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Challenges and conservation implications of *Polylepis* woodlands in the Andean region: Defining actions for sustainable management

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Key words: Andes, anthropogenic impact, climate change, community management, conservation strategies, endemic species.

Ključne besede: Andi, človekov vpliv, podnebne spremembe, družbeno gospodarjenje, naravovarstvene strategije, endemiti.

Abstract

Polylepis species represent one of the most important and endemic woodlands of the mid- and high-elevation regions of the Andean Cordillera. I provide a review of the current situation of *Polylepis* woodlands, discuss the potential effects of various conservation measures and consider the likely impact of climate change on tree phenology and tree regeneration, aiming to foster the conservation and sustainable management of these woodlands through proper environmental planning. I argue that in addition to the delineation and extension of protected areas, it is essential to incorporate actions such as forestation, forest policies, environmental education and local community participation. To be effective, conservation measures should be implemented in an international transdisciplinary research framework and in harmony with site-specific conditions. Finally, given the likely but uncertain influences of climate change on *Polylepis* woodlands, further research (and communication of that research) is needed to improve forest management strategies and research priorities for the Andean region.

Izvleček

Vrste rodu *Polylepis* so med najpomembnejšimi endmičnimi gozdnimi vrstami v srednje in visokogorskem pasu andskih Kordiljer. V članku predstavljamo pregled trenutnega stanja gozdov z vrstami *Polylepis*, razpravljamo o potencialnih učinkih različnih naravovarstvenih ukrepov in predvidevamo možen učinek podnebnih sprememb na fenologijo dreves in njihovo regeneracijo, vse z namenom spodbuditi ohranjanje in trajnostno upravljanje teh gozdov z ustreznim okoljskim načrtovanjem. Poleg omejitve in razširitve zavarovanih območij je nujno vključiti različne akcije, kot pogozdovanje, gozdarsko politiko, okoljsko izobraževanje in vključevanje lokalnih skupnosti. Neodvisno od naravovarstvenih strategij, pa moramo vzpostaviti ukrepe, ki bodo temeljili na mednarodnih transdiciplinarnnih raziskavah in bodo v skladu z lokalnimi rastiščnimi razmerami. Zelo verjetno bodo podnebne spremembe nedoločeno vplivale na rast in razvoj vrst rodu *Polylepis,* zato s tem člankom želimo vzpodbuditi raziskovalce k prihodnjim raziskavam v določene smeri. Rezultati in informacije, ki jih bomo dobili v prihodnjih letih na mednarodnem nivoju bodo ključne za izboljšanje gospodarjenja z temi gozdovi, izbiro raziskovalnih prioritet in strategij v Andih.

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Introduction

The Andean Cordillera extends from western Venezuela to Argentina and is considered a global biodiversity hotspot (Myers et al. 2000). The geographic and climatic variability of this region create conditions where organisms develop special adaptations to survive and thrive (Rahbek et al. 2019). One such group of organisms are plants belonging to the genus *Polylepis*. These slow-growing trees and shrubs represent a large fraction of the natural and native vegetation of the Andes (Kessler 2006). In addition to the climate stabilizing services provided by most woodlands, *Polylepis* woodlands are especially important for providing critical ecological functions in a vulnerable environment, as well as a variety of environmental goods and services, including hydrological regulation, soil protection and biodiversity conservation, among others (Cranford & Mourato 2011). Furthermore, they offer critical habitat for endangered and threatened species (e.g., Gareca et al. 2010a, Sevillano et al. 2018).

Due to climate change, Andean ecosystems are increasingly exposed to higher temperatures and changes in precipitation patterns in both directions (increase and decrease) (Urrutia & Vuille 2009), creating uncertain conditions for the future for the mid- and high-altitudinal ecosystems. The high-elevation Andean areas experience some of the greatest impacts of climate change, of which the retreat of glaciers is the most eye-catching (Francou 2013). Understanding the response to the effects of climate change is of paramount importance for conservation efforts and mitigation in anthropogenic and natural ecosystems.

