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Original Article

Economic valuation of the ecosystem of the high Andean hydrographic basin tributary of the Chumbao River, through multicriteria analysis

Valoração econômica do ecossistema da bacia hidrográfica do alto andino (afluente do rio Chumbao) a partir de análise multicritério

A. I. Barrial-Lujan[a]*, G. Rodríguez[b], M. L. Huamán-Carrión[c], F. Espinoza-Montes[d], D. Barrial-Acosta[e], M. C. Delgado Laime[c], J. C. Arevalo-Quijano[f], W. G. Castro-Paniagua[f], C. Barrial-Lujan[g] and D. D. Reynoso-Canicani[f]

[a]Universidad Andina del Cusco, Escuela de Posgrado, Cusco, Perú
[b]Universidad Nacional del Santa, Facultad de Ingeniería Agroindustrial, Chimbote, Perú
[c]Universidad Nacional José María Arguedas, Facultad de Ingeniería, Andahuaylas, Perú
[d]Universidad Nacional del Centro del Perú, Facultad de Zootecnia, Huancayo, Perú
[e]Universidad Nacional Micaela Bastidas de Apurimac, Facultad de Ciencias Empresariales, Abancay, Perú
[f]Universidad Nacional José María Arguedas, Facultad de Ciencias Empresariales, Departamento de Educación y Humanidades, Andahuaylas, Perú
[g]Universidad Tecnología de los Andes, Facultad de Ingeniería, Andahuaylas, Perú

Abstract

Environmental wealth is the main basis of the social, cultural and economic development of a country, but if there is an absence of the valuation of these natural resources, it can lead to a disproportionate usufruct that causes the deterioration of the ecosystem and even collateral effects of human health. This research aimed to know the total economic value of the ecosystem of the high Andean water basin tributary of the Chumbao River, located between 2000 to 4800 meters above sea level belonging to the province of Andahuaylas, Apurimac region in Perú. The valuation procedure consisted of using the analytical method of multicriteria valuation applying the concept of Total Economic Value, which involved direct and indirect uses related to environmental assets, in which a collective panel of people from different training disciplines (experts) participated, which were made up of researchers, engineers, public officials, farmers and ecologists who had extensive knowledge about the environmental asset. of the geographical area in reference; and once the paired comparison survey was done, the total economic value was quantified up to three amounts, so the respondents were formed into three statistically significant segments (SIG<0.05). The cluster (1): assigned a weighting that quantifies to an economic value of USS 4,359,179,489.46; followed by cluster (2): an intermediate value of USS 4,029,902,444.41 and cluster (3): assigned a lower value to USS 774,163,167.16. Thus, it follows that, on average, 51.78% equals value in use and 48.21% equals value in non-use, respectively. This value expressed as an interval reflects the environmental ethical positions of the groups and makes available as an indicator to government authorities and society in order to exercise actions of environmental sustainability high andean.

Keywords: environmental assets, discount rate, hierarchical analysis, paired comparison, ecosystem valuation.

Resumo

A riqueza ambiental é a principal base do desenvolvimento social, cultural e econômico de um país, todavia, se não houver a valorização desses recursos naturais, pode levar a um usufruto desproporcional que causa a deterioração do ecossistema e até mesmo efeitos colaterais da saúde humana. Esta pesquisa teve como objetivo conhecer o valor econômico total do ecossistema da alta bacia hidrográfica andina afluente do rio Chumbao, localizado entre 2.000 e 4.800 metros acima do nível do mar pertencente à província de Andahuaylas, região de Apurimac no Peru. O procedimento de avaliação consistiu na utilização do método analítico de avaliação multicritério aplicando o conceito de Valor Econômico Total, que envolveu usos diretos e indiretos relacionados a ativos ambientais, no qual participou um painel coletivo de pessoas de diferentes disciplinas de formação (especialistas), composta por pesquisadores, engenheiros, funcionários públicos, agricultores e ecologistas que possuíam amplo conhecimento sobre o bem ambiental. da área geográfica em referência; e uma vez feito o levantamento de comparação pareada, o valor econômico total foi quantificado em até três valores, de forma que os respondentes foram divididos em três segmentos estatisticamente significativos (SIG < 0,05). O cluster (1): atribuído um peso que quantifica a um valor econômico de US$ 4.359.179.489,46; seguido pelo cluster (2): um valor intermediário de US$ 4.029.902.444,41 e cluster (3): atribuiu um valor inferior a US$ 774.163.167,16. Assim, conclui-se que, em média, 51,78% equivalem a valor em uso e 48,21% equivalem a valor em não uso, respectivamente. Este valor expresso como um intervalo reflete as posições éticas ambientais dos grupos e disponibiliza como um indicador para as autoridades governamentais e a sociedade a fim de exercer ações de sustentabilidade ambiental alto andino.

