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A Landscape's Social and Ecological Services are Equally Valued by Andean Farmers When Deciding Where to Grow a Crop

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Understanding the complex socioecological relationships between farmers' practices and landscape changes is critical to developing more successful agroecological management strategies. A restructuring of agricultural landscapes to include a larger proportion of natural habitats is routinely promoted in sustainable agriculture. However, our knowledge of how different landscape features (eg natural versus social) and associated functions influence farmers' decisions about their daily practices remains limited. Here, we explored how smallholder farmers perceive agricultural landscapes and their related functions along a gradient of agricultural intensification (from 11 to 3% of natural habitats) in the Ecuadorian Andes. To this end, we used real-time high-precision aerial images acquired with an unmanned aerial vehicle. Our analysis of 199 free-listing surveys revealed that farmers equally valued natural (eg hedges, watercourses) and social features (eg roads, arable land availability) of the agricultural landscapes when deciding where to grow their crops. These features were related to a large array of functions, some of which were perceived as a service by one farmer and as a nuisance by another. Among ecological services, farmers identified a potential strategy to improve several agricultural regulation services based on vegetation and hedgerow management. This suggests that incentives to preserve natural vegetation in agricultural landscapes could be perceived favorably by farmers. Finally, we found that Indigenous farmers value agricultural landscapes differently from non-Indigenous farmers. This needs to be taken into account when promoting the adoption of landscape management strategies such as ecological intensification.

Keywords: *sustainable food systems; lupine crop; Ecuador; landscape services; farmers.*

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Introduction

A landscape is "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Déjeant-Pons 2006: 369). Landscape planning largely depends on how people perceive the social (eg cultural, political) and natural (eg climate, biodiversity) parts of their environment and their associated services (Schaich et al 2010; Baker et al 2015). Landscape perception research has long engaged the interest of scientists and resource managers from a variety of disciplines and professions (Zube et al 1982; Pfund et al 2011), particularly in agricultural systems. Indeed, these systems influence the provisioning of a number of ecosystem services (eg food, fiber, and fuel), which depend in turn upon an array of supporting and regulating services as inputs to production (eg soil fertility and pollination) (Zhang et al 2007). Human perception of landscape is widely recognized to shape and maintain landscapes worldwide, and it has therefore recently been included in ecosystem management and restoration (Calvo-Iglesias et al 2006; Campos et al 2012) and cultural service evaluation (Tveit 2009; Soliva et al 2010; Howley et al 2012). Therefore, understanding how people relate to nature in diverse landscapes is key to identifying sustainable development pathways (Chan et al 2016; Pascual et al 2017). This implies consideration of the ways in which perceptions are influenced by human culture and worldviews (Kaltenborn and Bjerke 2002; Park et al 2008; Ren 2019), age (Lyons 1983; Zube et al 1983), contact with nature, and education (Tveit 2009; Lima and Bastos 2019).

Understanding the determinants of landscape perception by users is particularly relevant in rapidly changing agricultural systems. There is ample evidence that the worldwide restructuring of agricultural landscapes has profoundly affected the services they provided to societies—mostly through the expansion of monocultures and the resulting elimination of noncrop habitat (Tscharntke et al 2005; Gurr et al 2016). For example, these factors are routinely blamed for causing major loss of agrobiodiversity (Lin et al 2008), with consequences for pest control, water retention, and soil fertility (Tamburini et al 2016), as well as human–nature relatedness (Caulfield 2019; Riechers et al 2020), among others. As the modification of ecosystem and social services in changing landscapes can be addressed by a concerted effort to redesign agrosystems, scientists need to work with farmers to assess how they value the natural and social features of the landscapes in which they live (Landis 2017). For example, integrated agroecological approaches sustain and enhance natural functions of natural habitats in agricultural landscapes, yet farmers will only implement these approaches if they value these habitats more than anthropogenic features. We therefore need to learn more about smallholder perceptions of landscapes to better tailor incentives toward agricultural landscape management issues. This effort is of particular importance for smallholders living in low-income countries because landscapes simultaneously provide environmental, social, and economic benefits that can help build resilience (Altieri 2002; Liu et al 2015).

In this study, we aimed to understand how smallholder Ecuadorian farmers in the Andes perceive features and functions of landscapes that have different proportions of natural habitats (Figure 1A, B). This study was part of a broader participatory research program focused on habitat management strategies for pest suppression, including landscape-scale effects, to improve the resilience of small-scale farming systems through locally adapted, resource-efficient, and systemic interventions. Agricultural practices of the Ecuadorian Andes typically involve a combination of traditional practices and modern techniques to deal with the unique terrain (steepness) and climatic elements of the region (lack of seasonality in both temperature and rainfall, high daily variability in temperature, high rainfall variability on a local basis). However, industrial agriculture (eg flower and broccoli monocultures) has profoundly affected both social (eg human mobility) and environmental components (eg proportion of natural habitats, abundance of crop pests) of the Andean landscape over the last decades (Caulfield 2019). The main agricultural practices in the Ecuadorian Andes include terracing for hillside cultivation, crop rotation (potatoes, maize, quinoa, barley, flowers, and various vegetables), livestock grazing, and agroforestry. These practices are found in all 4 landscapes presented to farmers, but with different levels of intensification (Figure 1C). In terms of landscape evolution, fallow land with natural vegetation has been brought into use for pasture, crops, or tree plantations by slashing and burning. The specific objectives of our study were to (1) identify the landscape features (eg natural or social) that are most valued by farmers for crop production (where the term "social" refers to artifacts produced by humans or to things managed by humans in the landscape), (2) assess the services or nuisances that farmers associate with these features, and (3) determine whether sociocultural variables (eg sex, age, Indigenous group membership) affect landscape perceptions.