It is well known that the conservation of tropical forests will help to achieve the UN Sustainable Development Goals (SDGs) (see Swamy et al. 2018); however, there has been a disproportionate focus on tropical rainforests, whereas current conservation strategies for drier *Polylepis* woodlands fall alarmingly short of this goal. As a first step towards conservation, Andean community must be informed about the problems *Polylepis* woodlands face so that the most appropriate conservation strategies are implemented.

Here, I review the following aspects: (1) the delineation of the species composition and distribution of the genus *Polylepis*; (2) the current situation with an outline of the most important challenges *Polylepis* woodlands face; (3) a description of the species regeneration capacity; (4) discussion of conservation strategies, including a short description of the views of how *Polylepis* woodlands will respond to climate change; (5) co-development of conservation and preservation strategies among diverse stakeholders that address conservation goals and local livelihoods; and (6) the need for transdisciplinarity in research and educational efforts. The present work is an important complementary study to the review provided by Renison et al. (2018).

Methods

The Systematic Literature Review (SLR) method proposed by Kitchenham et al. (2007) was used for the review process. Subject-relevant literature was obtained via the Google Scholar search engine. All possible pair combinations of "*Polylepis*" with the following terms "Andes", "conservation", "climate change", and "local community", using AND as the Boolean search term, were searched. Peer-reviewed journal articles published in three databases, ISI Web of Science, Scopus and Latindex, were selected. In addition, some official reports and theses indexed in Google Scholar with important and relevant information were also considered. This review mainly drew from studies conducted in the Andes region in English and Spanish. Given the vast number of publications, the search was conducted until reach a database with 200 documents, and this study filtered the articles that met the criteria and were in line with the aim and scope of this review. A total of 70 documents (research and review articles, reports, book chapters, and theses) were selected.

Results and discussion

Polylepis woodlands

The genus *Polylepis* (family Rosaceae, tribe Sanguisorbeae) is distributed throughout the Andean region, exclusively (Simpson 1979). The species of this genus are characterized by anemophilous pollination, evergreen foliage, dry fruits, and twisted trunks covered with a red, multi-layered bark (Simpson 1979, Kessler 2006; Figure 1). *Polylepis* tree species are the highest elevation woody angiosperm, naturally occurring in fragmented forests in areas typically dominated by shrubs or grasses (Goldstein et al. 1994), with a tree line that even grows in elevations over 5000 m (Rada et al. 2001). The classification of taxa in the genus is a challenge due to the morphological variability within the populations and the extensive hybridization among the different *Polylepis* species (Romoleroux 1996, Schmidt-Lebuhn et al. 2006). Kessler & Schmidt-Lebuhn (2006) suggest that hybridization likely takes place among all species of the genus, when they grow in close geographic proximity to each other. Therefore, there is no scientific consensus about the real number of species due to the different classifications used, e.g., Bitter (1911) recognized 33 species, Simpson (1979) only 15 species, Kessler & Schmidt-Lebuhn (2006) 26 species, and more recently Segovia-Salcedo et al. (2018) described 28 species that comprise the *Polylepis* genus. Given *Polylepis* species' diversity, *Polylepis* woodlands are established across broad spatial extents and at mid- and high-elevations, furthermore, *Polylepis* adaptations have led to certain species exclusively occurring in different habitats, largely differentiated by temperature and precipitation regimes (Kessler 2002).

