Are public good ecosystem services generated by on farm conservation of crop diversity valued by the general public?

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Abstract

Agrobiodiversity is associated with a range of important but poorly quantified public good ecosystem services, the conservation of which requires public support. With a view to determining the general public's willingness to pay (WTP) for such conservation, 491 adult Peruvian residents were interviewed using a stated preference choice experiment (CE) to elicit the value they place on crop genetic resources conservation, using quinoa as a case study. Strong support for the conservation of quinoa diversity was revealed, in particular when conservation was framed in terms of conserving the national cultural identity or food security. Respondents were willing to donate most for quinoa conservation to minimise production losses and to maintain the crop's existence. Findings demonstrate the significant and frequently ignored social welfare benefits associated with non-market agrobiodiversity-related public good ecosystem services, in this case equivalent to a third of market production values. Given the relatively modest costs of securing such ecosystem services, we calculated a conservative benefit-cost ratio of 1.7.

1. Introduction

An unprecedented and irreversible loss of agrobiodiversity is occurring at the ecosystem, species and genetic levels throughout the world, with threats to diversity getting stronger (FAO 2015,2019). This is despite the fact that the existence of such diversity is the basis for sustainable agriculture, food and nutrition security, ecosystem health and adaptation to climate change (Hajjar et al., 2008; Bellon et al., 2020; Tesfaye and Tirivayi, 2020). Unlike wild diversity, agrobiodiversity is the result of thousands of years of interaction between humans and the environment, with its continued existence dependent on the maintenance of such public good "evosystem" (i.e. evolutionary process-related) services (Faith et al., 2010).

With many of the world's agrobiodiversity hotspots being found in developing countries, a fundamental conundrum is thus experienced by society today — how to safeguard the biodiversity maintained in the fields of the rural poor whilst meeting those same people's development needs and rights? This is because although agrobiodiversity can be used to mitigate risks and stabilise both yields and incomes (Di Falco and Chavas, 2009; Poudel and Johnson, 2009; Kassie et al., 2017; Tesfaye and Tirivayi, 2020; Maligalig et al., 2021), and, in the long run, improve the welfare of local communities (Kremen and Merenleder, 2018), farmers' short-term decisions are often based on how 'profitable' crop varieties or livestock breeds are (Bellon et al., 2020). Global market integration, land use change and migration further contribute to changing farmer maintenance of crop diversity (Zimmerer and de Haan, 2017; Goldberg et al., 2021).

Failures in existing policies and markets which favour high-input, high-output "improved" varieties and breeds exacerbate farmers changing practices and agrobiodiversity loss (Smale et al., 2004; Pascual and Perrings, 2007; Narloch et al., 2013). Traditionally used varieties are being driven out whose range of non-market values is not reflected in their price (Bellon et al., 2020). In addition to environmental benefits, for example related to climate change adaptation, these include their role in maintaining cultural traditions (including food culture), local identities and traditional knowledge (Smale et al., 2004; Nautiyal et al., 2008; George and Christopher, 2020). This leads to an underprovision of genetic diversity at the national and global levels, while those farmers maintaining agrobiodiversity in their fields are often left uncompensated for their opportunity costs of providing a public good ecosystem service.

The existence of diverse benefits indicates the complex incentives underpinning the strategy of many smallholder farmers in developing countries who continue to grow multiple crop species in an integrated farming system, maintaining *de facto* crop diversity. Nonetheless, there is no guarantee that socially desirable levels of diversity will be maintained by them. Markets alone cannot be expected to reward farmers adequately for managing socially desirable levels of agrobiodiversity (Narloch et al., 2011; Drucker an Appels, 2016). It is therefore important to understand non-market values associated with home consumption, cultural values and other non-tangible benefits to farmers and the society.