To achieve these objectives, we reviewed the multitude of methodological approaches developed to study landscape perceptions based on visual stimuli. Most are based on pictures from a human viewpoint, either from real landscapes (Tveit 2009) or from images generated by computer (Ode et al 2009), while a participatory mapping approach where stakeholders draw schematic landscapes proposes a zenithal view. Participatory research using maps has proved to be particularly relevant for the depiction of natural and sociocultural features known by smallholder communities (Corbett 2009). This process encompasses various aims, such as the presentation of the research project to the community in order to raise awareness and encourage participation (Caulfield et al 2020), the identification and mapping of the dominant land uses and their change over time to foster community resource management (McCall and Minang 2005), or knowledge sharing about hazards and vulnerabilities to enhance the resilience of the community (Valdivia et al 2010). Recently, real-time, high-resolution maps obtained using uncrewed aerial vehicles (UAVs) have helped farmers to identify fine-scale soil and vegetation characteristics, which are helpful in making decisions about crop management and farm planning (Xiongkui et al 2017; Colloredo-Mansfeld et al 2020). We chose a combination of these approaches, using a zenithal view of landscape pictures obtained with a UAV, as this makes it possible to present a large panel of landscape features based on real local landscapes.

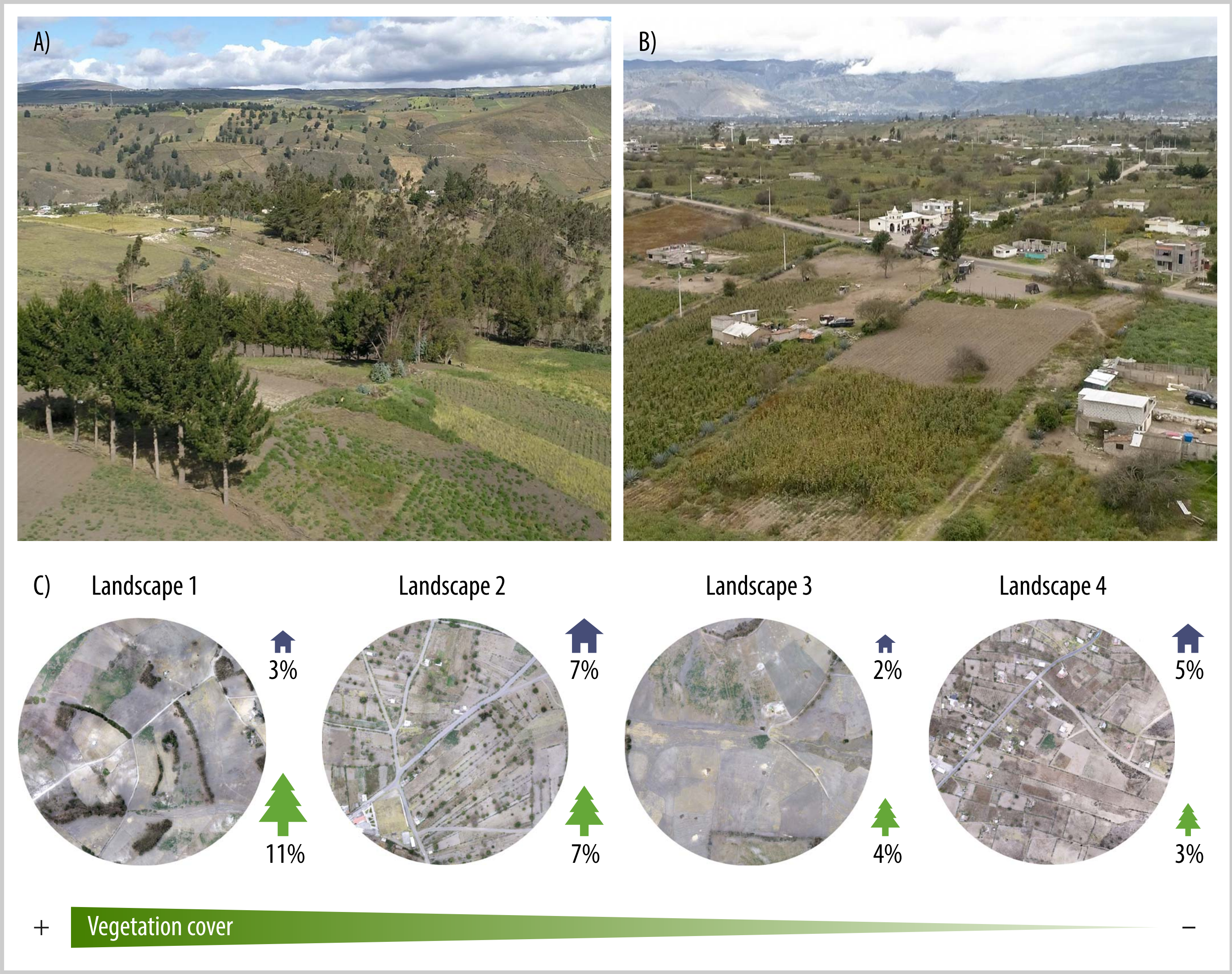
Material and methods

Farmer surveys

Our interview protocol consisted of 3 steps carried out over 5 workshops with a total of 199 farmers expressing interest in the study: (1) a landscape preference exercise (choosing a landscape); (2) identification of important landscape features for growing crops (free-list analyses); and (3) socioeconomic surveys. The farmers belonged to communities with which our team has maintained regular relations and organized several capacity-building workshops over the past 2 years, as part of a participatory research project on insects associated with lupine crops. Our sample was therefore not random as it focused on lupine growers, but it was purposefully collected from 5 provinces of Ecuador (Carchi, Chimborazo, Cotopaxi, Imbabura, and Pichincha) to encompass a diversity of agricultural practices and human cultures.