Current situation and issues facing *Polylepis* woodlands

As indicated in several studies, *Polylepis* woodlands could originally have covered large tracts of the Andean territory (Kessler & Driesch 1993, Zutta et al. 2012). Currently, *Polylepis* woodlands form isolated stands, rather than a continuous vegetation cover, and the degree of conservation ranges from deficient to very low. *Polylepis* woodlands are restricted to specific sites (e.g., rocky slopes and stream edges), which can be attributed in part to the sporadic occurrence of suitable microhabitats and partly to human influence (Simpson 1986). Residual and fragmented homogenous stands are usually located on exposed foggy mountainsides in self-enriched soils, high in organic matter (Pretell et al. 1985). Slopes are favourable locations because those landscapes provide a habitat with less interspecific competition, less access by cattle and loggers, and better protection against the wind (Smith 1978, Osha 2000). For example, in line with the above, Coblentz & Keating (2008) and Toivonen et al. (2018) demonstrated that *Polylepis* fragments have topographic preference that changes with elevation.

There are active debates regarding explanations for the current fragmented network of *Polylepis* woodlands. Kessler (2002) describes two hypotheses for this distribution: "the hypothesis of a natural fragmentation" and the "hypothesis of a fragmentation by human intervention". Fjeldså (2002) indicated that the strong and continuous anthropogenic pressure over the centuries is the cause for the current patched distribution of the *Polylepis* woodlands. Recently, Valencia et al. (2018) suggested that precipitation and landscape heterogeneity are the controlling factors for the distribution of *Polylepis* woodlands in the pre-human period; with the arrival of human activities, a "hyper-fragmentation" took place during the last 1000 years. On the other hand, Gosling et al. (2009)

Figure 1: *Polylepis reticulata* woodland in the Cajas National Park, Azuay, Ecuador (Author: Adrian Sucozhañay).
Slika 1: Gozdovi vrste *Polylepis reticulata* v narodnem parku Cajas National Park, Azuay, Ekvador (avtor: Adrian Sucozhañay).

stated that *Polylepis* did not form permanent continuous woodland before the arrival of humans. It remains unresolved which of these hypothesized causes for the loss of *Polylepis* woodlands is valid.

Currently, the over-use of resources is considered the prime cause for the loss of *Polylepis* woodlands. The forests face pressure from livestock grazing, logging, controlled burning, and road expansion (Purcell & Brelsford 2004), all of which limit the habitat extension and composition (Jameson & Ramsay 2007). Kessler & Driesch (1993) concluded that anthropogenic burning presents the greatest threat to the high Andean forests. Renison et al. (2002) and Cierjacks et al. (2008a) confirmed that fire considerably affects the regeneration processes of *Polylepis* forests by reducing survival, seed production and height growth, while cattle trampling and grazing even at moderate levels seem to have minor consequences for these forest communities (Cierjacks et al. 2008b). However, the influence of grazing should not be underestimated. Renison et al. (2010) demonstrated that livestock has a significant influence on forest soil degradation, and Teich et al. (2005) and Zimmermann et al. (2009) reported that in situations of overgrazing, few young *Polylepis* plants manage to survive. A combination of both burning and excessive grazing prevent the regeneration of young trees by increasing soil degradation, which affects seed viability (Renison et al. 2004). It can be concluded that human activities influence the density and height of the forest, tree regeneration, and even the genetic constitution of *Polylepis* populations (Gareca et al. 2013).

Because of continued fragmentation, whether natural or anthropogenic, *Polylepis* woodlands are now one of the most highly threatened ecosystems in the world (Kessler 2006). Many of the *Polylepis* species are classified as vulnerable or in danger of extinction within the Red List of Threatened Species (IUCN 2019), and their disappearance is likely altering ecosystem functioning. In fact, the current area coverage of these woodlands is uncertain due to its continuous reduction; moreover, the lack of high-quality imagery of the Andean region hinders a proper mapping of the extension of these forests and restrict this analysis to reduced areas (e.g., micro-scale).

Regeneration capacity

The few studies examining regeneration rates have shown that regeneration took place at the edges of the *Polylepis* woodlands (Cierjacks et al. 2007, Morales et al. 2018a). Cierjacks et al. (2007) concluded that the edges of the *Polylepis* stands are areas of high natural recruitment. In the interior of these forests, large numbers of seeds occur, while the seedlings preferentially develop at the edges, indicating that favourable light conditions are required for growth and establishment (Cierjacks et al. 2007). Torres et al. (2008) and Morales et al. (2018a) found that seedling densities decreased with increasing distance away from the forest and suggest that this short-distance seed dispersal may slow forest expansion. These studies are in agreement with Cáceres (2007) findings which showed using imagery that *Polylepis* woodlands expand over their same areas, i.e. in areas where woodlands already existed and not over upper floors or free areas adjacent to these woodlands.