It is in this context that we present a case-study from Peru, a country in which, unlike those of the European Union, there is no functioning long-term agricultural policy funding mechanism for agrobiodiversity conservation. The study aims to identify: i) which public good ecosystem service attributes of quinoa are most valued by the general public; ii) who values which attributes the most; iii) what the impact of information framing is on these values; and iv) to what degree the public's willingness to pay for conservation might be sufficient to cover the estimated costs of implementing such a programme (cost-benefit analysis). To do so we used a total economic value (TEV) framework and conducted a willingness to pay choice experiment (CE) -a multi-attribute preference assessment method - among the Peruvian public in selected locations. The TEV framework provides a structure through which different types of benefits to society, both direct and indirect, can be aggregated in order to construct a comprehensive valuation. Under the framework, any public good or service may consist of both use (actual and option) and non-use (existence, altruistic, and bequest) values (OECD, 2006).

The results can be useful for designing interventions that seek to maximise the value of the ecosystem services being conserved. Over recent years a body of work has emerged that specifically seeks to develop and provide market-based incentives for the conservation of agrobiodiversity, such as payments for agrobiodiversity conservation services (PACS). These schemes can be implemented potentially at modest cost and designed in ways that are socially equitable (Narloch et al., 2011,2013; Wainwright et al., 2019; Drucker and Ramirez, 2020). However, scaling-up these largely project-related PACS interventions to effectively secure a national and global public good requires government support, which can be facilitated through information regarding which ecosystem services the public value most (which in turn can influence conservation strategies).

Under similar circumstances, stated preference methods have been widely used to elicit the value that the public places on different attributes of biodiversity, including in the specific case of agrobiodiversity (e.g., Krishna et al., 2010; Pallante et al., 2016; Botelho et al, 2018; Häfner et al., 2018). A number of these studies have also explicitly sought to demonstrate the existence of positive benefit-cost ratios, to guide the design of biodiversity policies and as a means of justifying existing or increased conservation funding (e.g., Zander et al., 2013; Martin-Collado et al., 2014; Tyack and Ščasný, 2018; Drucker and Ramirez, 2020).

2. Method

2.1 Research context

Peru is one of ten megadiverse countries and a centre of origin for crops important to the livelihoods of the poor, many of which are also of global importance. It possesses 184 species and hundreds of varieties of domesticated native plants, of which many species/varieties of these crops are considered "severely threatened" (FAO, 2015). There are over 5700 accessions of quinoa (*Chenopodium quinoa Willd*) conserved in seven genebanks, that have been characterised into 24 races (Tapia and Fries, 2007; Tapia et al., 2014), constituting thousands of varieties.

Many of these are at risk of disappearing (Kost, 2016) in large part as the national and international market is concentrated around only 15–20 mostly white varieties out of an approximate total of 3000 (Rabines/MINAGRI, pers. Com, 2014; Rojas et al., 2009). The resulting genetic erosion threatens Peru's food and nutritional security, the sustainability of its high-altitude production systems and its ability to adapt to future climate change, along with emerging pests and diseases.

Furthermore, quinoa plays an important role in many Andean cultural traditions (Rojas et al., 2009) and its high profile in Peru in general makes it an ideal crop around which to explore its many non-market public good ecosystem service values and the general public's willingness to support its in situ on farm conservation. Estimating the potential magnitude of such support and devising mechanisms to capture such values is critical, given that poverty rates in the arid Andean rural highlands can reach over 50% (INEI, 2015, p.63).

2.2 Choice experiment design

In a CE, respondents are presented with a series of choice tasks, known as choice sets, each containing a finite number of alternatives which describe an hypothetical environmental good or policy outcome in question (Hanley et al., 2001). CEs have been used extensively to evaluate farmer participation in schemes providing ecosystem services (e.g. biodiversity conservation: Sardaro et al., 2016; carbon sequestration: Aslam et al., 2017) or to gauge their preferences for crop traits improving livelihoods (e.g. Kassie et al., 2017; Maligalig et al., 2021); as well as to determine consumer/general public willingness to pay for ecosystem goods and services (Zander et al., 2013; and Martin-Collado et al., 2014, Blare et al., 2017; Müller et al., 2020; Drucker and Ramirez, 2020).