Palavras-chave: ativos ambientais, taxa de desconto, análise hierárquica, comparação pareada, valoração de ecossistemas.

*e-mail: abarrial@unajma.edu.pe
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1. Introduction

The great variety of landscapes, natural regions, biomes, life zones, ecoregions and diverse ecological floors define Peru as one of the megadiverse countries of the world (Perú, 2019a). In the basins of the Pacific slope of Peru, where 65% of the national population lives, the high andean ecosystems are covered by grasslands and occupy a fifth of the surface, but receive more than a third of the total rainfall (Mosquera et al., 2022). In this geographical area, grasslands of various ecotypes collect, store and supply water, which are the sustenance of domestic, agricultural, irrigation, hydroelectric generation and recreational needs in the region (Badamfirooz et al., 2021). Likewise, in the high andean basins there are wetlands that generate plant fibers, food and genetic resources, store and regulate flows, capture carbon and represent an invaluable cultural heritage for its spiritual and religious significance (Arévalo Quijano et al., 2021; Crispin, 2015; Huamán-Carrión et al., 2021). That is why the water produced by these ecosystems in headwaters of andean basins are essential for the socioeconomic development of the country (Barrial-Lujan et al., 2021). In this sense, the high Andean ecosystems are important spaces of life and cultural wealth, fertile in symbolism, mythologies and spiritual values for numerous indigenous and peasant communities. Such historical and traditional values, many of them directly linked to wetlands, are part of the andean cultural heritage and must be taken into account in the management of the natural space. However, over the years human activities have produced changes in the use and land cover of natural grasslands that impact the provision of water ecosystem services, but not much is known about the type or degree of impacts. The limited knowledge of the ecohydrology (relationships and interactions between hydrological and ecological processes) of andean grasslands, especially under conditions of degradation, fragmentation and conversion, hinders the efforts of several institutions interested in the sustainable management of these ecosystems, such as water companies that need to provide a reliable water supply to users (Mosquera et al., 2022). Currently, biodiversity loss is occurring at rates never before seen in human history. Nearly one million species face extinction; if we do not fundamentally change our relationship with the natural world, this will cause the disappearance of opportunities for well-being and development of the population (Perú, 2019a). Therefore, it is essential to make a quantitative measure expressed at the economic level about the importance of the ecosystem functions of the environmental asset both tangible and intangible. The importance of estimating the value of the environment is due to the fact that: Today's society is a market society, so the greatest reference it has to gauge the importance of an asset is its monetary value. In this way, when determining the value of the environmental asset in quantitative terms, a greater awareness of the usufruct of the natural resource is transmitted and promoted, which guarantees its sustainability (Aznar and Estruch, 2015). A tool that allows us to quantify the benefits that an environmental ecosystem brings to society is economic valuation (Perú, 2016). And, therefore, in environmental or ecological economics valuation methods were developed with different approaches, including: (i) the avoided or induced cost method; (ii) the method of travel costs; (iii) the hedonic price method (iv) contingent valuation method and others that do not merit extending it so they are less usual and inconsistent. The first three are considered the revealed preference method (indirect approach) and the last corresponds to the declared preference method (direct approach); the different values attributed to environmental goods and services and their estimation techniques may be exclusive, alternative or competitive; because valuing them a natural resource is a complicated process, little understood by most of society because it presents difficulty in its moderation, because not all environmental benefits and costs have a market price, given that the environment is not a private good, but a public good (Barrial-Lujan et al., 2022; Romero et al., 2020). For the present research, the analytical multicriteria valuation method (AMUVAM) has been chosen because it presents elementary advantages over the methods described above, so it includes the concept of total economic value, which involves direct and indirect uses related to environmental assets in question (Romero et al., 2020). As well as reports Gomez (Gómez-Aguayo and Estruch-Guitart, 2019), The advantages of the multicriteria method stand out: i) ability to deal with qualitative and quantitative criteria (Leung and Cao, 2001; Swiercz and Ezzedeen, 2001); ii) accessibility in the implementation phases (Braglia et al., 2004); ii) Adaptability to any type of economic and territorial environment (Gómez-Aguayo and Estruch-Guitart, 2019); iv) consistency in results, because the data is provided by experts; v) possibility of covering one or more ecosystem services in the same study; and, vi) solve common problems in valuation such as the incommensurability of the environmental attributes of assets (Swiercz and Ezzedeen, 2001).