The establishment of seedlings at forest edges makes them vulnerable, being an easy target for herbivory because the tender leaves are rich in nutrients and due to the lack of effective physical or chemical defences (Giorgis et al. 2010). The success of the survival of the seedlings is also related to their growth rate, which can change with elevation; unfortunately, vegetative growth is infamously slow in high mountain environments. Hertel & Wesche (2008) stated that regeneration pattern of *Polylepis* trees changed markedly along an elevational gradient. For example, Marcora et al. (2008) found for *Polylepis australis* a decreasing tree vitality, radial growth, seed productivity, and seed mass with increasing elevation, from 900 to 2700 m.

Polylepis species have slow growth rates. For example, Renison et al. (2005) found that seedlings of *Polylepis australis* in Argentina at elevations of approximately 2000 m grow in height at a rate of 69 mm per year, Saravia and Vintimilla (2016) showed that *Polylepis reticulata* trees at ~ 3800 m in Ecuador grow in diameter at a rate of 0.78 and 1.17 mm per year for young and mature trees, respectively, and Domic & Capriles (2009) found that *Polylepis tarapacana* trees at elevations between 4200 and 4600 m in Bolivia grow in diameter at a rate of 4.6 mm per year. The study of the growth rates of different *Polylepis* species has been widely addressed by the scientific community (e.g., Colmenares 2002, Hoch & Körner 2005, Gareca et al. 2010b, Duchicela 2011, Alvites et al. 2019).

Polylepis species located in high mountain areas are subject to drastic intra-daily temperature variations, suffering low temperatures or even frost (Goldstein et al. 1994, Rada et al. 2009). Low temperatures lead principally to slow metabolism rates due to the inhibition of meristematic activity, hindering growth (Hoch & Körner 2005). Despite *Polylepis* species are anatomically and physiologically adapted to tolerate and minimize frost damage (Rada et al. 2001, Azócar et al. 2007), yet, temperature is a decisive factor in limiting tree growth at high elevations (Kessler et al. 2014). Furthermore, biogeochemical cycles are controlled by temperature and are responsible for the low rates of leaf renewal and litter decomposition (Duchicela 2011, Pinos et al. 2017). Rada et al. (1996) and Carabajo (2017) demonstrated that the photosynthetic potential of *Polylepis* species is very high, although it only manifests itself in short periods of time when climatic conditions are favourable, corroborating that temperature is likely the principal abiotic factor controlling tree phenology. The studies presented thus far provide evidence that slow growth rates and the special tree phenology of *Polylepis* woodlands are linked to temperature, and this condition turns into a negative factor by reducing effective regeneration rates.