The landscape preference experiment was carried out to assess farmers' perceptions of landscape features and related services and nuisances. To this end, we obtained UAV images of landscapes in the region (from 2861 to 3218 m above sea level) with a proportion of natural vegetation cover (mainly woody vegetation composed of trees and bushes) ranging from 3 to 11% and human infrastructure cover (mainly houses, roads, and storage) ranging from 2 to 7% of the entire landscape (see Figure 1C). In accordance with the purpose of our larger research project, landscapes were selected in areas where lupine is commonly grown. These are typically quite arid environments, which explains the low vegetation cover. The landscape pictures were merged as orthophotos and then cropped as circles with a 300 m radius (for more details, see Struelens et al 2021). The orthophotos were then processed using the free online software Photopea (www.photopea.com) to harmonize their tones, contrasts, and colors. The edited orthophotos were printed on 1 × 1 m polyvinyl chloride canvases to be shown to farmers. Farmers were asked to choose one of the 4 landscapes in which they would preferentially grow their main crop (in our case, mainly Andean lupine, *Lupinus mutabilis*, or potato, *Solanum tuberosum*) and to justify their

FIGURE 1 Diversity of agricultural landscapes presented to smallholder farmers in the Ecuadorian Andes. Typical bird's-eye views of: (A) Landscape 1, with a comparatively high proportion of trees and large parcels; (B) Landscape 4, with a comparatively high density of human infrastructure; (C) images of the 4 study landscapes obtained with the uncrewed aerial vehicle. The 4 landscapes were chosen to represent a gradient of natural vegetation cover (tree icon) and anthropogenic features (house icon). Landscape numbering is the same in Figures 1 and 2.



choice. More specifically, we asked farmers to focus on a cultivated field delineated in the center of each orthophoto. A patch of the same focus crop was duplicated across all pictures to ensure that farmers could only rely on surrounding landscapes to justify their preferences and not on the visual characteristics of the focus crop. We ensured that all respondents understood that the spatial scales and resolutions were identical across all landscape pictures.

Focus crops were highlighted with a marker to also ensure that farmers understood that these would be the crops from which they could choose. Each respondent was isolated when interviewed to guarantee that they would not be influenced by other farmers' answers. Farmers were first asked if they could recognize any of the 4 landscapes; if so, their answers were discarded from subsequent analyses to avoid any bias caused by personal attachment to the place. After explaining they had to choose between focus crops, respondents were asked, "Which parcel would be the best spot to grow a crop? And why?" Interviewers recorded the favorite landscape choice and then wrote down the farmers' justifications for their choice as a free list (ie recording response order). Free lists are simple tools to elicit contents of the cultural domain by asking respondents to list as many elements as possible about a concept. They are widely used in psychology and anthropology because they allow the association and salience of concepts to be easily and effectively studied (Gravlee et al 2013). Justifications consisted of landscape features on which the farmers relied to make their choice. If, for a given landscape feature, the respondent did not explain the reason behind their choice, the interviewer tried to obtain this response once by asking "Why did you choose this feature?" Then, this last step was repeated for each landscape feature (ie element of the free list). This information was later used to identify landscape features and their services and saliency (see below).

Finally, the last step of the survey aimed at collecting sociocultural characteristics that could influence farmers' perceptions. These explanatory variables were chosen based on previous studies (Lyons 1983; Zube et al 1983; Kaltenborn and Bjerke 2002; Park et al 2008; Chan et al 2016; Ren 2019) that showed they had significant effects on landscape preference (see Introduction): age, sex, level of education, ethnicity, contact with external organizations, daily time spent in the field, family size, and workforce (see more details below). To determine ethnicity, we asked farmers to self-identify as either belonging to an Indigenous or non-Indigenous ethnic group.

All responses were collected on electronic handheld devices using KoBo Toolbox (KoBo 2019). All Quechua speakers were interviewed in Quechua by Ecuadorian students and researchers. Verbal consent was obtained prior to the interviews from all farmers.

Data analyses

All the answers—hereafter referred to as items—from the landscape choice experiment were classified according to 2 factors: (1) the landscape feature on which farmers focused their justification for their landscape preference, and (2) the reason behind the landscape feature, usually a social or ecosystem service or disservice provided by the landscape feature. Final free lists contained both landscape features and associated services and nuisances. Among the landscape features, isolated trees, forest patches, and other woody vegetation items (eg shrubs) were combined within the same category (trees), while hedges were considered separately because farmers themselves perceived hedges differently (eg parcel delineation). Both landscape items and their related services and nuisances were classified as either ecological or social (see Appendix S1, *Supplemental material*, https://doi.org/10.1659/mrd.2024.00001.S1). Unlike Jones et al (2016: 154), who considered crops as "cultivated natural capital," we separated farmers' consideration of social versus ecological features, as farmers themselves tend to do so in this region. For example, most farmers see cropped and grazing areas mainly as social features (fully dedicated to food production) and hedges as natural ones (as they spend little time maintaining them). In our classification, the landscape's social features included agricultural features (livestock pastures, shape and extent of an arable field) and built infrastructure (roads, houses, storage), while ecological features included geomorphological properties (flat terrain, elevation, bare soil) and green and blue belts (trees, hedges, rivers).