The alternatives presented in a CE vary with regard to the levels associated with each of the attributes and respondents are usually asked to choose their most preferred alternatives. By making this choice, respondents trade-off the attributes and the associated costs that come with the chosen alternative. A key component of the experiment is the definition of attributes used in the choice experimental design (Johnston et al., 2017). The attributes and levels for this study drew on the approach used by Zander et al. (2013) and Martin-Collado et al. (2014), and were adapted to the Peruvian crop genetic resource context in consultation with Peruvian genetic resources and agricultural experts. Each attribute represents a component of the TEV so that the sum of the separate attribute values may be used as a proxy for the TEV of the public good ecosystem service associated with the maintenance of quinoa diversity in farmers' fields. The four attributes included Andean landscape conservation (includes ecological processes and aesthetics), insuring against the risk of agricultural production loss in the context of broader food security issues, quinoa diversity conservation and the maintenance of traditional knowledge and cultural practices – the latter including aspects of food culture (see Table 1).

As a monetary value, which is required for the calculation of welfare estimates, we selected a one-off donation (in Peruvian Soles) to a conservation programme for the crop in question. The use of one-off payment vehicles described as donations are common when evaluating environmental goods and services through respondents' stated preferences (e.g. Veríssimo et al., 2009; Kragt and Bennett, 2011). Although one-off payments are criticised for not being incentive compatible (Johnston et al., 2017), we opted against the use of a non-voluntary tax contribution vehicle as many respondents may fall outside of the tax net. Nor did we select a repetitive payments vehicle as we did not want to make assumptions about how long payments are needed to successfully conserve crop varieties, which could potentially require support in perpetuity. The one-off payment vehicle also helps to simplify respondent understanding of the total cost of the CE alternatives.

[Table 1 here]

A generic design was used, and each choice set consisted of three alternatives from which respondents were asked to select their most preferred. One of the alternatives was always described as status-quo (SQ), while two others represented different scenarios under a quinoa crop diversity conservation programme. The SQ alternative did not involve a personal cost for respondents and can be interpreted as leaving things to business-as-usual and a consequent continuing erosion of quinoa diversity. The other two scenarios involved a one-off contribution towards a conservation programme and would result in benefits associated with an increase in such diversity (or at least avoiding any further decline). Given the number of attributes and their levels (Table 1), there would have been too many possible combinations ($3^3*2^1*7^1 = 378$) to use all of them in the survey and hence a choice experiment was designed which only included a fraction of these combinations. The use of qualitative levels for two of the attributes (Conservation of Andean Landscape - Improve, Stable, Decrease; and Risk of Agricultural Production Loss - High, Medium, Low), as have been used in other studies (Zander et al., 2013; Martin-Collado et al., 2014; Drucker and Ramirez, 2020) was necessary due to the challenges of articulating potential impacts in quantitative terms with regard to such multidimensional concepts as landscapes and food security. The design was pre-tested before the main survey started.

An important issue in experimental design is with regard to the identification of efficient designs capable of generating statistically significant attribute combinations associated with a given sample size (Rose and Bliemer, 2008). We generated a Bayesian efficient design (see Sándor and Wedel, 2001; Ferrini and Scarpa, 2007) of 24 choice sets which were blocked into three blocks using the software STATA. Each respondent was assigned one block of eight choice sets each (see Figure S1 in Supplementary Information for an example of a choice set). The design was based on prior parameter estimates that we assumed after expert consultation and literature review (Zander et al., 2013). Using prior parameter estimates leads to more reliable parameter estimates for a given sample size, even if the information on the parameters is scant and the priors mis-specified (Bliemer et al., 2009). While we did not know the exact values of the priors, we were quite certain about the expected signs.

2.3 Sampling and data collection

With a view to exploring how public willingness to support genetic resources conservation may vary between segments of rural and urban populations as they become more geographically distant from the genetic resource in question, population samples were selected around the important Andean quinoa producing regions of Puno and Cusco. These included the regional capital cities themselves, whose populations are respectively 135,300 and 437,500 (INEI, 2017), as well as the surrounding rural areas where incomes might be expected to be even more constrained compared to within the cities themselves. Surveys were also realised in the national capital, Lima (population 9.17m [INEI, 2017], which is distant from these quinoa producing areas but with higher average incomes.

With a view to limiting enumerators' risk due to the challenges of visiting households in Peru, a “second-best” convenience sampling method was used that involved enumerators randomly recruiting participants in central or communal areas, such as town squares, bus stations and markets. Although convenience sampling can result in the risk of selection bias (Moore, 2001) and unbalanced samples, given the experimental design and randomised treatment used here no major issues arising from demographic imbalances were anticipated. As can be seen in Table 1, there is in fact significant overlap between the sample and the actual demographics.

