Dynamics of post-fire natural regeneration of high Andean ecosystems in the district of Chiara. Ayacucho-Peru

Dinámica de regeneración natural post-incendio de ecosistemas altoandinos en el distrito de Chiara. Ayacucho-Perú

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Abstract: The dynamics of natural regeneration of high Andean ecosystems disturbed by fires in the district of Chiara, Ayacucho - Peru was studied. Three study zones were established along the Ayacucho - Cusco road, district of Chiara: Toccto, Incapaperqan and Qewillaqocha, characterized by areas with and without fire impact, applying the band transect sampling method. In Qewillaqocha the most frequent species were *Festuca dolichophylla, Plantago australis, Luzula racemosa, Calamagrostis vicunarum, F. dolichophyla* had the greatest coverage, followed by *C. vicunarum*. In density, creeping and cespitose species such as *Lachemilla pinnata, L. racemosa* stood out; in non-impact vegetation, *F. dolichophylla* was the most representative, followed by *C. vicunarum*. In Incapaperqan, plant species are in regrowth, highlighting *Bromus catharticus, F. dolichophylla, Poa* sp., and *Muhlenbergia peruviana*; in the non-impacted zone, *F. dolichophylla* predominates, followed by *L. pinnata* and *C. vicunarum*. In Toccto, there are resprouts of *F. dolichophylla*. In the non-fire zone, *F. dolichophylla* is the most frequent, followed by *C. vicunarum*. The burned areas presented higher species richness in relation to areas without impact, the diversity indices are very low in both cases. The affected areas will recover with the first rains and will be in full splendor within 4-5 years. F. dolichophylla does not die completely in the fire. Regeneration by seeds is very slow.

Keywords: Fire, natural regeneration, high Andean ecosystems, pajonal.

Resumen: Se estudió la dinámica de regeneración natural de ecosistemas altoandinos perturbados por incendios en el distrito de Chiara, Ayacucho - Perú. Se establecieron 3 zonas de estudio a lo largo de la carretera Ayacucho - Cusco, distrito de Chiara: Toccto, Incapaperqan y Qewillaqocha, caracterizadas por áreas con y sin impacto por incendios, aplicando el método de muestreo en transecto de banda. Se registró la flora dicotiledónea con 116 especies y monocotiledónea 40, en Qewillaqocha las especies más frecuentes fueron *Festuca dolichophylla, Plantago australis, Luzula racemosa, Calamagrostis vicunarum, F. dolichophyla* tuvo mayor cobertura, seguido de *C. vicunarum*. En densidad resaltaron especies rastreras y cespitosas como *Lachemilla pinnata, L. racemosa*; en

vegetación sin impacto, *F. dolichophylla* es la más representativa seguido de *C. vicunarum*. En Incapaperqan, las especies vegetales están en rebrote, resaltando *Bromus catharticus, F. dolichophylla, Poa* sp*., y Muhlenbergia peruviana*, en la zona sin impacto predomina *F. dolichophylla*, seguido de *L. pinnata* y *C. vicunarum*. En Toccto, hay rebrotes de *F. dolichophylla. En* zona sin incendio, *F. dolichophylla* es la más frecuente, seguido de *C. vicunarum*. Las zonas incendiadas presentaron mayor riqueza de especies en relación a áreas sin impacto, los índices de diversidad son muy bajas en ambos casos. Las áreas afectadas se recuperarán con las primeras lluvias y estarán en pleno esplendor entre 4-5 años. *F. dolichophylla* no muere completamente en el incendio. En tanto la regeneración por semillas es muy lenta.

Palabras clave: Incendios, regeneración natural, ecosistemas altoandinos, pajonal.

Introduction

Throughout history, fire has played an important role in the evolution of ecosystems and human life. It is a natural regulator of ecological processes that helps maintain stability and promote ecological succession. However, human intervention has altered this stability, even in areas where fire was a natural process. This is reflected in important changes in the structure and composition of species[1].

Nevertheless, the effects of fire on natural ecosystems are diverse and vary in extent[2]. Nevertheless, they play an important role in the dynamics and functioning of ecosystems worldwide. Fire is recognized as a natural disturbance in many ecosystems[3], but it is also used as a tool in land management in many countries, especially to clear and prepare land for agricultural purposes[4].

In the high part of the Chiara district, there are fragile ecosystems made up of grassy pastures and puna grasslands, with a particular biodiversity, which are at risk due to various factors such as human activities. In these areas, there have been more than 21 cases of forest fires (FI) in various ecosystems and ecological levels during the year 2020, affecting flora and wildlife.

Events caused by the inhabitants of nearby communities, most of them intentionally burned for economic and cultural purposes. Activities such as stubble burning, pasture improvement, intensive agriculture, among others. For the inhabitants, this activity is a necessity, except in cases where they cannot control the intensity of the fire, which becomes a problem. It is important to note that in these community's fire was used as a management tool, unlike the perception of other people and public institutions[2]. In this regard, the human factor has a high incidence in its origin, about 96 % are due to negligent or intentional actions[5].

However, from the scientific-environmental point of view, they are events that cause negative impacts on high Andean ecosystems. They have repercussions on biodiversity and the landscape, causing migration, death of wildlife, generating soil degradation, modifying its physical and chemical properties, and producing erosion due to the loss of vegetation cover. They also contribute to global warming by emitting carbon dioxide and altering the hydrological cycle[6].

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The Andean regions of Peru represent current climatic models, both for their climatic and geographic characteristics. Their climate is affected by human action or activities in other remote places that generate environmental changes. One of the most important geographical characteristics of the region is the Andes Mountain Range, which in Peru extends parallel to the Pacific Ocean coast, forming a particular barrier that channels the air current, providing dry environments on the Pacific slope and humid conditions in the east. It also influences the interaction between the tropics and the extra-tropics[7].