Items were coded by the first author using the following process: From the 706 items from respondents, 285 were excluded from service analysis because answers were too short or the intention behind them was not clear. The 421 items left were harmonized to obtain 213 different items. These items were in turn coded into 39 broader categories, either originating from the Common International Classification of Ecosystem Services (CICES) or following our own definitions when CICES was not applicable. These 39 categories were then merged into 19 final categories (see Appendix S2, *Supplemental material*, https://doi.org/10.1659/mrd.2024.00001.S1).

We computed a salience index (Smith's *S*) for each landscape feature based on the free lists given by farmers. The salience index accounts for both the frequency of a given item within a population and the importance (ie order in the free list) for each individual within this population. The salience index was chosen because it makes it possible to elicit a social representation that goes beyond the individual item. We used Smith's *S* index from the R package AnthroTools (Purzycki and Jamieson-Lane 2017), with the following formula (Smith and Borgatti 1997):

$$S_i = \frac{\sum_{j=1}^{N} \left(\frac{L_j - R_{ij} + 1}{L_j} \right)}{N}$$

where S_i is Smith's *S* salience for item i, L_j is the list length from farmer j (ie the total number of items cited by farmer j, after harmonization), R_{ij} is the citation rank of item i in list j, and N is the total number of lists (interviewed farmers). Ecosystem services were related to the list of services in CICES v5.1 (Haines-Young and Potschin 2018), when relevant, while social services were given our own classification (see Appendices S1 and S3, *Supplemental material*, https://doi.org/10.1659/mrd.2024.00001.S1). Because respondents were asked to compare different landscape images, several items focused on the absence, rather than on the presence, of a given landscape feature (eg "this landscape does not have road access"). Missing features were also considered as justifications linked to services, even though they were classified as a negation. Similarly, links between landscape features and services were either positive or negative depending on the respondent's justification. Several respondents only mentioned a landscape feature with no association with a service or a nuisance. These answers were used to compute the salience index of landscape features but were excluded from the natural/social service analysis.

We used a generalized linear model (GLM) with a quasibinomial family to explore whether landscapes were explained by sociocultural variables. The dependent variable "ecologically based justifications" was expressed as the ratio of farmers' answers related to ecological landscape features divided by the total number of items in the free-listing survey. This ratio ranged between 0 (farmers only cited social landscape features to justify their choices) and 1 (farmers only cited ecological landscape features to justify their choices), informing the choice of a quasibinomial distribution. We chose 5 sociocultural variables: Indigenous group membership, contact with external organization, the daily time spent in the field, age, and sex. We expected that the first 3 variables might significantly affect farmers' choices toward the landscapes' natural features. In contrast, we hypothesized that men and young people would prefer anthropogenic features, as they are involved in the transportation of products to markets and often value connection to nearby urban centers for job or study opportunities (see Zube et al 1983; Kaltenborn and Bjerke 2002; Park et al 2008; Chan et al 2016; Ren 2019). The validations of these assumptions were performed using the P value for the Wald test, and the overall goodness of fit of our model was assessed using a Hosmer–Lemeshow test. All analyses were performed using R version 3.5.1.

Results

Farmer characteristics

We surveyed 199 farmers (126 women, 73 men) from 5 provinces of Ecuador aged 14 to 85 years (mean = 49.4 years). As shown in Table 1, the sampled population showed a large variability in education level, daily time spent in the field,

TABLE 1 Socioeconomic characteristics of the farmers interviewed (n = 199). Minimum, mean, and maximum values are shown.

Variable/value	Minimum	Mean	Maximum
Age (years)	14	49.4	85
Education level (years of study)	0	6.6	18
Daily time spent in the field (hours)	0	5.8	14
Workforce (number of people)	0	1.7	10
Family size (number of people)	1	4.5	12

workforce (number people helping with agricultural work, not counting the interviewed farmer), and family size (number of people including the interviewed farmer).

Landscape features valued by farmers for lupine production

From our landscape preference experiment, we found that most farmers (36.5%) preferred the landscape with the highest proportion of natural vegetation (Landscape 1 in Figure 1), followed by Landscape 2 (26% of votes) and Landscape 4 (24.9%; Figure 2). The least preferred landscape (12.7% of votes) had a low proportion of both natural vegetation and human infrastructure (mainly cropland, Landscape 4).

The average length of farmers' lists of landscape features and services/nuisances was 3.92 ± 1.95 (min = 1, max = 12). Overall, the landscape features that had the highest salience (ie importance both for individuals and across individuals) were trees, roads, and houses (Figure 2). For Landscapes 1 and 2, the features identified to justify the landscape choice were mainly ecological (53.9 and 54%, respectively), whereas farmers focused mainly on social features for Landscapes 3 and 4 (67.5 and 60%, respectively). Among all the landscape features, houses received the most divergent opinions, with 57.6% of the farmers considering their absence from the landscape as positive. We observed that some farmers cognitively analyzed the images. For example, some of them assessed topography even though the zenithal view made it difficult to observe; flat terrain received divergent perceptions, with 37% of answers considering it as negative (Figure 2).