Sample size calculation used a cluster sampling approach (Walker and Adam, 2011) considering District population, an expected WTP contributor’s rate of 0.4 for Lima and 0.3 for the regional cities, a sample precision level between 0.1 (Lima and Puno) and 0.15 (Cusco) in a normal distribution z with p-value equals to 0.95. To take into consideration population heterogeneity, we considered a population heterogeneity of 0.15 in Metropolitan Lima and 0.1 in the regional capital cities, assuming a more heterogenous population in Lima. Finally, optimal cluster size was measured based on heterogeneity of population and cost of data collection. As a result, the minimum sample size was determined to be 471 (192 in Lima, 195 in Puno and 84 in Cusco). Four-hundred and ninety-one adult Peruvian resident respondents were interviewed between July and September 2017 in Cusco (91), Puno (200) and Lima (200). The interviews were administered in Spanish (and occasionally in local languages Quechua and Aymara) by three groups of trained enumerators in their respective locations. Subjects were not compensated for their participation, eliminating any selection bias related to financial incentives. Only adults were interviewed, and consent was established before each interview.

2.4 Questionnaire

We used a three-part structured questionnaire. First of all, respondents were presented with questions related to their familiarity with and use of different varieties of quinoa. Secondly, they were presented with the CE tasks. In the third section, we asked for basic demographic information (gender, age, occupation, income, education, household composition, socio-economic status and wealth) and about the degree to which respondents make donations to good causes in general.

Information was provided with regard to agrobiodiversity in general. Prior to being presented with the choice sets, respondents were also reminded that achieving good conservation outcomes has a cost, that quinoa varieties are not the only crop that may require conservation funding, that there may be other good causes to support and that their household budgets need to cover other expenses too. This so-called cheap talk script helps minimise hypothetical bias that could lead respondents to overstate their willingness-to-pay (Ladenburg and Olsen, 2014). Having provided instructions on how to read the choice sets and make selections, eight choice sets were then individually presented.

2.5. Information framing

Framing is an effective way to increase awareness and potential WTP, as well as also increasing the scope sensitivity of welfare measures (Czajkowski and Hanley, 2009). This is because the value of environmental good or service not only depends on their physical characteristics, but also on the context within which they are located. In CE this refers to how the goods and services are described to respondents, in addition to their attributes. By providing different information to different sample treatment groups, respondents can be primed by the introduction of a stimuli before making their choices. This can trigger an emotional response, establish context, or change a subjects’ frame of reference (Weingarten et al., 2006).

Numerous case studies have shown framing to increase WTP in specific contexts for both direct and non-direct use products. Banerji et al. (2016), for example, found that nutritional information significantly increased WTP for vitamin-fortified millet in India. Bergstrom et al. (1990) found that framing increased WTP for American wetlands when respondents were reminded how different program attributes related to desirable consumption services. By contrast, Fox et al. (2002) found that Chinese consumers were willing to pay less for pork products when information about harmless irradiation was presented. These findings suggest that the effects of information framing can move WTP in both directions, depending on the person’s perception of the information included.

We used two different framing scenarios, one about the national identity (NI) significance of quinoa and one about food security (FS). The NI framing text contained a series of historical facts which detail quinoa’s native history to Peru and attempts by Spanish colonizers to eradicate the crop upon their arrival in the 16th century (Figure S2 in Supplementary Information). We hypothesised that this stimulus involving cultural nationalism will increase the appreciation of native crops, and hence respondents' WTP. The FS framing utilised a series of questions regarding personal food security, under the hypothesis that heightened sensitivity to potential food shocks may increase the valuation of biodiversity and hence WTP for its conservation, given its role as an informal insurance mechanism.

The sample was split into three treatments with two groups of respondents being randomly presented with additional information either about the NI or the FS. A control group did not receive either of these additional information texts. All three treatment groups received basic information regarding what agrobiodiversity is, why it is important and current status/threats.