In the Sierras de Córdoba, Argentina, in the study "Impact of fires on plant diversity", they concluded that fire had no significant effect on the number of tree species and was considerably less on shrub species. However, herbaceous species increased in the year following the fire and then became balanced with unaffected forest. The vertical structure of the landscape was severely altered due to the disappearance or drastic reduction of the tree layer. In the burned sites, a lower abundance and diversity of regeneration of tree and shrub species was observed compared to sites not affected by fire[8].

Similarly, a study in a strategic ecosystem of the Rabanal páramo in Boyacá, Colombia, on the "Functional Groups of Microorganisms in Páramo Soils Disturbed by Forest Fires". They found significant linear correlations between the different groups of microorganisms in the two types of soils evaluated, indicating positive interactions between the groups of microorganisms analyzed. These interactions suggest that the populations are working synergistically and enabling comet metabolism processes, which could facilitate the recovery of degraded soil[9].

In the Tintales micro-watershed in Boyacá, Colombia, they evaluated two types of vegetation affected by fires and found that the rocky outcrop presented greater variety and diversity of species, with the Asteraceae family being the most representative. The dominant species were *Hypoxis decumbens*, *Pteridium aquilinum* and *Andropogon bicornis*. While recurrent forest fires have caused changes in the structure and composition of the vegetation. However, the vegetation found does not differ much from other studies conducted in this area and region[10].

While in the Maule Region, Chile, "on a fire in a forest ecosystem of the Roble-Hualo type", they found degradation of the structure of the forest canopy and shrubland. Increase in potential radiation on the forest floor, reduction in leaf area and canopy cover. An increase in some chemical variables such as organic matter (MO%), pH and available potassium (Kd) in the shrubland soil, but not in the forest. The regeneration process after the fire was scarce in both areas, and there was a considerable loss of diversity in both tree and shrub vegetation, which affected the composition of the vegetation in both the forest and the shrubland[11].

At the national level, studies on "Fires in the wetlands of the central coast of Peru: a frequent threat". The evidence showed that these fires occur with high frequency, at least one fire per year in the last ten years. All of these fires are caused by human activity and the consequences for biodiversity and ecosystem services are unknown[12].

In a study realized in the annex of Totorani, Arequipa - Peru, research on the impact of fire on grassland and shrubland plant communities. They found that 43 % of the shrublands and 54 % of the grasslands showed regrowth after the fire. When analyzing soil samples, they observed that, in both shrublands and burned grasslands, pH and potassium (K) content decreased compared to the unaffected area. However, they found an increase in conductivity, total nitrogen, phosphorus and organic matter content; the increase in nitrogen content being the most significant. In addition, they observed a change in the physical structure of the soil in the area affected by the fire compared to the unaffected area[13].

Likewise, in the study "Impact of pasture burning on soil characteristics in the province of Chupaca, Junin - Peru", they obtained results that indicate a significant decrease in the bulk density, clay content and exchangeable calcium of the soils. On the other hand, an increase was observed in silt content, pH, organic matter, available phosphorus (P) and potassium (K), as well as in exchangeable magnesium (Mg) and sodium (Na). However, no differences were found in total porosity, field capacity, sand content, calcium carbonate

(CaCO.) content and cation exchange capacity (CEC). They also mention that burning vegetation has been a traditional practice of the communities in the area, as well as in other areas of the country, with the purpose of increasing the productivity of their lands. It is believed that burning vegetation contributes nutrients to the soil and favors crop development[14].

The objective of the present work was to evaluate the dynamics of natural regeneration of high Andean ecosystems disturbed by fires in the district of Chiara, along the Ayacucho-Cuzco road between Toccto, Incapaperqan and Qewillaqocha.

MATERIALS AND METHODS

Study area. It is located in the district of Chiara, along the Ayacucho - Cusco highway between the coordinates 584407.10 m E- 8527636.28 m S, altitude 4147 masl and 601060.89 m E - 8519727.86 m S, altitude 4183 masl (Figure 1). It belongs to the bh-MS life zone with a greater presence of water bodies, soils with better drainage and presence of organic matter (OM), annual precipitation between 600 to 800 mm and temperature between 8 and 12° C. Generally, daytime temperatures are relatively high, decreasing with altitude, reaching 0° C at night. Cloud cover and rainfall are scarce compared to other regions, so there is sunshine throughout the year. Its topographic relief is steep in parts with rocky outcrops[15,16].
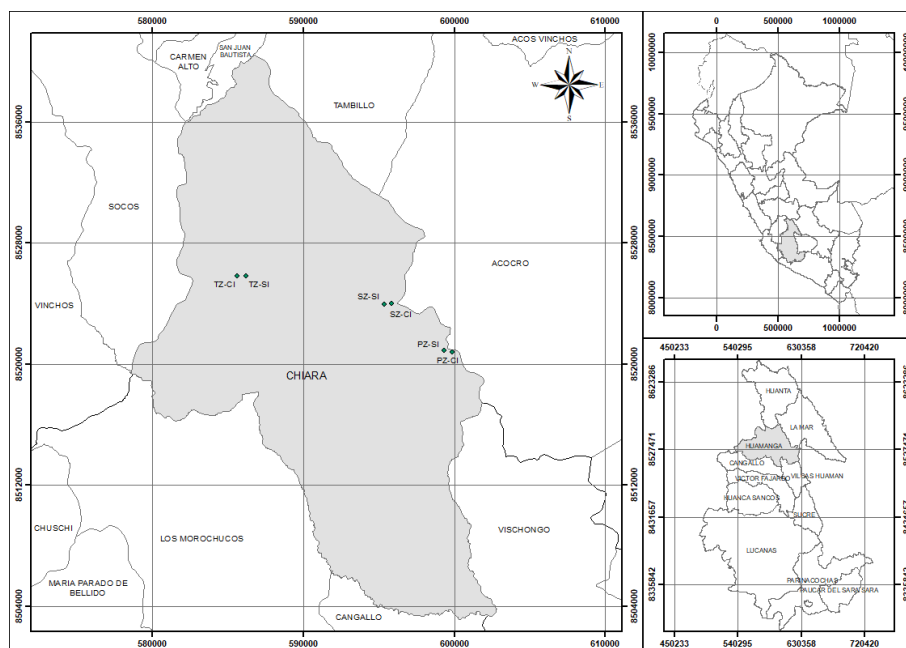

FIGURE 1
Geographical location of the study area. Chiara District, Ayacucho-Peru

Methodology. It was basic-descriptive, considering qualitative floristic variables such as floristic composition and quantitative approach to structural characteristics.