Services and nuisances associated with landscape features

Farmers linked landscape features to 8 ecosystem services and 8 social services (Figures 3, 4). Among the social services, accessibility, cropping practices, and economic income were the most prominent services identified, whereas water regulation, wind protection, and soil formation were the most cited ecosystem services (Figures 3, 4). Our results also showed that some ecological and social features could be linked to both social and ecosystem services at the same time, and the relationships could be both negative (nuisance) and positive (service) (Figure 4). For example, roads were positively linked with accessibility in most cases but also negatively related to security (a drawback of accessibility), to air quality (dust and contamination), to water regulation (water runoff), and to economic income (presence of road increases land cost). Overall, nuisances associated with ecosystem services represented 10.7% of all responses. Some landscape features showed a high number of connections with several services, such as trees (8 links), houses (8 links), or roads and soil (4 links). For example, 32.5% of farmers mentioned a positive effect of hedges or trees on wind protection, water regulation, pest control, soil erosion control, and soil formation (extracted from Figure 4).

Sociocultural variables affecting landscape perceptions

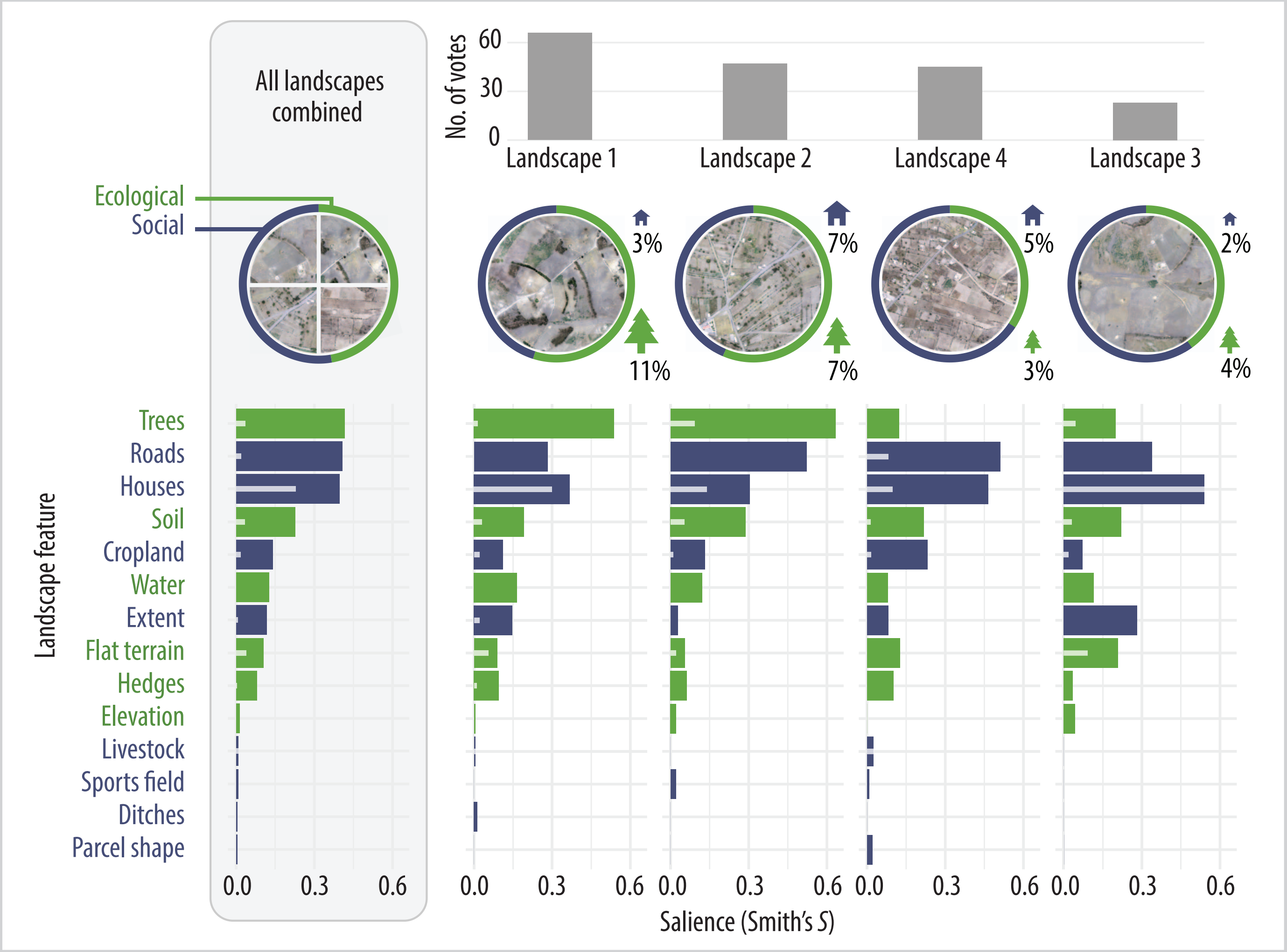
Overall, the Hosmer–Lemeshow test of our GLM analysis of farmers' ecologically based justifications was not significant (χ-squared = 2.2463, degrees of freedom = 8, P value = 0.9725), indicating that data were well distributed and that our linear model satisfactorily captured the variance of the data. The insignificance of the intercept in the GLM implies that the response function is not different from zero when all the predictors are set to zero (Table 2). For our quasibinomial regression model, this means an event probability of 0.5. Contrary to our initial hypothesis, the GLM showed that Indigenous farmers, when describing the reasons why they selected a particular landscape in the choice experiment, referred significantly more to social features of the landscape than did non-Indigenous farmers. Age, sex, daily time spent in the field, and contact with external organizations did not significantly affect the natural versus social perception of landscape features.