Challenges to conservation: pitfalls of strategies and climate change

Conservation actions aimed at protecting forested areas are key in the conservation of biodiversity through preserving main ecosystem processes, which are crucial for sustainable development (Hoffmann et al. 2011). Current woodland conservation measures in the Andes consisting of the creation of protected areas or restricted forest access are unable to slow down the disappearance of the remaining *Polylepis* forests (Purcell & Brelsford 2004, Purcell et al. 2004). The creation of protected areas is an initiative that, in theory, should preserve and conserve the different biological resources contained in them; however, it has several negative aspects, such as the disconnection of ecological areas by blocking corridors (Saura et al. 2018). In fact, there is a wide debate about the efficacy of this tool: we have those who say that this measure has served to conserve and save biodiversity (e.g., Bruner et al. 2001, Geldmann et al. 2013); conversely, there are those who criticize its effectiveness (e.g., Ervin 2003, Parrish et al. 2003). Zutta et al. (2012) found that the lack of protection standards of highland ecosystems throughout the Andean region leave *Polylepis* woodlands vulnerable since protected areas in the Andean countries represent a low percentage in relation to the extent of *Polylepis* forests (e.g., Quispe-Melgar et al. 2019). Another key factor of the limited effect of area isolation is the poor management of protected areas; insufficient funds for monitoring and management leads to a decline in conservation capacity. Moreover, the hiring of people who are prepared to live in and care for those areas is not easy. In response to the lack of funds, an alternative option is the creation of community-led private conservation areas. However, to be successful, this action needs to be implemented in accordance with the vision and objectives of the national administration to avoid future conflicts (Bury 2006). Thus, this action, without adequate management and planning, represents an insufficient and inefficient long-term conservation measure. Furthermore, the protection of ecological areas does not stop the expansion of human settlements around those areas, which will inevitably approach them (Wittemyer et al. 2008). Toivonen et al. (2011) found that the distance to villages and roads is correlated to the degradation degree of *Polylepis* woodlands.

Another of the most common strategies in the Andean countries is forestation (defined in this study as reforestation or afforestation actions), implemented through different programmes and projects, of which the short-term effects are difficult to detect (Simoes-Macayo & Renison 2015). Long-term monitoring is required to determine the strategy's efficacy up to several decades for planted *Polylepis* trees due to their slow growth rate. To enhance the conservation level, forestation should aim at not only the promotion of forest expansion but also the conversion of the degraded *Polylepis* woodlands to healthy woodlands by a mix between regenerating, young, and mature stands, as suggested by Renison et al. (2011). In *Polylepis* forestation projects seeds must be selected based on mass as an appropriate way to enhance germination (Seltmann et al. 2007).

Forestation must be implemented with caution since: 1) forestation reduce the total water supply to downstream users in most Andean regions (Bonnesoeur et al. 2019), and some *Polylepis* species could absorb considerable amounts of water (e.g., *Polylepis reticulata* – Pacheco 2015), which could possibly affect the hydrological cycle of the basin where the forestation process is implemented, 2) forestation with non-native *Polylepis* species generates hybridization between species and causes local loss of genetic diversity (Schmidt-Lebuhn et al. 2006), and 3) forestation with exotic species, such as eucalyptus and pines, could enhance the loss of native tree species and causes visual damage of the landscape. However, Gareca et al. (2007) found that there are no negative effects on *Polylepis subtusalbida* regeneration patterns when growing with pine and eucalyptus trees, therefore, the extent to which exotic species affects native species remains unclear.

To further complicate conservation efforts, the effects of climate change superimpose the complex biodiversity distribution patterns along the altitudinal, latitudinal and moisture gradients in the Andes mountain region. Climate change projections for the Andes indicate an increment in temperature in the twenty-first century (Urrutia & Vuille 2009, Marengo et al. 2010). In contrast, the low temperature of the Andean mountain range was considered one of the main reasons for the slow growth rate and consequently its low rate of effective regeneration. Thus, the question can be asked: how will the increase in temperature influence the growth and regeneration of these woodlands? So far, the phenological responses of *Polylepis* species to climatic changes have been poorly studied. Marcora et al. (2008) claimed that an increase in temperature could restrict *Polylepis australis* to its upper distributional altitudes in central Argentina; Gareca et al. (2012), using hydrothermal models, studied the potential effects of global warming in seed germination of *Polylepis besseri* in the Bolivian Andes and found that with an initial temperature increase, seed germination will increase; however, when maximum temperature modelled surpasses the optimum temperature for seed germination, germination will eventually decrease; and Cuyckens et al. (2016) projected the future potential distribution of *Polylepis tarapacana* woodlands in the Andean Altiplano under climate change scenarios by using species distribution models, and found that will be severely reduced in the future. These seemingly conflicting findings demonstrate that there are clear gaps in our understanding of how climate change will impact mid- and high-mountain Andean woodlands.