FIGURE 2
Physiographic characteristics of Qewillaqocha. Chiara District, Ayacucho-Peru

Figure 3
Physiogeographic characteristics of Incapaperqan. Chiara District, Ayacucho-Peru

The band transect method was used[17]. For this purpose, three work zones were selected by convenience along the Ayacucho - Cusco highway, in the district of Chiara, being the localities Toccto, Incapaperqan and Qewillaqocha, areas with and without fire impact.

To determine the number of sampling units (SU), the National Inventory Guide for flora and vegetation published and validated by the Ministry of the Environment was taken into account. They recommend that for an area of less than 1000 ha, the number of MU should be at least 6[18,19].

Sampling was carried out on a linear transect of herbaceous flora, using a 50 m winch, on both sides of the line and at 10 m intervals, 4 subUM of 1 m^2 were established to determine parameters where species counts were necessary. Finally, averages were obtained for each study area for the corresponding estimates.

FIGURE 4
Transect evaluation method. Chiara District, Ayacucho-Peru

Floristic composition. Samples were collected in 2 field trips between January to December 2021 and March 2022. The method used was an intensive search within the MU and adjacent areas, in different directions in the areas of Toccto, Incapaperqan and Qewillaqocha, located in the district of Chiara. Samples were collected in triplicate, pressed, dried and mounted[20].

FIGURE 5
Minimum m^2 area applied in the vegetation evaluation. Chiara District, Ayacucho-Peru

Plant samples were identified in the field and doubtful species were confirmed in the Botany Laboratory of the National University of San Cristóbal de Huamanga, using specialized bibliography and botanical keysGramineae (Poaceae) of Peru[21]. In addition, we consulted specialists and reviewed the exsiccata of virtual herbaria such as Field Museum Herbarium (F)[22,23]. The classification of angiosperms (Division Magnoliophyta) according to Cronquist[24] and the updating of names with a specialized page[25].

Evaluation of plant community characteristics. Important parameters were considered to interpret the dynamics of natural regeneration of these ecosystems, such as frequency, density and coverage. Information that allowed estimating the importance value index (IVI). Information was collected in each of the transects and MU, both in areas with and without impact to compare the three ecosystems.

FIGURE 6

Floristic composition resulting from natural regeneration. Chiara District, Ayacucho-Peru

To measure species diversity in the studied community, the Shannon - Wiener, Simpson & Margalef index[19,26] was used. The number of species constitutes the richness and the number of individuals of each species the abundance. The following table was used for its interpretation[27].

Values	Significance
< a1.5	Low diversity
1.6 - 3.5	Medium diversity
> 3.5	High diversity

The three study zones (Qewillaqocha, Incapaperqan and Toccto) were also coded as follows: Qewillaqocha (PZ-CI first sampling zone with impact, PZ-SI without impact). SZ-CI (Incapa-perqan second sampling zone with impact, SZ-SI without impact), TZ-CI (Toccto third sampling zone with impact, TZ-SI without impact). Also: A with impact. B without fire impact.

Results

TABLE 1

Floristic composition Qewillaqocha Incapaperqan and Toccto Chiara Ayacucho2021

| Family	Genus	Species
Asteraceae	Bidens	*Bidens andicola*
	Cotula	*Cotula mexicana*
	Gamochaeta	*Gamochaeta purpurea*
	Hypochoeris	*Hypochaeris taraxacoides*
	Paranephelium	*Paranephelius ovatus*
		Paranephelius uniiflorus
	Baccharis	*Baccharis tricuneata*
	Werneria	*Werneria nubigena*
Apiaceae	Oreomyrrhis	*Oreomyrrhis andicola*
Cyperaceae	Scirpus	*Scirpus rigidus*
Gentianaceae	Gentiana	*Gentiana* sp.
Hypericaceae	Hypericum	*Hypericum silenoides*
Juncaceae	Luzula	*Luzula racemosa*
Papilionaceae	Astragalus	*Astragalus uniflorus*
	Lupinus	*Lupinus microphyllus*
Poaceae	Agrostis	*Agrostis breviculmis*
	Bromus	*Bromus catharticus*
	Calamagrostis	*Calamagrostis vicunarum*
	Festuca	*Festuca dolichophylla*
	Muhlenbergia	*Muhlenbergia peruviana*
	Nassella	*Nassella* sp.
	Poa	*Poa* sp.
Plantaginaceae	Plantago	*Plantago australis*
		Plantago tubulosa
Portulacaceae	Calandrinia	*Calandrinia acaulis*
Rosaceae	Lachemilla	*Lachemilla pinnata*

