after the induction of the succession. In 2016, the richness recovers, reaching 31 species in April and July, but then decreases to 10 species. The average diversity is 2.13 bits/individual, and the dominance is low for all sampling seasons.

In RNC, the initial richness was 30 species, which decreases to four species after the induction of succession. The richness increases to 12 species by 2016, with the sampling ending at 11 species. Diversity on average is 2.65 bits/individual, and dominance, as in TPC, is low for all sampling seasons.

Finally, in UCP, the initial richness was seven species. Contrastingly, after induction of succession, the richness increased to 12, suggesting that induction disturbed the dominant structure, which, in turn, allowed other species to enter and establish themselves—species that were either latent in the soil or else introduced by the wind. The sampling concludes with a richness of four species,

Table 3. Values of species richness, Shannon–Weaver diversity index and dominance for each agroecosystem and monitoring date (w.d., without data).

Location	Parameters	2015			2016			2017		
		Jun.	Set.	Dec.	Apr.	Jul.	Oct.	Jan.	May	Oct.
Ocopata	Richness (S)	**9**	2	4	**8**	5	6	6	9	**10**
	Diversity (H)	2.4930	0.6501	1.9058	2.0934	1.3804	2.1410	1.8178	2.3285	2.0934
	Dominance (D)	0.2206	0.7222	0.2813	0.3021	0.5191	0.27	0.378	0.2477	0.3126
Tupicocha	Richness (S)	**28**	1	1	**31**	**31**	8	9	w.d.	**10**
	Diversity (H)	4.3901	0.0000	0.0000	2.9287	2.6127	2.5348	2.0097	w.d.	2.594
	Dominance (D)	0.0562	1.0000	1.0000	0.0531	0.0548	0.1540	0.1614	w.d.	0.1536
Rancas	Richness (S)	**30**	4	2	**12**	**10**	6	4	**19**	**11**
	Diversity (H)	4.3093	1.9751	0.9545	2.7642	2.9114	2.3718	1.9072	3.7193	2.9546
	Dominance (D)	0.0636	0.2593	0.5313	0.2296	0.1663	0.2099	0.2778	0.0934	0.1754
Ucupi	Richness (S)	w.d.	w.d.	**7**	**12**	6	7	2	**16**	**4**
	Diversity (H)	w.d.	w.d.	1.8943	3.1653	1.9736	2.5781	0.9494	3.0874	1.3388
	Dominance (D)	w.d.	w.d.	0.3633	0.1352	0.3238	0.1852	0.5346	0.1679	0.5018

which supports the assumption of initial dominance. The mean diversity is 2 bits/individual, and the dominance is medium, both at the beginning and end of the test.

Based on the floristic composition of the plots, the only common species among the four agroecosystems is *Medicago polymorpha*, which is associated with the landscape in question: periodically visited by cattle and exposed to excessive sun, seasonal rain and frost. Five species appear in three of the four agroecosystems: *Brassica rapa* subsp. *campestris* and *Verbena litoralis* (OCP, TPC and RNC), *Oenothera rosea* and *Trifolium repens* (OCP, RNC and UCP) and *Bidens andicola* (TPC, RNC and UCP).

The description of the plant community composition is essential to observe spatial and temporal changes in parameters of ecological importance. Indeed, the analysis of communities allows to monitor the variations in the agroecosystem; therefore, vegetation is an adequate indicator since its structure and composition reflect the vital ecosystem factors (Matteucci & Colma, 1982).

Conclusion

The early post-agricultural succession of the four agroecosystems evaluated in Cajatambo presents a floristic composition represented by 78 species belonging to 30 botanical families, of which the Asteraceae (16 species), Fabaceae (11 species) and Poaceae (8 species) families stand out.

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