This research presents the estimation of the total economic value of the environmental asset of the high andean water basin slope of the chumbao river, Andahuaylas, Peru. This approach provides reliable information that can facilitate the inclusion of the concept of ecosystem services in current conservation policies, as well as explore policy alternatives focused on the sustainable use of natural resources.

2. Materials and Methods

2.1. Description of the study area

The geographical location of this study is located between the coordinates 73°41' and 73°14' west longitude and between 13°67' and 13°47' south latitude. The altitude varies from 2000 to 4800 meters above sea level. The area is 133.67 square kilometers. Politically it is located in the Southern Highlands of Peru which belongs to the province of Andahuaylas, Apurimac region (referred to in the figure 1). In this area there are four lagoons called Pampahuasi, Antacocha, Pacococha and Huachacocha (ANA, 2005). In 2015 the Ministerio del Ambiente (MINAM) recognizes as a puna ecoregion, belonging to the andean region, which is characterized by having a humid bioclimate, with vegetation cover of grassland formation with extensive pastures, the physiography is characteristic of high mountain, its ecological floor is classified in altimontano for its physiognomy of vegetation, geographical distribution of plant and animal species, biodiversity, soils and climate; its ecosystem is classified as pajonal de puna humid, with vegetation cover of andean pajonal; it presents wetlands, located in pluvial terraces, depressions flat and slightly inclined surfaces, whose main food is rainfall, which is part of a hydromorphic ecosystem distributed in this high Andean region (Perú, 2015, 2019a). The climatic conditions are recorded an average relative humidity of 90.86% ranging from 26.2% to 100%; the minimum temperature of -0.09 °C and maximum of 14.94 °C; solar radiation varies between 2 W/m^2 to 1279 W/m^2 with an average of 374.58 W/m^2; rainfall averaged 0.05 litres per m^2; The wind speed recorded a maximum of 14.6 m/s, whose direction has a rotation of 108 to 228 degrees (Huamán-Carrión et al., 2021). The most representative species of flora in this area are: Azorella compacta, Campanula sp, Hypochaeris taraxacoides, Hypochaeris sessiliflora, Werneria caespitosa, Werneria nubilis, Senecio incana, Perezia pigmaea, Gnaphalium grandilorum, Baccharis tola var. Incarum, Parastrephya lucida, Parastrephya lepidopholia, Nototriche longirostris, Berberis sp, Opuntia flocosa, Scirpus rigidus, Gentiana sedifolia, Festuca dolycophylla, Calamagrostis vicunarum, Calamagrostis rigescens, Stipa ichu, Poa sp, Aciachne pulvinata, Bromus unioloides. And the representative fauna of the area are the species: mustela frenata, Vicugna vicugna, Glama glama, Phoenicoparrus andinus, Anas puna, Chloephaga melanoptera, Larus serranus, Lycalopex culpaeus andinus, Fulica gigantea, Lagidium peruanum, Vicugna pacos, Columba livia, Zenaida auriculata, Zonotrichia capensis, Spinus spinensis (Barrial-Lujan et al., 2021).

2.2. Method of economic valuation of environmental assets

In this research he has focused on four major phases, which in turn were formed by different stages. In the first of them, experts were chosen who had extensive knowledge of the high andean zone of the micro-basin of the chumbao river, given their employment relationship (scientific activity or professional exercise) or cultural was linked to the environmental asset in reference. In the second, a multicriteria method was used to obtain the weights in importance of the different alternatives (environmental assets) using the technique of the hierarchical analytical process. In the third, the goods and services included in the market were calculated by income update method to be used as a "pivot" value and calculate the value of the rest of the components of the environmental TEV and, finally, the values of each of the components of the total economic value were obtained through the partial weights calculated in the second and third phases respectively. The following points explain the methodology of each of the phases in detail.

2.2.1. 1st phase: election of experts for the economic valuation of the environmental asset

Taking into account the nature of the method used in this study, inclusion and exclusion criteria were used in order to specify the peril of the collective group, as seen in Table 1. Consequently, 75 experts were appointed whose work and/or professional activities had links with the natural resources of the area under study.