A

B
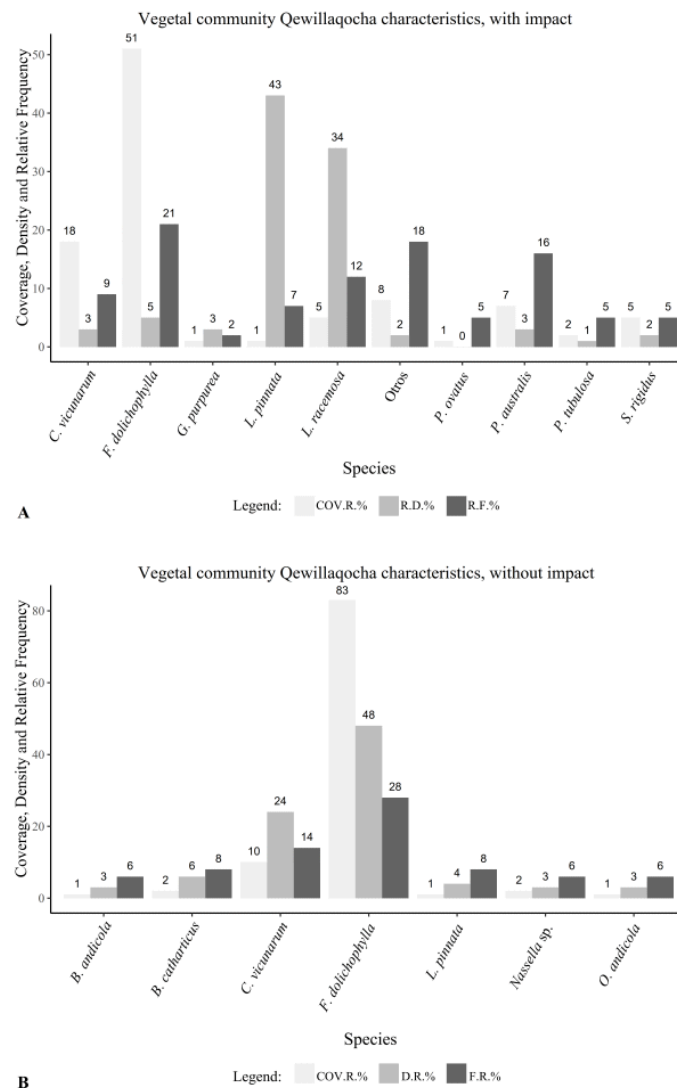
FIGURE 7
Frequency, density and relative cover of species in the locality of
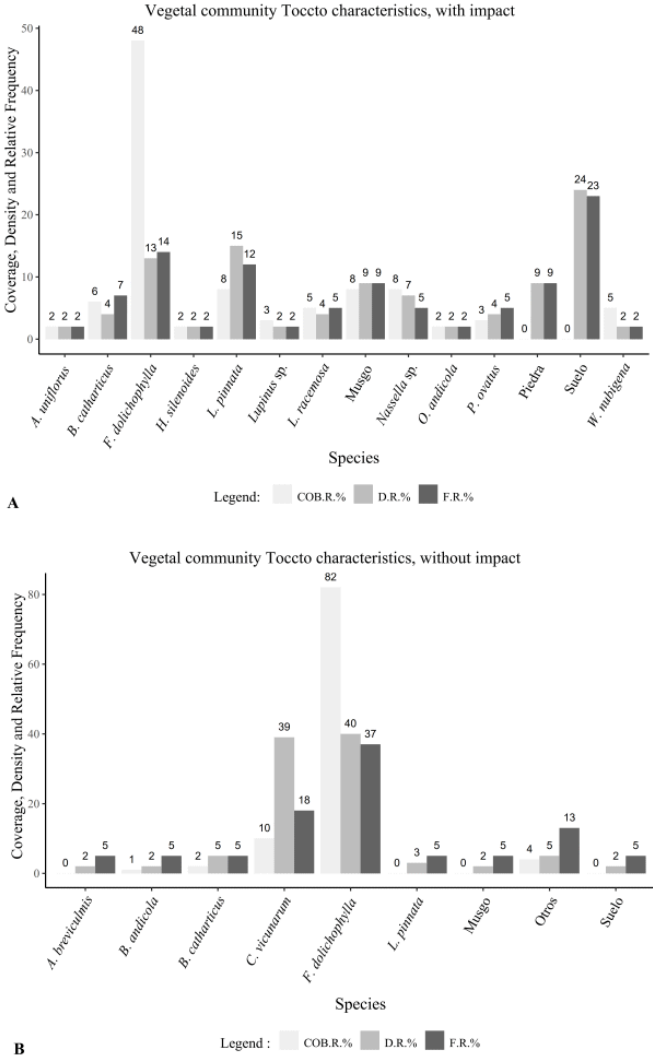Qewillaqocha, with and without fire impact. Chiara. Ayacucho-2021