2.6 Data analysis

Choice experiments are based on random utility theory (Luce, 1959; McFadden, 1974) and the characteristics theory of value (Lancaster, 1966). One commonly applied method is the random parameter logit (RPL) model which was also used here to analyse the choice data. RPL models are able to account for panel-data, such as those obtained in this study with each respondent answering eight choice sets, allowing unobserved preference heterogeneity across individuals to be considered (see e.g. Hensher and Greene [2003] for detailed model specifications). For attributes with three levels (see Table 1) the reference levels were the ones of the SQ alternative. Dummy variables for the other two levels were created and included in the models, so to model the preference for the change from the SQ.

Interaction terms were included between the SQ alternative and parameters that were assumed to have a significant impact on whether respondents preferred to donate to one of the two conservation program alternatives or the SQ. Such interaction terms related to location (Cusco, Lima, Puno), respondents' age, gender, income and level of education, as well as the framing group they were in.

Results are presented for one baseline RPL model without interactions and one model in which we included the interaction terms between the SQ alternative and location. Both models were estimated using 2000 Halton draws.

Welfare estimates from the RPL model results were calculated using simulations. The simulated distributions were obtained by dividing draws from the distributions of the attribute coefficients by draws from the distributions of the coefficient of the monetary attribute. 10000 Halton draws were used in these calculations.

Stated preference methods such as choice experiments are often criticised for their insufficient sensitivity to scope regarding variations in the proposed scales of the environmental good or services to be improved (Czajkowski and Hanley, 2009). Here we followed the approach by Tavárez and Elbakidze (2019) and tested for scope effects to validate our results. We estimated a logistic regression model with the dependent variable indicating whether or not an alternative was chosen by a respondent (binary 0/1), the cost (one-off donation) and dichotomous variables indicating the number of improvements made through the conservation program relative to the status quo as the explanatory variables. With this we tested whether or not respondents were willing to pay more for more improvement as would have been expected under neoclassical economic behaviour.

3. Results

3.1 Sample description

The gender-ratio of the respondents was roughly equal (48% female) and approximated that of the country as a whole (Table 2). The average age was 39 (ranging between 18 and 77). More than 75% of respondents had post-secondary education, implying that they were better educated than the national average. About 39% of the sample earned less than the minimum monthly wage (US$ 258) while 65% had incomes within the average income range for Puno, Cusco and Lima (US$183-$374/month). As per design, a third of respondents (164) received additional information about NI, a third (165) about FS, and a third (162) was treated as a control group and did not receive any of the additional information.

Table 2
Sample description (N = 491)

Characteristic	Sample Statistics	National Statistics (Peru, 2017 Census)*
Female (%)	48%	51%
Average age (SD)	39.4 (13.8)	32
Location (%) Puno Cusco Lima	41 18 41	N/A N/A N/A
Education (N = 488)		> 15 years old
Primary education	2%	18%
Secondary education	22%	45%
Technical post-secondary	31%	14%
University	44%	20%
Income (US$), N = 462		
0-121	16%	Puno: US$ 182 Cusco: US$ 233 (Metropolitan) Lima: US$ 374#
122–258	23%	
259–606	42%	
607–1515	15%	
1516–3030	2%	
> 3030	0%	
*Censos Nacionales 2017: XII de Población, VII de Vivienda y III de Comunidades Indígenas https://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1539/libro.pdf		
#INEI, 2017		

[Table 2 here]

3.2 Choice experiment results

Almost 90% of the choices made resulted in a conservation program alternative being selected over the SQ. Results of the baseline RPL model (Table 3) showed that respondents preferred all levels of the attributes associated with the conservation of quinoa attribute to that of the SQ, i.e. they disliked the implications for quinoa diversity conservation under the current situation (SQ). Respondents preferred the highest attribute level (90% of varieties) related to the existence of quinoa varieties in 50 years relative to rates of only 50%, which in turn was preferred to rates of only 10%. They also preferred the maintenance of cultural traditions over the loss of such traditions. By contrast, respondents preferred only the medium attribute level associated with 'Risk of production loss' and 'Conservation of the Andean Landscape' over the highest level and the SQ level. The similar mean WTP and confidence intervals indicated that the difference between the medium and high levels of these two attributes were not statistically significant.