2.2.2. 2nd phase: calculation of weights

The Analytic Multcriteria Valuation Method, hereinafter AMUVAM, is one of the existing methods within the valuation by comparison for natural spaces or environmental services. This method has traditionally been composed of both the Analytical Hierarchical Process, hereinafter AHP and the updating income method for the use of a "pivot" value formed by the values that are part of the market, that is, those that can be valued directly in monetary terms (Aznar and Estruch, 2015).

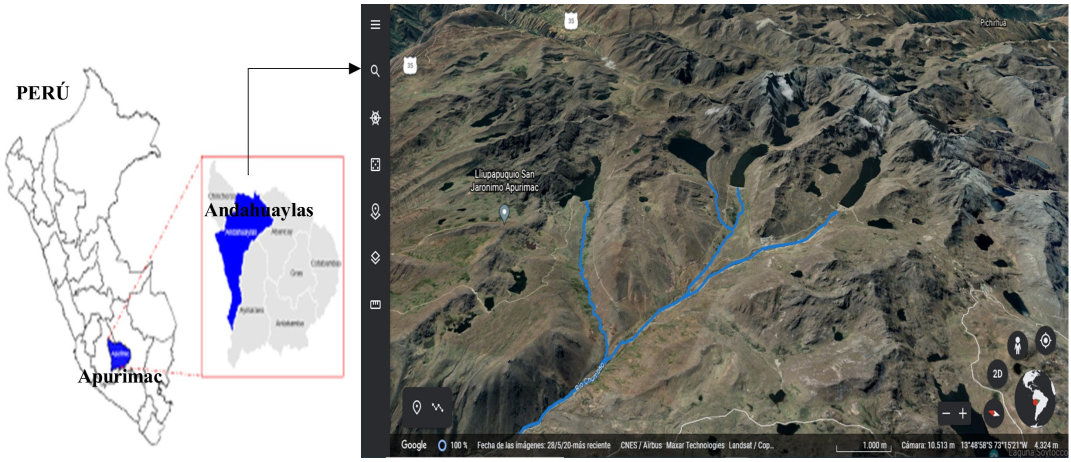

Figure 1. Location of the study area high andean microbasin of the chumbao river, Andahuaylas, Peru (Google Earth, 2023).

2.2.3. Analytic Hierarchy Process (AHP)

The Analytical Hierarchical Process (AHP) described by (Saaty, 2008), it consists of a scientific approach that allows to assist in the decision-making process. AHP provides the objective mathematics to process the personal preferences and inescapable subjectivity of an individual or a group in the decision-making process. And it consists of developing criteria with their respective priorities that will be used to judge alternatives. Usually, the criteria depend on the understanding of the decision-maker(s), which can be measured on different scales, such as weight and length; or are even intangible for which there is no scale (Villarreal-Gutierrez, 2017). The fundamental scale of pairwise comparison described in Table 2 is used for measurement.

To avoid errors in paired comparison matrices, the inconsistency ratio greater than the maximum the calculations are carried out as follows: value required by the method itself must be reviewed. These maximum error levels are stipulated at 10% for matrices of rank n > 5; 9% for range n = 4; 5% for range n = 3 and 0% for range n = 2 (Aznar and Estruch, 2015; Saaty, 1980). The calculations are made following the Equations 1, 2 and 3.

The consistency index (CI)

$$CI = \frac{CA - n}{n - 1} \quad (1)$$

Where: CA: consistency average; n: number of criteria.

The CA value is obtained by normalizing the generated matrix with each expert opinion value and the eigenvector was calculated as an arithmetic average for each row,

Table 1. Collective group to be surveyed.

Number of respondents	Participating institutions
5	Sub-regional Agrarian Directorate of Andahuaylas
3	Sub Regional Production Directorate of Andahuaylas
3	Chamber of Commerce, Industry and Tourism of Andahuaylas
3	Foreign Trade and Tourism Directorate of Andahuaylas
4	Workers of the District Municipality of San Jerónimo (directorate of local district economic development)
8	Workers of the municipality of Andahuaylas (district local economic development office and environment office)
4	Workers of the District Municipality of Talavera (district office for local economic development)
4	Workers of the Local Water Authority – Andahuaylas zonal office
5	Higher Technical Productive Institute Apurímac
3	Biologist, researcher and teacher at the José María Arguedas National University
3	Microbiologist, researcher and teacher at the José María Arguedas National University with academic headquarters in Andahuaylas
3	Agroindustrial Engineer, researcher and teacher at the José María Arguedas National University with academic headquarters in Andahuaylas
2	Engineer in Food Industries and professor at the José María Arguedas National University with academic headquarters in Andahuaylas
5	Agronomist, researcher and teacher at the Technological University of the Andes with academic headquarters in Andahuaylas
5	Environmental Engineer and Natural Resources from the Technological University of the Andes with academic headquarters in Andahuaylas
5	Farmers from the community of Lliupapuquio
5	Farmers from the community town center of Chumbao
5	Farmers from the community of Chihuampata

Table 2. Paired comparison scale.