Figure 8

Frequency, density and relative cover of species in the locality of Incapaperqan, with and without fire impact. Chiara. Ayacucho-2021
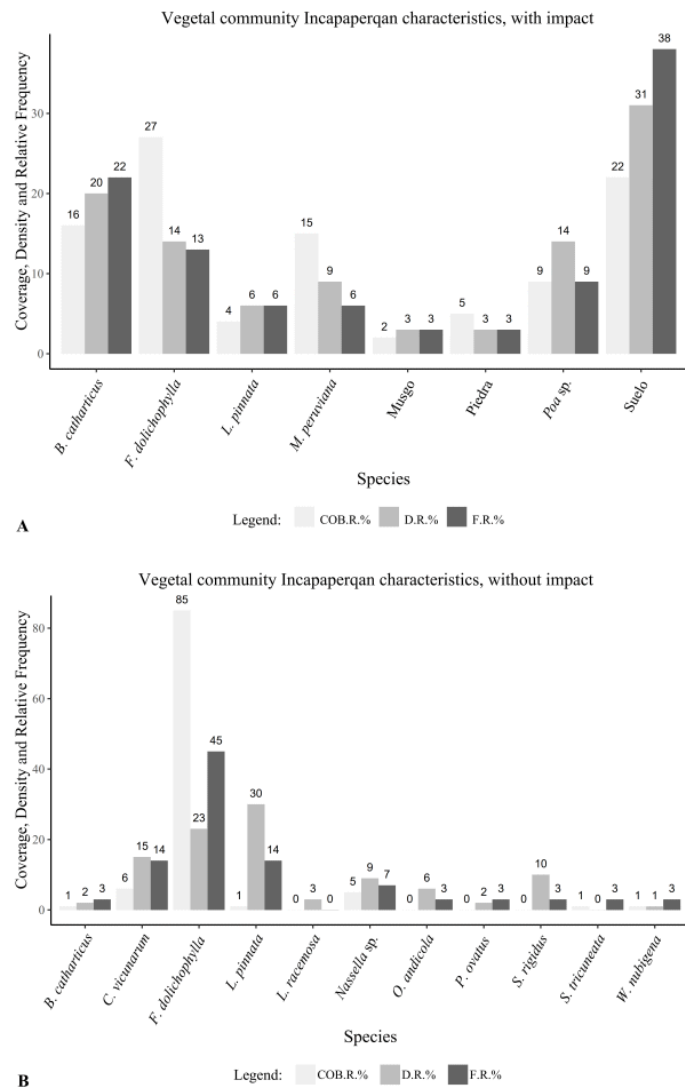
FIGURE 9
Frequency, density and relative cover of species in the locality of
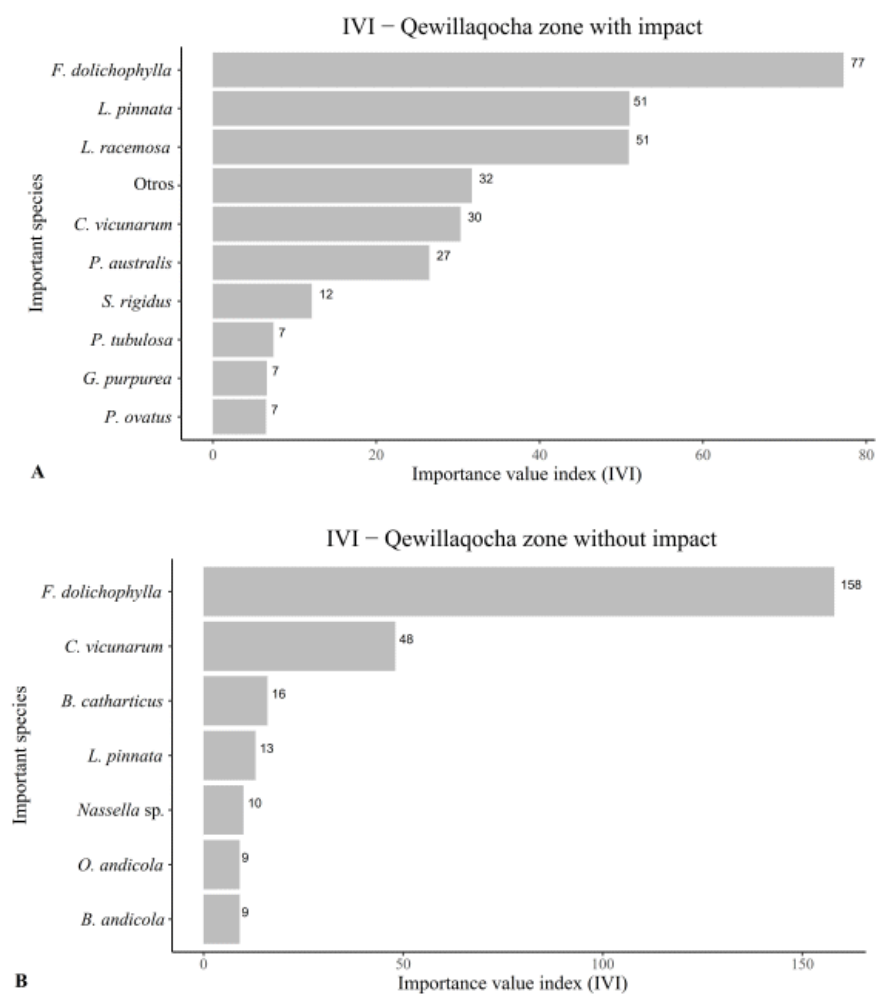Toccto, with and without fire impact. Chiara. Ayacucho-2021

Figure 10
Importance value index of vegetation in the locality of Qewillaqocha, with and without Chiara impact. Ayacucho-2021
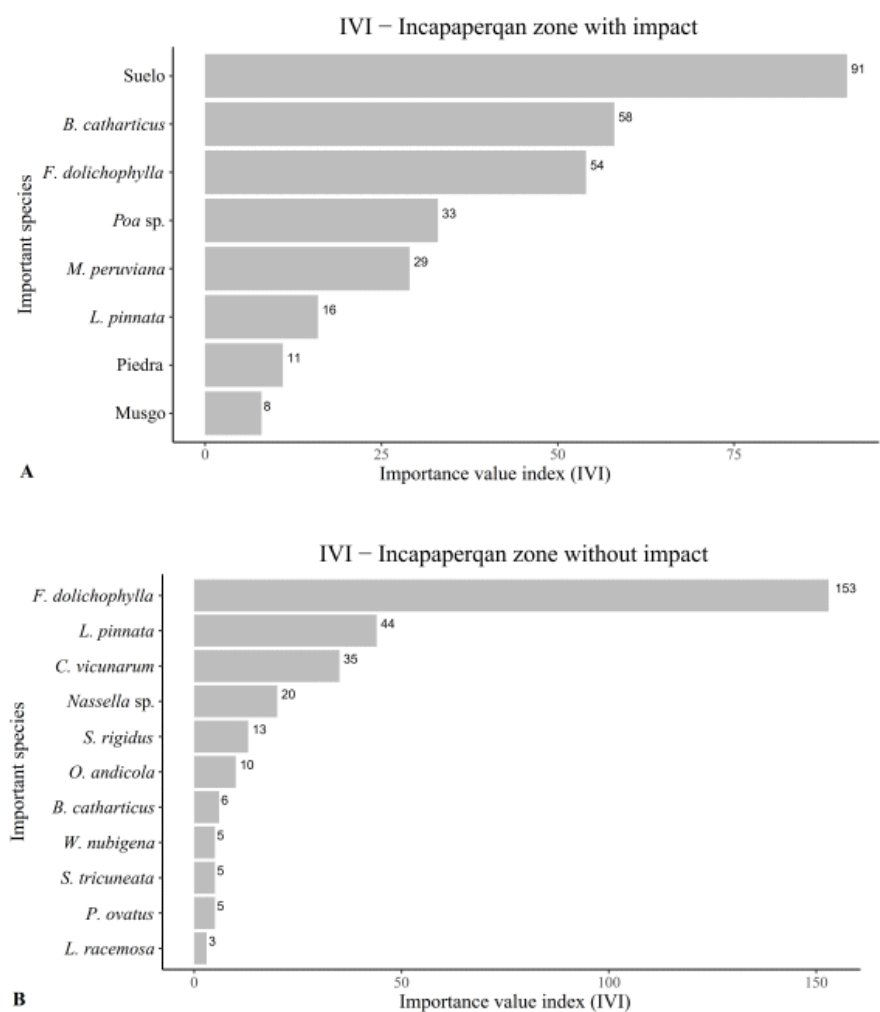
FIGURE 11
Importance value index of vegetation in the locality of
Incapaperqan, with and without Chiara impact. Ayacucho-2021