Discussion

Farmers' landscape evaluation: natural and social influences

Our study showed that farmers relied on both natural and social features of the landscapes when evaluating their suitability for farming practices—in our case, an appropriate location to grow their crop. Farmers primarily relied on water availability in their landscape choice (Figure 3), which reflects the climatic and socioecological context of the study regions. Farmers have few irrigated crops and are therefore very dependent on rainfall. Wind protection, soil erosion control, and pest control were also identified by farmers as important services provided by landscapes. Concerning social features and services, roads and accessibility were the most valued by farmers, reflecting the farmers' dependency on transportation to manage their fields (frequently kilometers away from each other) and for market access (Devaux et al 2009). Interestingly, all these services were linked to 2 key features of the agricultural landscape: trees and hedges. Woody vegetation and hedgerows can afford a number of ecosystem services, such as water provision, wind protection, soil conservation, and pest control (Montgomery et al 2020). Therefore, our results suggest that water, one of the most limiting factors for crop production in the study area, could be managed by increasing noncrop vegetation around agricultural parcels and that incentives to preserve natural vegetation could be perceived favorably by farmers. Our results also suggest that farmers may be eager to preserve natural vegetation, as

FIGURE 2 Farmers' landscape preferences and the salience of landscape features used to justify their choices. The top panel shows the number of farmers that chose each landscape to grow their focus crop. Landscape features were classified as either social (dark blue) or ecological (green). The donut charts around the landscape pictures represent the overall proportions of social and ecological features for each landscape. House and tree pictograms reflect the proportions of forest and infrastructure (houses and roads) in each landscape, respectively. White lines within bars show the proportion of items for which the absence of the landscape feature motivated the farmers' choice. Landscape numbering is the same in Figures 1 and 2.



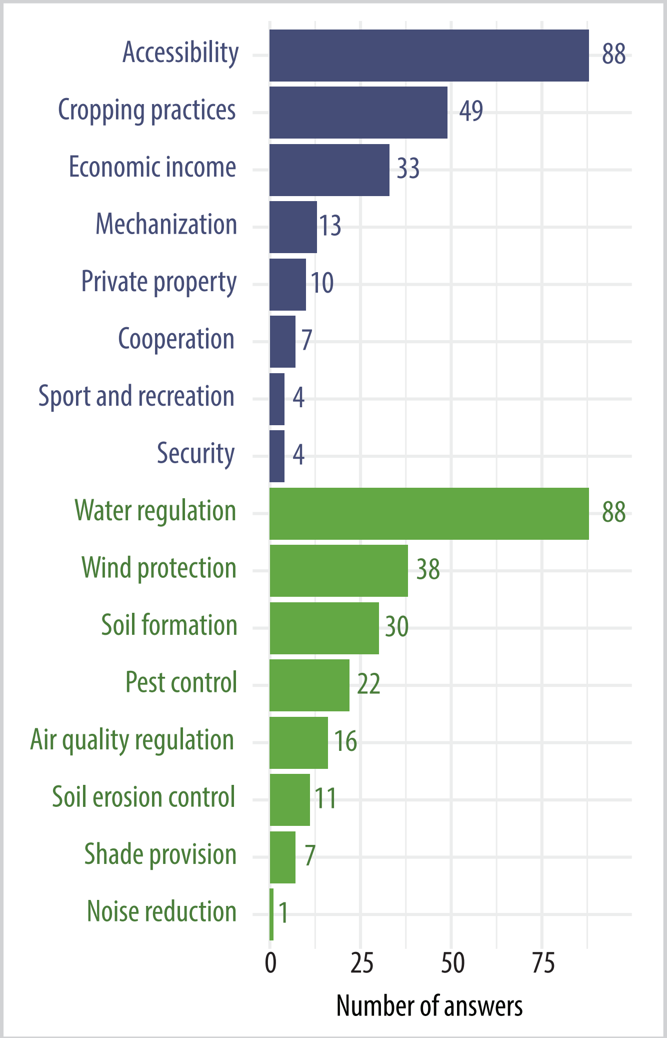
some of them already perceive these benefits from the landscape. Landscapes with higher proportions of vegetation were preferred over simpler landscapes, which echoes studies that found landscape simplification to be associated with a decrease in landscape relational values (Riechers et al 2020). However, only limited numbers of farmers (32.5%) were aware of the services provided by vegetation and hedges.

Perceived values and nuisances of landscape features

Interestingly, the same link between a landscape feature and service could be perceived positively by one farmer and negatively by another. For example, some farmers valued trees as positive elements for water availability, while others saw them as nuisances that compete with crop plants for water. This is in line with previous studies that have shown the subjective perception of services (Rescia et al 2008; Silwal et al 2017; Dendoncker et al 2018). Individual farmers' attitudes towards landscape elements and their perceived benefits or nuisances can be shaped by a variety of factors, including farmers' previous experiences (eg enjoyable recreational activities versus negative encounters), cultural beliefs and values (eg sacral and aesthetic appreciation versus utilitarian perspective), economic interests (eg intensive agriculture versus tourism), psychological and educational factors (personal connection to nature versus formal education about nature services), information sources (eg biased information from the media, governments, nongovernmental organizations), or local contexts (eg drought versus floods, strong winds, social norms). Understanding these discrepancies in perception and balancing the negative and positive values of ecosystem services in landscape analyses are crucial for effective landscape management and conservation efforts.

Our results also showed that 10.7% of landscape features were related to a nuisance (ie negatively linked with their related services). Even though positive relationships were dominant in our study, other studies have argued that the nuisance of certain landscape features can motivate more people to take action than can the services provided by

FIGURE 3 Importance of services from the landscape perceived by farmers. Services have been classified as either social (first 8, dark blue) or ecological (second 8, green).



landscape features (Conway and Yip 2016; Blanco, Dendoncker, et al 2019; Blanco, Sourdril, et al 2019). This suggests that special care should be taken when dealing with negative links between features and services. In our case, several ecological landscape features were perceived to have negative relationships with water regulation, pest control, and soil erosion control. Therefore, farmers' perceptions of nuisances should be further explored through participatory studies before attempting to promote an increase in landscape vegetation within agrosystems.