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong demonstrated importance
9	Extreme importance
2,4,6,8	Comparison between the above values

Then the final values of the eigenvector per row were added to obtain the CA, also called $\lambda_{(max)}$ The number of criteria in this case was five comparative elements.

The Random Consistency Index (RCI) is given by:

$$\boldsymbol{RCI} = \frac{1.98(\boldsymbol{n}-2)}{(\boldsymbol{n})} \tag{2}$$

Entonces, la relación de consistencia (CR) está dada por:

$$\boldsymbol{CR} = \frac{\boldsymbol{CI}}{\boldsymbol{RCI}} \tag{3}$$

The measures described above allow us to establish to what extent the decision in the peer comparison is consistent and not influenced by contradictions or biases (Romero et al., 2020).

2.2.4. 3rd phase: calculation of the "pivot" value through the income update method

It is known as the PIVOT value to a market-connected security. In other words, the pivot value is based on the present and future income derived from the usufruct of resource resources, so the VUD is the component of the TEV that can be expressed directly in money because it is directly detected by the market (that is, it contains those activities of the environmental asset that are controlled by the market). For the purposes of mathematical calculation, the method was described by Ramsey in 1989. Whose application was used in environmental assessment by Aznar y Estruch (Aznar and Estruch, 2015), in which they used the discount rate in the valuation of income-producing assets. And, therefore, the income generated to society by economic activities is calculated with Equation 4 expressed below:

$$\mathrm{V} = \sum_{i=1}^{n} \frac{Ri}{(1+\mathrm{r})^{\wedge} i} \tag{4}$$

Where: "V, is the Value of the environmental asset by its direct use value functions; Ri, is the future income generated by the good in year i for its owner; r, is the update rate that expresses the preference for money in the owner's time (Social Rate of Temporal Preference); and n, is the period during which the good will generate profits.

2.2.5. 4th phase: valuing ecosystem services

Once the monetary value of environmental goods and services has been obtained through market data (Direct Use Value) and the weights previously obtained through experts, the valuation of the remaining components of the TEV can be carried out using simple three rules. Therefore, the total economic value of the high andean zone of the microbasin of the chumbao river is the artimetic sum of each component of the TEV or previously calculated study variables.

2.2.6. The study variables

By virtue of the above, the AHP methodology as a multi-criteria tool allows experts to give weight to the evaluation criteria or alternatives through a systematic comparison between peers of each of the options under evaluation (Romero et al., 2020). Therefore, the variables to be compared by the experts in this study were based on the methodology used by Aznar Bellver and Guijarro Martínez (2012) which consists of the interrelation of the components of the environmental asset in question with a TEV approach. In which the tangible and intangible resources is given by the UV. Even if individuals do not use a resource, it can be valuable to them, thus introducing the concept of NUV. For each case they are described in Table 3.

Once the profits of anthropogenic activities (agricultural, livestock and fishing) have been defined, the environmental rate (r) is updated, which will take the social discount rate r = 3.77%, calculated for Peru in the medium term (Kamiche and Diderot, 2018; Perú, 2019b), according to the equation described by Ramsey in 1928 (individual or pure time preference rate (0.88%); representing the elasticity of the marginal utility curve of consumption.

$$DUV \text{ Value} = \frac{\text{Cash flowofthe services provided by DUV}}{\text{Discount rate}} \tag{5}$$

2.2.7. Calculation of the total economic value (TEV) and its related components

Once the pivot value of Equation 5 is known, the TEV is determined by the arithmetic sum of its partial components that are implicit in that evaluation, as indicated in Equations 6, 7, 8, 9 and 10. This way approximates the real value of environmental assets.

Table 3. Identification and description of the Total Economic Values (TEV) components.