Table 3
Results of RPL model without (Model 1) and with (Model 2) interaction terms

	Model 1			**Model 2**		
	Coefficient	SE	SD	Coefficient	SE	SD
Risk of production loss: Low	0.96***	0.11	1.24***	1.11***	0.11	1.13***
Risk of production loss: Medium	1.01***	0.12	1.54***	1.17***	0.12	1.40***
Percentage of Quinoa varieties still existing in 50 years: 90%	1.01***	0.12	1.66***	1.19***	0.11	1.62***
Percentage of Quinoa varieties still existing in 50 years: 50%	0.68***	0.11	1.25***	0.88***	0.10	1.14***
Maintenance of Traditional Knowledge and Cultural Practices	0.70***	0.10	1.44***	0.83***	0.09	1.34***
Conservation of the Andean Landscape: Increasing	0.86***	0.12	1.332***	0.97***	0.12	1.31***
Conservation of the Andean Landscape: Stable	0.94***	0.11	1.02***	1.03***	0.10	1.02***
One-off donation	-0.04***	0.003	0.04***	-0.03***	0.002	0.03***
SQ	-0.55***	0.12				
Interactions						
SQ * National Identity				-0.50***	0.18	
SQ * Food Security				-0.69***	0.18	
Puno				0.89***	0.16	
Cusco				-0.93***	0.25	
Loglikelihood	-3107.9			-3069.3		
Pseudo R^2	0.28			0.29		
Significance at 1% (***), 5% (**) and 10% (*) levels						

Location had a significant impact on whether or not respondents chose the SQ alternative. Respondents from Puno were more likely to choose the SQ alternative (and hence be least likely to be WTP for conservation programmes) than those from Lima and Cusco (in that order) (Model 2 in Table 3). There was no significant difference found between the WTP of urban and rural respondents, as well as the other demographic parameters tested (income, age, gender and education).

Framing, however, had a significant impact on respondents' choices. Those who were informed about the importance of quinoa for Peru's national/cultural identity or for food security were more likely to donate than those who were not provided with additional information about the reasons to conserve quinoa.

[Table 3 here]

Respondents had the highest WTP for securing bequest/existence and option values (Table 4). They were WTP USD8.76 for the certainty of 90% of quinoa varieties continuing to exist in 50 years and USD8.73 for a medium level of risk associated with agricultural production loss, while relatively strong preferences were also expressed for low levels of risk (USD8.37). Similarly, landscape conservation values were also important and "medium" level values preferred; with respondents willing to donate USD8.15 for ensuring a stable conservation status compared to USD7.52 for improving that status conservation. WTP for maintaining traditional knowledge and cultural practices (including food culture) was USD6.15.

Table 4
WTP estimates from baseline RPL model (no interactions), for both priming groups (FS: food security and NI: national identity) and control group (no priming)

Attribute	**WTP Pooled (95% confidence interval)**	**WTP NI group (95% confidence interval)**	**WTP FS group (95% confidence interval)**	**WTP control group (95% confidence interval)**
1a. Risk of production loss: Low	27.6 (3.6–50.6)	32.7 (2.3–62.0)	27.6 (6.9–47.5)	22.7 (0.6–43.8)
1b. Risk of production loss: Medium	28.8 (-1.0–57.4)	35.6 (-5.0–74.6)	27.4 (8.1–45.9)	29.0 (0.6–56.2)
2a. Percentage of Quinoa varieties still existing in 50 years: 90%	28.9 (-3.2–59.7)	27.0 (-9.7–62.4)	33.9 (4.1–62.7)	24.4 (-6.5–54.0)
2b. Percentage of Quinoa varieties still existing in 50 years: 50%	19.7 (-4.5–42.9)	19.3 (-2.2–40.0)	27.7 (5.2–49.4)	14.6 (-9.3–37.7)
3a. Conservation of the Andean Landscape: Increasing	24.8 (-0.9–49.5)	27.3 (3.8–49.8)	24.9 (1.2–47.7)	19.6 (-6.9–45.1)
3b. Conservation of the Andean Landscape: Stable	26.9 (7.2–45.9)	31.5 (3.9–58.1)	25.7 (14.1–36.7)	20.8 (2.1–38.8)
4. Maintenance of Traditional Knowledge and Cultural Practices	20.3 (-7.5–47.1)	17.8 (-16.9–51.2)	22.0 (-2.5–45.5)	15.5 (-7.1–37.7)
Total (Soles) of highest WTP for each type of attribute (= 1b + 2a + 3b + 4)	**104.9**	**111.90**	**109.2[#]**	**89.7**
Total (USD equivalent) of highest WTP (USD)*	**31.79**	**33.93**	**33.09**	**27.18**
Percentage change relative to control		**24.7%**	**21.7%**	
Percentage change relative to pooled sample		**6.7%**	**4.1%**	
*Exchange rate during the months of the survey was approximately USD 1 = New Peruvian Soles 3.3				
[#]Total includes 1a rather than 1b, as food security group WTP now higher for the former than the latter				