IVI − Toccto zone with impact
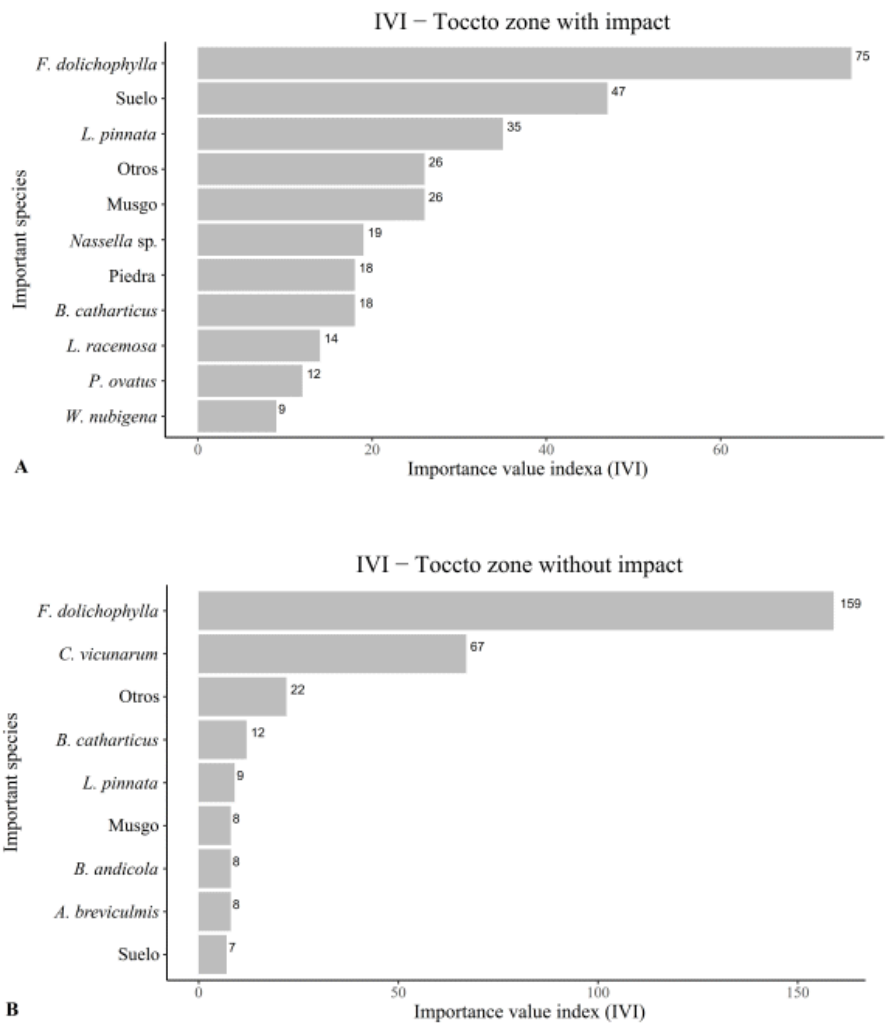
IVI − Toccto zone without impact

FIGURE 12
Importance value index of vegetation in the locality of
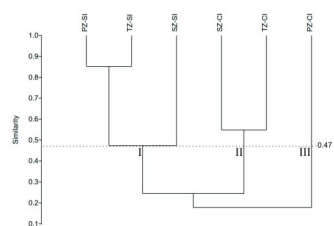Toccto with and without Chiara impact. Ayacucho-2021

FIGURA 13
Relación de similaridad a partir de índice de Bray-Curtis para las tres zonas de estudio con y sin impacto

Discussion

A database of the flora of the study area with and without impact has been generated (Table 1), represented by 11 families, 24 genera and 26 species. Being Asteraceae the most frequent in each of the sampling points, 7 genera and 8 species, followed by Poaceae 7 genera and 7 species and the others with a lower number of

species. However, in order to further investigate the flora of these fragile ecosystems, an inventory was taken in the areas adjacent to the sampling points, reporting a total of 156 species. Magnoliopsida 116 species and Liliopsida 40 species.

Information that facilitated the evaluation of the characteristics of the communities in the 3 study zones. Qewillaqocha Figure 7a with impact, the most frequent species were *F. dolichophylla, P. australis, L. racemosa, C. vicunarum* with 21, 16, 12 and 9 % each, the other species with less frequency. Similarly, in terms of cover, *F. dolichophyla* had the highest cover, followed by *C. vicunarum* with 51 and 16 %, the rest of the species with lower cover. This explains the habit and growth form of the two species, which are grasses. It is necessary to emphasize that *F. dolichophylla* is the main component of the high Andean grasslands, it is characterized by forming tillers, a type of aggregate vegetative growth that has allowed it to survive, thus showing its ability to resprout and resist the periodic burns that occur from time to time. They sprout easily with the first rains of the season and are available as fodder for cattle and sheep in the area. This form of growth is a particular characteristic of several high Andean cespitose species that grow at ground level, others have subway stems that allow them to survive. Regarding their density, the greatest number of individuals was observed in creeping, cespitose species such as *L. pinnata* 43 %, *L. racemosa* 34 % and the others with a lower number of individuals. This reflects that there is no correlation between density and cover, in this case, they are small species, they grow mostly in an accumulated form, while the others are of greater growth, foliage and biomass.