Co-developing conservation and preservation strategies among diverse stakeholders

Conservation efforts have both benefits and costs: benefits include preserving and strengthening ecosystem functions, whereas costs can include direct management costs as well as lost economic opportunities, such as human development, agriculture, and mining. A common land-management challenge is avoiding placing costs, but not benefits, on marginalized communities (Escobar 1998). Developing these strategies in Andean communities requires direct collaboration with stakeholders in a way that reflects the historical context, addresses land use priorities, promotes climate and environmental justice, and encourages social and collective learning for all participants (e.g. Villarroel et al. 2014).

Renison et al. (2018) and Morales et al. (2018b) pointed out that research communication and cooperation between academic researchers and restoration practitioners are key for the conservation of *Polylepis* forests. Involving local communities will empower them, open a dialogue, and encourage collegial relationship with the scientific community. In this way, local traditional knowledge and scientific knowledge are interchanged and will likely contribute to the generation of more effective ways to prevent and/or combat negative side-effects of climate change and anthropogenic activities. Experience in the Andes has shown that natural resources management is encouraging the collaboration between villagers and entities (municipal, governmental and NGO) with scientists and academic specialists (Dewulf et al. 2004, Mathez-Stiefel et al. 2017).

Two priorities should be education regarding ecosystem services and involvement (and employment) in conservation, towards raising local interest in *Polylepis* protection (Purcell et al. 2004). Because the valleys of the mid- and high-elevation Andes are intensively farmed and grazed by local communities (e.g. Etter & Villa 2000), substantial gains could be made by teaching and incentivizing agroforestry techniques, including intercropping, to minimize clearing and other processes that ultimately degrade soils and are less agriculturally sustainable. Many Andean communities are willing to adopt those novel land-use techniques, but at least some traditional components should be contained in the proposed changes to ease their acceptability (e.g. Bernet et al. 2002, Winters et al. 2004). Moreover, solving the problem of unsustainable wood consumption is another key to the successful conservation of *Polylepis* woodlands, hence cooperation with local villagers will help to identify and develop alternatives for fuelwood and timber (Aucca & Ramsay 2005). Through collaborative approaches in knowledge generation and knowledge application, new and place specific practices may be developed to protect sociocultural and ecological functions of the landscape.

A conservation action that usually involves several stakeholders is the forestation projects with native tree species. One of the best examples was the planting of approximately one million *Polylepis* seedlings in Peru from 2001 to 2016. The area comprises a national park and surrounding areas and private conservation areas. The project was led by the Asociación Ecosistemas Andinos (ECOAN), with the collaboration and support of several public and private institutions, NGOs, actors, and local communities (ECOAN 2017). The main focus of ECOAN's conservation philosophy lies on agreements with local people (Aucca & Ramsay 2005).

From an economic point of view, the generation of additional sources of income for the local people might facilitate their participation in conservation practices (Mitchell & Eagles 2001). Such profit can be generated, for example, by the development of local ecotourism. Its unique growth form and designation to be the highest elevation forest-type in the world warrants ecotourism potential. However, the impact of tourism and recreation in the Andean ecosystems has been poorly studied (Barros et al. 2015). Therefore, this should not be implemented without a proper environmental planning.

Each conservation action must be in accordance with the vision and mission of the governmental environmental entities at the regional or local scale. Therefore, conservation actions must be previously informed and authorized by the stakeholders of the area in question for three primordial reasons: 1) they should not intervene in current governmental or private conservation plans (the most adequate is to join current plans or future phases), 2) they should not repeat actions (this often results in a waste of time and resources), and 3) they should assure legal permits are in place. Andean governments and private organizations must evaluate and reform their strategies to favour long-term development over short-term profit and choose viable and real solutions instead of momentary actions that pursue political or administrative goals. It is important to realize that conservation of Andean ecosystems is only feasible when they are integrally pursued, concurrently tackling the full spectrum of problems the local communities face. Herein, the main needs are health, nutrition and education. Based on the results of Aguilar et al. (2009), I argue that once these needs are covered by any stakeholder, the increases in human health and the well-being of the local inhabitants will likely enhance their motivation to participate in conservation programmes of forest ecosystems.