Abbreviations	Criteria Values	Description
DUV	Direct Use Value	It represents the benefits produced by natural assets either as materials for production processes or as goods.
IUV	Indirect Use Value	Value of goods and services that are necessary to obtain direct use value and are not detected by the market.
OV	Option/quasi-option	Value of the asset with unknown functions or that is conditioned to possible future uses
EV	Existence Value	Value of the asset by allowing the conservation of the resource, such as flora or fauna or cultural values, landscapes, etc.
BV	Bequest Value	It is the value of the environmental asset to bequeath the benefits to future generations.

Note. The abbreviations described have the following meaning: DUV, direct use value; IUV, indirect use value; OV, option/quasi-option; EV, existence value; and BV, bequest value.
Source: Aznar and Estruch (2015); Romero et al. (2020).

$$IUV = \frac{DUV}{DUV\ weight} * IUV\ weight \quad (6)$$

$$OV = \frac{DUV}{DUV\ weight} * OV\ weight \quad (7)$$

$$EV = \frac{DUV}{DUV\ weight} * EV\ weight \quad (8)$$

$$BV = \frac{DUV}{DUV\ weight} * BV\ weight \quad (9)$$

$$TEV = DUV + IUV + OV + EV + BV \quad (10)$$

3. Statistical Analysis

Cluster analysis of variance (ANOVA) and multiple comparisons using Tukey's HSD test were used. clusters were identified according to the Euclidean distance; the hierarchies of the agglomeration were made by simple linkage and the Ward method, for all cases the criteria test was sig≤ 0.05.

4. Results

The valuation of environmental goods and services includes hedonic, ethical, cultural, religious connotations, among others. After having completed the paired comparison matrix of the TEV components of each of the experts and checking its consistency, the eigenvectors were calculated in Table 4.

Table 4. Eigenvectors from the paired comparison survey.