TABLA 2
Índice de diversidad de las zonas de muestreo Qewillaqocha
Incapaperqan y Toccto Chiara Ayacucho-2021

Variable	PZ-CI	PZ-SI	SZ-CI	SZ-SI	TZ-CI	TZ-SI
Especies	17	13	7	11	12	13
Individuos	204	80	34	92	39	96
Dominance_D	.303	.2916	.2024	.1815	.1571	.3112
Simpson_1-D	.697	.7084	.7976	.8185	.8429	0.6888
Shannon_H	1.622	1.709	1.739	1.934	2.113	1.557
Margalef	3.009	2.738	1.701	2.212	3.003	2.629
Equitability_J	.5727	.6663	.8936	.8064	.8505	.607

TABLA 3
Índice de diversidad según Shannon – Wienner (H) de las zonas de
muestreo: Qewillaqocha, Incapaperqan y Toccto. Chiara. Ayacucho-2021

Zonas	H	Varianza	t	df	Valor p
PZ-CI	1.622	.008	-.5227	149.9600	.6020
PZ-SI	1.709	.019			
SZ-CI	1.739	.013	-1.3702	76.7740	.1746
SZ-SI	1.934	.008			
TZ-CI	2.113	.021	2.9263	97.4620	.0043
TZ-SI	1.557	.016			

TABLA 4
Índice de diversidad según el índice de Dominancia (D) de las zonas de
muestreo: Qewillaqocha, Incapaperqan y Toccto. Chiara. Ayacucho-2021

Zonas	D	Varianza	t	df	Valor p
PZ-CI	.303	.0005	.2360	125.0300	.8138
PZ-SI	.292	.0018			
SZ-CI	.2024	.0013	.5045	57.3540	.6158
SZ-SI	.1814	.0004			
TZ-CI	.1571	.0010	-3.4178	107.6300	.0009
TZ-SI	.3112	.0010			

In Qewillaqocha (Figure 7b) without impact, an ecosystem that has not suffered IF, but located very close to the previous zone. They were evaluated to see whether or not there was a difference in their floristic composition and structural characteristics related to frequency, cover and relative density. It is observed that *F. dolichophylla* is the most representative in this plant formation, with a frequency of 28 %, coverage 83 % and density 48 %, followed by *C. vicunarum* 14, 10 and 24 % respectively, the others with minimal representation. This is due to the fact that these species form the grasslands, grow densely and occupy almost the entire area and do not allow other species to grow.

In the second sampling zone, Incapaperqan, which suffered FI in 2021 (Figure 8a) with impact, structural characteristics different from the first sampling zone, affected 1 year earlier, are observed. The existence of bare soil is noticeable; there is still not much vegetation cover. Plant species are just appearing, the regrowth of perennial and ephemeral plants was very slow. However, it was necessary to highlight the presence of very frequent species such as *B. catharticus, F. dolichophylla, Poa* sp. and *M. peruviana*. In the same zone (Figure 8b), but without impact, *F. dolichophylla* was observed, the most representative in terms of frequency, cover and density. As in the first zone, this species was the most dominant according to the parameters evaluated, followed by *L. pinnata* and *C. vicunarum*. It is necessary to mention that the physiography of this zone is different from the first one. The third sampling zone, Toccto (Figure 9a), ecosystem impacted by IF in 2021, is very similar to the second sampling zone, the regeneration of the ecosystem is in process, they are still recent shoots, in each established transect it was clearly noted scarce vegetation cover and greater area of bare soil, presence of few species in isolation, others conglomerated according to the growth characteristics of each species. The resprouts of *F. dolichophylla* are in their splendor with 48 % cover in relation to other species of cespitose growth, such as Asteraceae, legumes, and even grasses. In the same area (Figure 9b), but in vegetation not impacted by IF, as in the previous areas without impact. According to the parameters studied, *F. dolichophylla* was observed as the most frequent 37 %, followed by *C. vicunarum* 18 %, the others with lower percentages, as well as density and cover 85 and 82 % respectively.

Regarding the IVI in the first sampling zone Qewillaqocha (Figure 10a) with impact we observed that *F. dolichophylla* was the most important followed by *L. pinnata* and *L. racemosa*. While in the zone without impact (Figure 10b), the same species *F. dolichophylla* was the most important, which reinforces the results of the structural characteristics of each sampling zone with respect to frequency, cover and relative density, followed by *C. vicunarum, B. catharticus* and the others with lower percentages. These species were dominant, with very dense growth in undisturbed ecosystems, not allowing the growth of other species.

In the second sampling zone, Incapaperqan locality (Figure 11a) with impact, the IVI highlights bare soils as dominant, due to little vegetation cover, they are in the process of recovery, considering the fire that occurred recently in 2021. Therefore, resprouts are recent, *B. catharticus, F. dolichophylla* and others are slowly regenerating and forming cover of these ecosystems. If we compare the IVI of the same zone without impact (Figure 11b), we observe that *F. dolichophylla* was of greater importance, followed by *L. pinnata* and *C. vicunarum*.

In the third sampling zone, Toccto locality with impact (Figure 12a), we observed that the IVI is represented by *F. dolichophylla*, one of the species that recovers gradually, followed by the frequency of bare soils, without vegetation and slow recovery. Also, pioneer species that resprout quickly such as *L. pinnata*, mosses and *Nassella* sp., are observed. While in the vegetation without impact (Figure 12b), the IVI indicates *F. dolichophylla* as the most important, a species that forms the dense high Andean grasslands, few species grow next to them such as *C. vicunarum, B. catharticus, L. pinnata* among others.