Transdisciplinary research and education

The production of new scientific knowledge in the search for solutions to the complex conservation challenges faced by *Polylepis* woodlands, such as climate change and anthropogenic pressure, requires intensive interaction and agreement among researchers, policymakers, and practitioners. Several gaps exist in our current knowledge about *Polylepis*; therefore, I suggest that future research efforts across an international transdisciplinary framework should focus on the following aspects: 1) determine the phenological responses of *Polylepis* species to climatic changes (e.g., tree growth rates, seeding and germination, net primary production, carbon fluxes); 2) establish an actualized baseline of the spatial coverage and transformation processes of *Polylepis* woodlands; 3) evaluate the effectiveness of protected areas in relation to the degree of conservation; 4) develop accurate projections of *Polylepis* stands in relation to climate change scenarios; 5) analyse the costs and benefits of conservation, forestation or restoration efforts for *Polylepis* woodlands; and 6) develop ecohydrology studies (e.g., sap flow measurements, rainfall interception processes, the capture of fog and mist, soil infiltration) for a better understanding the water flux dynamics in Andean forested catchments.

Suitable forest research and development would benefit from an international forest governance cooperation, which will establish the policy, legal and institutional work fronts for international decision-making for these forests. Additionally, environmental education is a must to achieve sustainability, adaptation to climate change, and for stopping, solving and preventing forest destruction. Environmental education will facilitate the development of skills and thoughts oriented towards the conservation of ecosystems in general, and the *Polylepis* woodlands in particular (Purcell et al. 2004). There is no established universal methodology for environmental education, but its principles are based on educators' knowledge, transdisciplinarity, decision-making, and socio-cultural and economic features.

Conclusions

Natural forest conservation is a challenge in the mid- and high-altitudinal Andes, given their vulnerability and exposure to anthropogenic pressure, environmental conditions and climate change. It is recommended that each region tackle the problem of *Polylepis* woodland loss according to its environmental reality and local possibilities. A few main strategies to promote the conservation of *Polylepis* woodlands include the delineation of restricted zones (i.e., human interaction is strictly prohibited, only allowed for research purposes), the generation of economic incentives for the conservation of forests, the stimulation of ethical and aesthetic valuation of these environments, and avoidance of future human settlements near protected forests. Parallel aggressive policies must be implemented to regulate, prohibit and control anthropogenic activities on these fragile ecosystems, such as grazing, burning, expansion of the agricultural frontier, and illegal logging. Local administrations ought to play an important role through strategic planning of land use.

Although creating protected areas is the most commonly applied tool, it is not effective without promoting forestation actions for the restoration and recovery of these vulnerable woodlands. Notwithstanding, the consolidation and strengthening of existing protected areas together with the participation of local communities are currently the most effective conservation strategies.

When carrying out forestation projects: 1) the use of native species should always be given preference, 2) the use of non-endemic *Polylepis* species in the area should be avoided due to the high degree of hybridization and the consequent genetic loss, and 3) the hydrological alteration in the basin must be evaluated before the forestation take place.

Transdisciplinary research is a key element for the conservation of *Polylepis* woodlands, and we need to ensure that scientific knowledge is deployed persuasively into decision-making venues. Interchange of knowledge in combination with continuous environmental education programmes are crucial factors in strengthening community adaptation against climate change effects. Moreover, I believe that it is necessary to consolidate international networks for research and conservation purposes.

Finally, the purpose of this review paper was to critically evaluate past work on *Polylepis* woodlands and to map new research directions that will advance our current understanding of conservation and climate change issues. Additionally, I encourage practitioners to embrace strategies suited to address the SDGs.

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