N°	DUV	IUV	OV	EV	BV	CR (%)	CL	N°	DUV	IUV	OV	EV	BV	CR (%)	CL
1	0.0567	0.1556	0.0733	0.2908	0.4237	9.36*	1	39	0.5081	0.2368	0.0629	0.0461	0.1461	7.84*	3
2	0.1574	0.2689	0.1004	0.4219	0.0514	8.11*	2	40	0.0519	0.0796	0.1599	0.2016	0.5070	8.89*	1
3	0.4578	0.2559	0.0830	0.1621	0.0413	6.30*	3	41	0.4348	0.3378	0.1251	0.0599	0.0423	8.44*	3
4	0.1613	0.0353	0.0942	0.4553	0.2539	7.32*	2	42	0.1546	0.1696	0.0607	0.1990	0.4162	1.80*	1
5	0.1922	0.6083	0.0855	0.0614	0.0527	9.87*	3	43	0.0396	0.2141	0.0740	0.4956	0.1766	8.99*	2
6	0.5273	0.2617	0.0386	0.1243	0.0480	6.62*	3	44	0.0554	0.0865	0.1850	0.1417	0.5315	9.48*	1
7	0.5364	0.0351	0.1364	0.2309	0.0613	8.67*	3	45	0.5805	0.1853	0.0469	0.1142	0.0732	9.92*	3
8	0.1053	0.0546	0.0894	0.4728	0.2779	5.95*	2	46	0.4188	0.1616	0.0701	0.1821	0.1674	11.36**	-
9	0.4358	0.2671	0.0463	0.1601	0.0907	7.10*	3	47	0.4294	0.3487	0.1211	0.0649	0.0359	8.74*	3
10	0.1600	0.4384	0.2775	0.0696	0.0544	5.76*	3	48	0.0441	0.1557	0.1924	0.4924	0.1154	15.96**	-
11	0.1002	0.4921	0.2917	0.0662	0.0499	8.62*	3	49	0.4315	0.2327	0.1502	0.0860	0.0996	11.98**	-
12	0.4233	0.3450	0.1164	0.0672	0.0482	8.42*	3	50	0.5114	0.2576	0.1225	0.0617	0.0468	4.46*	3
13	0.3253	0.2845	0.0572	0.1159	0.2171	7.35*	3	51	0.4649	0.2770	0.1259	0.0696	0.0625	7.06*	3
14	0.0543	0.0873	0.0407	0.5877	0.2300	9.72*	2	52	0.5203	0.2319	0.0786	0.1335	0.0357	5.65*	3
15	0.3778	0.0621	0.1410	0.0959	0.3231	7.79*	3	53	0.4397	0.0898	0.2583	0.1643	0.0479	9.64*	3
16	0.1279	0.0817	0.4667	0.0544	0.2693	9.58*	1	54	0.5489	0.0338	0.0983	0.2207	0.0983	6.24*	3
17	0.0354	0.0945	0.1259	0.2850	0.4593	8.85*	1	55	0.4010	0.3041	0.0460	0.1726	0.0763	8.70*	3
18	0.0448	0.0615	0.3263	0.3254	0.2419	8.17*	1	56	0.3812	0.3198	0.1548	0.0925	0.0517	7.01*	3
19	0.1470	0.0506	0.0937	0.2417	0.4670	5.84*	1	57	0.1263	0.4187	0.2649	0.0966	0.0935	8.54*	3
20	0.4295	0.2959	0.1480	0.0409	0.0857	8.50*	3	58	0.1014	0.4172	0.3872	0.0524	0.0418	6.63*	3
21	0.3889	0.3121	0.1344	0.1105	0.0540	4.28*	3	59	0.4013	0.3054	0.0602	0.1452	0.0880	23.20**	-
22	0.2166	0.4358	0.0352	0.2201	0.0923	8.50*	3	60	0.0425	0.1329	0.4375	0.2899	0.0971	5.53*	1
23	0.2469	0.4357	0.1524	0.0642	0.1008	7.93*	3	61	0.4292	0.0469	0.2212	0.0903	0.2123	9.87*	3
24	0.0840	0.1444	0.4427	0.2839	0.0450	8.16*	1	62	0.1393	0.0919	0.4324	0.0528	0.2836	9.67*	1
25	0.0398	0.0792	0.2598	0.1361	0.4852	9.30*	1	63	0.0387	0.0795	0.1241	0.2747	0.4830	8.80*	1
26	0.3534	0.1194	0.0631	0.2796	0.1846	8.22*	3	64	0.0373	0.1227	0.3987	0.1037	0.3377	9.39*	1
27	0.4518	0.1296	0.0660	0.3031	0.0495	8.51*	3	65	0.2777	0.0452	0.0770	0.1426	0.4575	6.66*	1
28	0.0566	0.1427	0.0672	0.3983	0.3353	26.49**	-	66	0.4295	0.2160	0.1994	0.0730	0.0820	7.37*	3
29	0.4304	0.1179	0.2679	0.1185	0.0653	28.10**	-	67	0.4244	0.1458	0.1005	0.2781	0.0513	7.94*	3
30	0.0502	0.1193	0.2519	0.4912	0.0873	5.87*	2	68	0.0568	0.1409	0.2360	0.5176	0.0487	8.02*	2
31	0.0419	0.2693	0.4615	0.1549	0.0724	24.27**	-	69	0.4688	0.2199	0.1558	0.0998	0.0557	6.89*	3
32	0.0463	0.0967	0.4902	0.2078	0.1590	8.95*	1	70	0.2643	0.0890	0.1311	0.4500	0.0657	9.11*	2
33	0.0550	0.1661	0.1338	0.1874	0.4576	19.90**	-	71	0.0457	0.1480	0.2446	0.0824	0.4792	9.61*	1
34	0.0268	0.0835	0.3821	0.2923	0.2152	9.05*	1	72	0.0349	0.0394	0.1046	0.4188	0.4024	8.64*	2
35	0.4318	0.0371	0.2397	0.0734	0.2180	9.61*	3	73	0.4035	0.0619	0.1194	0.3642	0.0510	9.15*	3
36	0.4478	0.2674	0.0735	0.1496	0.0617	6.91*	3	74	0.0286	0.1337	0.2519	0.5187	0.0671	9.63*	2
37	0.4438	0.2833	0.0345	0.1717	0.0667	8.47*	3	75	0.5660	0.1923	0.1312	0.0744	0.0360	9.65*	3
38	0.3162	0.4599	0.1263	0.0546	0.0430	8.45*	3								

Note. The abbreviations described have the following meaning: DUV, direct use value; IUV, indirect use value; OV, Option/quasi-option; EV, existence value and BV, bequest value. Likewise, the asterisk (*) refers to a consistent ratio, while the double asterisk (**) refers to the inconsistency of the ratio. CR is consistency ratio and CL is cluster.