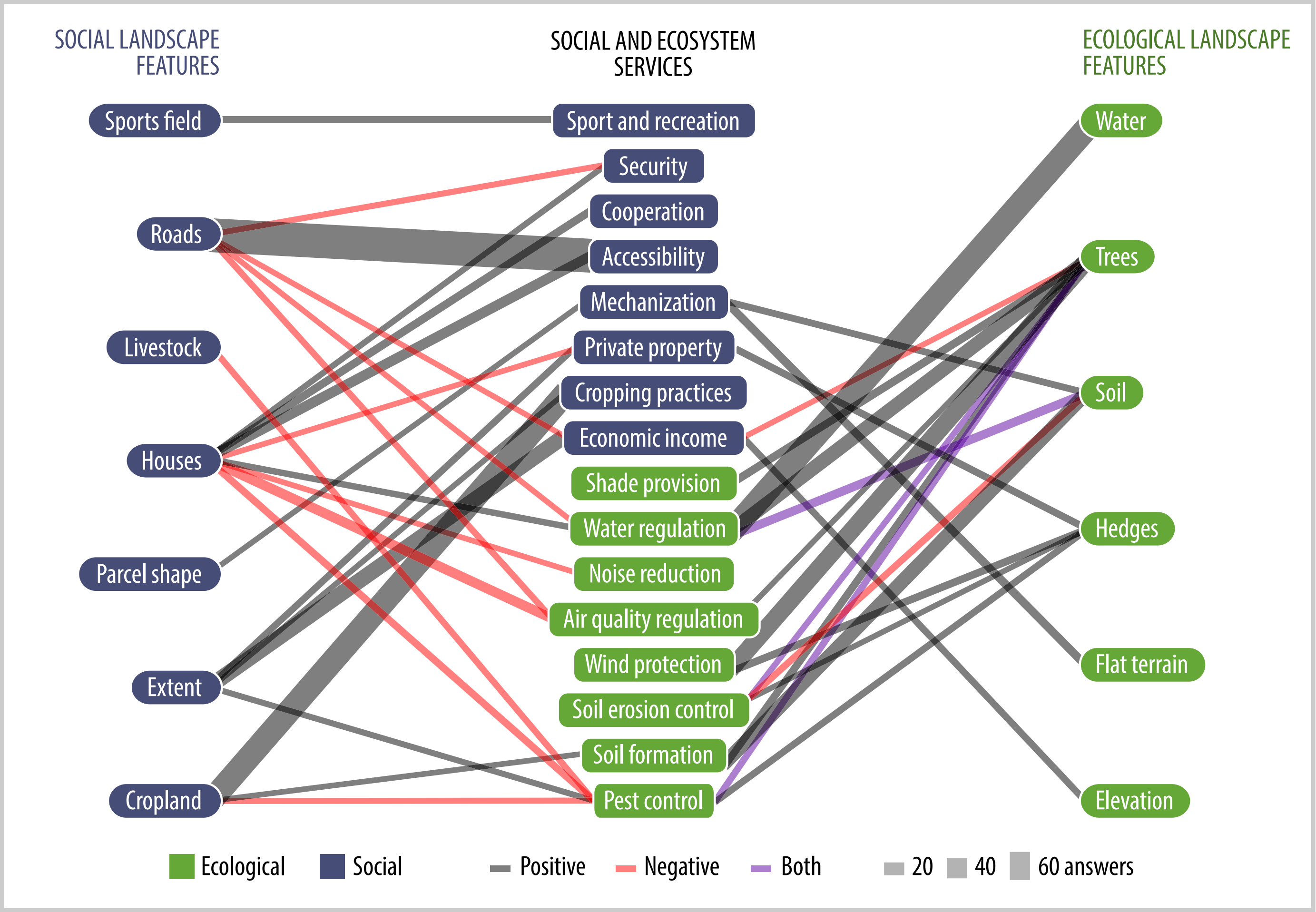
Integration of social and ecosystem perspectives in landscape perception

Another important result of our study is that Andean farmers looking at a landscape picture relied almost equally on natural and social features of the landscape when choosing an appropriate location to grow their crop (Figure 2). Additionally, these features were equally related to both social and ecosystem services and nuisances (Figures 3, 4). These findings are in line with recent efforts by landscape ecologists to recognize and integrate the social components of landscape for ecosystem service provision (Jones et al 2016). The social components of an agroecosystem deeply modulate the production of ecosystem services to people (eg farmer practices influence food production, roads influence the transportation of agricultural products; Spangenberg et al 2014). A recent attempt to consider these social components of ecosystem service production and delivery turned to the concept of capital, originating from economics (Jones et al 2016). In this framework, natural resources (eg crops, natural enemies) are considered to be natural capital, defining a potential supply of goods or services (eg food, pest control). The potential supply rarely translates into realized supply because human-derived capital controls the delivery of ecosystem services. Under this framework, a majority of landscape features can ultimately be related to both natural and human-derived capital, which is well illustrated in our Figure 4. Interestingly, in our study, ecosystem services were all related to regulating services (eg water regulation, soil erosion control, pest regulation, wind regulation), whereas human-derived capital spanned various types of capital, including financial (eg income), manufactured (eg roads and accessibility), social (eg cooperation), and human (eg cropping practices). Therefore, farmers' perceptions of landscape and its values are more diverse in terms of human-derived capital than ecosystem services.