When comparing the different points and the three sampling zones, Qewillaqocha (PZ-CI and PZ-SI), Incapaperqan (SZ-CI and SZ-SI) and Toccto (TZ-CI and TZ-SI) (Figure 13), the Dendrogram shows a similarity of 0.47, forming three groups. Group I is formed by the zones without impact PZ-SI, TZ-SI and SZ-SI, these 4 zones have more species in common when compared with the impact zone. Group II, zones with impact SZ-CI and TZ-CI, show a greater number of species in common. Group III, formed by the PZ-CI impact zone, is less similar to the others. This would indicate that there is a great difference in the floristic composition and structural characteristics of vegetation between the impacted and non-impacted zones.

In relation to species richness (Table 2), it is observed that according to Shannon and Wiener's calculations there is a low diversity and richness, which agrees with Simpson & Margalef. Except in the third study zone, which corresponds to the locality of Toccto, which is moderately diverse. This would indicate that these ecosystems are in the process of regeneration and that currently the post-fire flora is formed by those species that have developed a series of morpho-anatomical adaptations and forms of growth to survive the action of the fires, develop subway stems, or the way to grow accumulated. Similarly, a comparison between study zones in relation to the diversity indexes (Shannon-Wienner and Dominance) shows that there is no significant difference in diversity between the study points with and without impact in Qewillaqocha (PZ-CI and PZ-SI) and Incapaperqan (SZ-CI and SZ-SI), However, in Toccto, the TZ-CI and TZ-SI points show a significant difference in the diversity indexes, with the TZ-CI point being more diverse and the TZ-SI point showing greater dominance (Table 3 and 4).

These results of the high Andean grassland species affected by fires are gradually recovering by resprouting. It has been observed "in situ" that the "ichu" species are not completely burned, there are clumps on the ground, which are reactivated and resprout. There are few specimens that were totally burned, they no longer regenerate, but they are in smaller percentage. In this regard, due to the effect of fires, there is an apparent temporary loss of diversity of vegetation, which then recovers, as has occurred in other similar ecosystems[12]. Fire generates different responses in vegetation, most ecosystems provide stability in them. If there were no fire, plant communities would support an excessive accumulation of combustible material, stagnation of growth and inadequate reproduction[28].

Frequent species with greater coverage present subway bulbs, other forms of propagation and do not burn completely, these are the species that recover quickly, while others that propagate by seeds wait for favorable environmental conditions such as the rainy season. Fire has a negative effect on ecosystems, affecting biodiversity, distribution, abundance of species, affecting habitat and the ecological niche of species[4].

After the fire, in each of the ecosystems studied, the landscape looked calamitous, a totally black landscape full of ashes. Today, however, these ecosystems have recovered, and there is an immense greenness in the entire impacted area. It is surprising how the diversity of plant species have managed to survive and recover, not all of them, but most of them. Possibly the fauna is the most affected. It is necessary to highlight the dominance of one species, F. dolichophylla, in the recovery process.

In this regard, it is necessary to emphasize that species, populations, communities and ecosystems are dynamic, subject to change, adapting to environmental changes caused by interactions between organisms. In this sense, understanding them can help us to sustain these living systems, instead of continuing to degrade and destroy them[29].

The post-fire regeneration of species is related to their vital characteristics and their ability to resprout. Most of the surviving individuals have a subway part that facilitates regrowth, and the strength of the

regrowth determines the success of post-fire regeneration[30], the FI not only affects the vegetation, but also the edaphic communities, affecting their composition, density and diversity[2]. They also affect soil properties, increasing pH values and exchangeable bases, generating a decrease in the concentration of nutrients in soils and loss of OM[2].

Therefore, when a fire occurs, the soil undergoes a series of changes in its physical, chemical and biological properties, depending on the intensity and duration of the fire. When repeated fires occur, soil structure degrades, soil erosion increases and soil fertility decreases, leading to significant nutritional impoverishment[31].

MO values increase, as well as N, P and K; the opposite happens with the pH of the burned soil, which decreases, that is, it becomes more acidic, depending on the soil depth, intensity, frequency and time of exposure to heat[32].

When the FI is of low intensity, it contributes to the cycle of some nutrients, facilitating the control of pathogens in plants and preventing soil erosion. Meanwhile, a high intensity fire eliminates OM, evaporates greater amounts of nitrogen and essential nutrients, changes the soil structure and lowers its productive potential. The forest yielded a greater number of actinomycetes and arbuscular mycorrhizal fungi (AMF) associated with a greater assimilation of nutrients such as potassium[32], decrease absorption, water retention, porosity, aeration and infiltration capacity, producing a reduction in the availability of water in the soil and an increase in surface runoff, thus generating erosion[33].

Fire affects soil biological activity, which results in unstable nutrient cycling, decreases microorganisms that participate in the processes of MO decomposition and nutrient availability. They indicate that FIs affect the soil resource and will suffer overheating[34].

The research made it possible to record 11 families, 24 genera and 26 species at the sampling points. Considering the adjacent areas, 156 species in 27 families and 96 genera of phanerogamic flora, whose composition varies among the three sampling zones. The burned areas have a greater richness of species in relation to areas without impact. Likewise, the species with the highest frequency and coverage both in areas with and without impact are *F. dolichophylla, C. vicunarum, L. pinnata, L. racemosa* and *..peruviana*. In the 3 areas studied: Qewillaqocha, Incapaperqan and Toccto, the diversity indices are very low, even in areas with and without impact. The areas affected by fire recover with the first rains and are in full splendor between 4-5 years. *F. dolichophylla* does not die completely in the fire, as well as cespitose species, which are easy to resprout. The regeneration of species that propagate by seeds is very slow. Regarding social perception, the people of Chiara are aware of the effects of forest fires.

Therefore, this work will be an important contribution to understand the natural regeneration of vegetation, soil characteristics and the perception of the local population to these events in Andean ecosystems. This contribution will help to improve ecosystem management measures and will facilitate research and impact studies for interested people and institutions. It will allow the development of conservation programs in its broadest sense and make available the information generated. Considering that the Peruvian territory includes unique ecosystems at world level, exclusively or shared with neighboring countries. Unique ecosystems that harbor communities of extreme importance due to the presence of endemic species and species of economic use[35].

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Notes

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