[Table 4 here]

3.3 The total economic value of quinoa

The TEV of quinoa diversity conservation can subsequently be calculated by the summing the highest WTP values of the attributes which were obtained from the pooled sample RPL model without interaction terms. The TEV placed by the general public on the public good ecosystem services associated with a quinoa conservation programme was USD31.79 if medium levels of landscape conservation (USD8.15) and risk of production loss (USD8.73) were to be achieved, and 90% of varieties secured for the next 50 years (USD8.76), while maintaining cultural practices (USD6.15).

Given that there are approximately 3,380,960 households in the three studied regions in Peru (11.86m population – with an average household size of 3.51 persons (INEI, 2017)), this amounts to a total willingness to pay for quinoa conservation of USD107.5m (USD31.79 x 3.38m households).

4. Discussion

4.1 Quinoa's total economic value and conservation costs

The majority of respondents revealed strong support for conservation with their disliking the current state of quinoa diversity conservation under the status quo. With regard to the different components of TEV, respondents had the highest willingness to pay for securing bequest/existence and option values, followed closely by stable landscape conservation. This shows that non-market, indirect values are indeed valued and, in this case, considered to contribute more to human well-being than market values.

With regard to policy implications, since our WTP estimates were derived from a stated preference method, it should be noted that there nonetheless remains uncertainty whether all those respondents who said they would donate, would actually do so in a non-hypothetical setting, as how many people would really pay has been shown to be context-specific (Kim et al., 2012). Meta-analyses have found that people would pay about 75%, of what they promised (Murphy et al., 2005); while Morrison (2000) and List and Gallett (2002) found that no more than 30% of those who stated that they would donate something, would actually do so if given the opportunity. Zander et al. (2014) also used a similar weighting, which if we were to apply here in order to generate a conservative TEV estimate would result in a TEV of USD9.54 per person. When multiplied by 3.38m households (total = USD32.2m), this represents just over a third of the gross market value of Peru's annual quinoa production (USD93.4m in 2016, according to FAOSTAT).

The existence of such significant non-market values also helps justify the implementation of an actual conservation programme, as relative to the costs (USD19.75m for 2,700 varieties over 50 years, as estimated by Drucker and Ramirez, 2020), this results in a positive benefit-cost ratio of 1.7 (USD33.8m/19.75m).

4.2 Distance decay

Previous empirical evidence has shown that the location distance of environmental goods and services has a significant effect on the utility that individuals obtain and therefore the values they assign to them (e.g., Bateman et al. 2006; Olsen et al., 2020). This phenomenon of distance decay depends on the type of ecosystem service that primarily motivates respondents (Olsen et al., 2020). For example, for recreational and other direct use values, people living close to the associated ecosystem services have been found to obtain greater benefits and also assign higher overall protection values relative to those living further away (e.g., Bateman et al. 2006; Rolfe and Windle, 2012; Khan et al., 2019). For other values, such as cultural values, the effect of location and distance, has been less clear (Olsen et al., 2020).

We found that those living in the hotspot for quinoa diversity (Puno) were more likely to choose the SQ alternative (and hence be least likely to be willing to pay for conservation programmes) than those further away from the major consumer markets of Lima and Cusco. This result is consistent with Zander et al. (2013) who concluded that respondents who lived close to the genetic resources in question were in fact willing to contribute less to their conservation than respondents from distant cities.