Indigenous perspectives and implications for landscape perception

Finally, an interesting finding of our study is that Indigenous farmers focused less on ecological features of the landscape than did non-Indigenous farmers (Table 2). This result was unexpected given that Indigenous people in the Andes have a worldview that more thoroughly integrates humans as a part of nature than does the non-Indigenous worldview (Seligmann 2018). This finding may reflect the wish of Indigenous farmers to have better access to these social features, as they are living, on average, in poorer and more isolated places than non-Indigenous farmers. In particular, roads are key features, not only for the transportation of agricultural products, but also for access to health, education, and mobile phone and internet networks. In this sense, more anthropogenic landscapes can represent opportunities for better living. One should keep in mind that worldviews are not rigid sets of traditional norms and values, but they instead have a deep-seated logic and a large panel of alternative processes that give Indigenous people considerable flexibility and capacity to adapt to changes in their environment (Durston 1993). Another explanation for this unexpected finding concerns our methodology for identifying and interviewing Indigenous people. It is possible that some people who actually live in a Quechua culture may have self-identified as "non-Indigenous" because they were apprehensive of pervasive negative stereotypes associated with the Indigenous identity. Also, some Indigenous farmers may not have gained sufficient confidence in the interviewers and may have answered according to what they thought the interviewer wanted them to say. Finally, it is possible that the spiritual landscape of Indigenous communities may not be related to the proportion of natural features in the

FIGURE 4 Relationships between landscape features identified by farmers and ecosystem and social services. Social (left side, dark blue) and ecological (right side, green) landscape features are connected to services (center). Relationships between landscape features and services were perceived by farmers as positive (dark gray lines), negative (red lines), or both (purple lines). The width of the lines is proportional to the number of times each feature was mentioned by farmers.



landscape. As our study was not originally designed to address this question, more research is needed to take into account how agricultural decisions by Indigenous peoples are governed by their cultural and spiritual understandings in addition to ecological and social factors (see, for example, Read et al 2010).

With regard to other explanatory variables potentially affecting landscape perception by farmers, we hypothesized that contact with external organizations may have triggered more answers about the natural components of the landscape, as these are supported by many agroecological programs running in the region. However, our results did

TABLE 2 GLM results showing the extent to which farmers' ecologically based justifications are explained by sociocultural variables. The response variable corresponds to the ratio of ecological to social features identified in the landscape picture. Negative *z* values indicate that social features are preferred over ecological ones. Significant explanatory variables are presented in bold.

Parameter	Estimate	SE	*z* value	*P*(>|*z*|)
(Intercept)	−0.006	0.421	−0.014	0.989
Indigenous (yes)	**−0.481**	**0.204**	**−2.362**	**0.020)**[a]
Daily hours in field	−0.057	0.033	−1.727	0.087
Contact with external organizations (yes)	−0.035	0.220	−0.158	0.875
Age	0.007	0.007	0.985	0.327
Sex (male)	0.039	0.212	0.181	0.856

Note: SE, standard error.

not support this hypothesis (Table 2), which may be due to the heterogeneity of extension programs in their methodology for involving farmers (from basic assistance to workshops to participatory research), with consequences for their effectiveness in raising awareness and promoting understanding among participants (Davis 2008). Gender, age, and the daily time spent in the field also did not affect the farmers' focus on ecological features. These factors are usually associated with landscape and ecosystem service perceptions, even though some studies have found similar nonsignificant results (Lima and Bastos 2019).

Study limitations

There are at least 2 main limitations to our study. First, we were not able to determine the position of each farmer within our socionatural landscape gradient. This information might have been useful in assessing whether the preferred landscape was similar to the landscape in which each farmer lived and worked, thereby allowing more refined analyses and conclusions about how certain landscape features are integrated into farmers' decisions relative to others. Second, our conclusions about farmers' attention to social versus ecological features may have been influenced by the way in which we chose to separate social from ecological landscape features. For example, it could be argued that hedgerows or watercourses in agricultural landscapes are shaped and maintained by farmers and are therefore as anthropogenic as a cultivated field. Recent lines of research (eg relational thinking; Davis 2008) have argued that by referring to "social" and "ecological" as different classes of entities, researchers inadvertently reproduce the separation of a human–nature system that they describe as intrinsically coupled. Emphasizing the relationships, experiences, or practices of farmers, rather than the features they perceive in landscapes, may help to promote a more holistic view of human–nature connectedness in mountain systems (see Davis 2008).

Conclusion

Overall, our study showed that farmers rely equally on natural and social features of a landscape when evaluating its suitability for farming practices. This suggests an entanglement of the social and the ecological qualities in the production of landscape features and associated benefits/nuisances. Landscape features were related to a large array of functions, some of which were perceived as a service by one farmer and as a nuisance by another. Among ecological services, farmers identified a potential strategy to improve several agricultural regulation services based on hedgerow management, which suggests that incentives to preserve natural vegetation in agricultural landscapes might be perceived favorably by farmers. Further experimental studies should assess whether such a strategy has the potential to sustainably provide the benefits anticipated by farmers. Finally, we found that Indigenous farmers value agricultural landscapes differently from non-Indigenous farmers; this needs to be taken into account when promoting the adoption of landscape management strategies such as ecological intensification.

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Supplemental material

APPENDIX S1 Classification scheme for social and ecosystem services.
APPENDIX S2 Classification scheme for all responses within broader categories.
APPENDIX S3 Numerical values of salience for each feature in the 4 studied landscapes.

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