In the particular context of Peru, this could reflect the fact that residents in Lima and Cusco have higher average disposable incomes. But it could also be because those living where quinoa diversity is still locally abundant might not perceive the urgent need for conservation, thus weakening possible motivation for action (Fernández-Llamazares, 2016); or that such efforts would not provide them with sufficient additional non-market benefits to those already accruing to them. This suggests that when donations from the general public are being solicited for quinoa conservation, people outside the diversity hotspot region of Puno might be a priority group to target.

None of the other demographic parameters distinguished the respondents between those willing to donate and those who were not, despite the fact that studies in other contexts have shown that women are often more likely to pay for conservation, as are younger people and those with higher incomes and levels of education (amongst others, Blare et al., 2019).

4.4 Framing effects

The only other significant parameter was the framing group. Those people who did not receive additional information about why quinoa conservation is so important, were willing to pay the least. This finding is in line with previous studies, showing the importance of information and knowledge in general decision-making (Shreedhar and Mourato, 2019; Banerji et al., 2016). Given the impact of framing on WTP, public awareness campaign messages regarding quinoa diversity-related food security, national/cultural identity and other benefits should be carefully articulated whenever soliciting private donations or justifying conservation-related tax surcharges by government.

While those people who received information about the national/cultural identity and food security aspects of quinoa conservation were willing to pay more for all levels of the attributes 'Conservation of Andean Landscape' and 'Risk of Production Loss', they also preferred the medium levels of landscape conservation provisions and risk of production loss (Table S1 in Supplementary Information). A stable condition of the Andean Landscape could be preferred because the landscape is already regarded as how it should be, and respondents do not see the need to pay for further improvement. The preference for a medium level of production loss risk could indicate that the general public consider quinoa to be a widely available commodity crop in Peru and are thus unconcerned about a potential decline in production and an undersupply of it, as long as that risk is not high.

4.5 Study limitation

It is worth noting that the convenience sampling approach used, while resulting in significant overlap with national socio-demographics did have an over-representation of post-secondary educated respondents along with an under-representation of those earning less than a minimum wage. This may have resulted in an upward bias of the stated benefits (including, albeit common in stated preference studies, as a result of aggregating based on all households in the study regions), leading to the results needing to be interpreted with caution. By contrast, our conservative WTP calculations do not account for potential service purchasers from other parts of Peru and elsewhere, nor do they account for the value of the private ecosystem service benefits that would be generated and accrue to farmers under a conservation programme. The overall impact on total benefits is therefore ambiguous.

5. Conclusions

Hotspot countries such as Peru are ideally placed to implement agrobiodiversity conservation strategies while both a rich range of genetic resources and accompanying traditional knowledge still exist (unlike in many developed countries with funded conservation programmes). In the case of quinoa diversity, the general public revealed support for conservation, having the highest willingness -to-pay for securing bequest/existence and option values, followed closely by stable landscape conservation. Framing had an important influence on willingness-to-pay (suggesting the importance of public-awareness campaign articulation), as did distance from the quinoa diversity hotspot of Puno (suggesting the importance of targeting people in other regions too). Aggregated total economic value across the study region was found to be equivalent to one-third of the market value of annual Peruvian quinoa production. The existence of such significant non-market ecosystem service values also results in a positive benefit-cost ratio for conservation intervention, which can consequently be used as an argument to justify the allocation of government funds and private donations.

Declarations

Ethical Approval and Consent to participate

Survey participants agreed to participate in the interviews.

Consent for Publication

The results obtained are published with the consent of the survey participants.

Availability of supporting data

Anonymised survey data are available from the authors upon request.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the results reported in this paper.

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Author contributions

Conceptualization: Adam Drucker, Willy Pradel, Craig Scott, Sarah Elmes, Kleny Arpazi Valero; Methodology: Adam Drucker, Craig Scott, Kerstin Zander; Formal analysis: Craig Scott, Kerstin Zander; Writing - original draft preparation: Adam Drucker, Willy Pradel, Kerstin Zander; Funding acquisition: Adam Drucker

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Tables

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