In addition, Table 4 shows the wisdom of each respondent's answers contrasted by the consistency ratio (CR). Thus, 8 of the 75 matrices were inconsistent; therefore, respondents number 28, 29, 31, 33, 46, 48, 49 and 59 (marked with a **) responded inconsistently, in this way the respective assessment was with 67 consistent matrices. As for the conformations of the clusters (clusters) were associated by Euclidean distance, in which the proximity of each member by the nearest neighbor (referred to the coincidence in their appraisals) has been assessed. Thus, when performing the cluster ANOVA, each group was correctly classified as being different from each other and issued valuation judgments independently of each component of the TEV. Therefore, the first cluster group consisted of 18 individuals (26.87%); the second group consisted of 10 individuals (14.93%) and the third conglomerate group of 39 individuals (58.21%). In this way, we ensure that the information obtained from the respondents is correct and suitable for the multi-criteria model.

Table 5 shows the normalized values that form the aggregate eigenvector that represents the weights of the TEV components according to the clustered groups consulted.

4.1. Valuation of the PIVOT value and the rental update rate

The structure of production costs and the generation of profits were calculated through surveys of farmers from the different towns that make up the San Jerónimo district (Poltocsa, Champaccocha, Suylluacca, Lliupapuquio, Union Chumbao y Ccoyahuacho) and Andahuaylas district (Lirios, Pochccota, Huayhuaca, chumbao and Cuncataca) in order to know the PIVOT value.

Thus, the calculated cash flows of each of the main economic activities such as agriculture, livestock and artisanal fishing have generated a profit or income reached the sum of US$ 12 383 407.36 as Pivot value, as detailed in the Table 6. Therefore, by updating the calculated amount at a rate of 3.77% over the medium term (Kamiche and Diderot, 2018; Perú, 2019b); the Direct Use Value was known from the cash flow US$ 12,383,407.36 divided by the environmental update rate previously assigned, and specifically, the DUV results in the amount of US$ 328,472,343.77.

Once the value of DUV was obtained and the different weights of each element of the TEV of the environmental asset assigned by the intergroup group with significant differences between them were known, it allowed us to estimate the total economic value up to three amounts (High, medium and low value) according to the clusters formed as shown in Table 7.

Table 5. Aggregate and normalized vectors.

TEV	Cluster (1)		Cluster (2)		Cluster (3)	
	geometric means	**Normalization**	**geometric means**	**Normalization**	**geometric means**	**Normalization**
DUV	0.0641	0.0754	0.0730	0.0815	0.3660	0.4243
IUV	0.0939	0.1103	0.0973	0.1086	0.2089	0.2422
OV	0.2142	0.2516	0.1180	0.1317	0.1105	0.1281
EV	0.1752	0.2058	0.4806	0.5363	0.1072	0.1243
BV	0.3039	0.3570	0.1272	0.1420	0.0700	0.0812
	0.8513	1.0000	0.8962	1.0000	0.8625	1.0000

Note. The abbreviations described have the following meaning: TEV, refers to total economic value; DUV, direct use value; IUV, indirect use value; OV, Option/quasi-option; EV, existence value; and BV, bequest value.

Table 6. Cashflow from economic activity in the study area.

Activity	Incomes (US$)	Operational Costs (US$)	Margin (US$)
Agriculture	107,123,650.70	98,746,961.29	8,376,689.36
Cattle Farming	9,651,477.00	5,657,835.00	3,993,642.00
Fishing	19,040.00	5,964.00	13,076.00
Total year cashflow			12,383,407.36

Table 7. Value of each TEV component by cluster´s.

TEV	Components	Values (US$)		
		Cluster (1)	**Cluster (2)**	**Cluster (3)**
UV	DUV	328,472,343.77	328,472,343.77	328,472,343.77
	IUV	480,752,777.10	437,703,836.73	187,498,077.18
	OV		530,593,430.82	99,157,547.35
	1,096,613,756.07			
NUV	EV	897,255,857.18	2,161,042,859.40	96,206,889.16
	BV	1,556,084,755.34	572,089,973.69	62,828,309.69
Total		**4,359,179,489.46**	**4,029,902,444.41**	**774,163,167.16**

Note. The abbreviations described have the following meaning: TEV, refers to total economic value; UV, use value; NUV, non-use value; DUV, direct use value; IUV, indirect use value; OV, Option/quasi-option; EV, existence value; and BV, bequest value.

The first collective group or cluster (1) was formed by a miscellany of workers from the Local Water Authority institution of the zonal office in Andahuaylas and some academic professionals; who granted a high valuation amounting to US$ 4,359,179,489.46. Meanwhile, the cluster (2) that were made up of Biologists, Environmental Engineers and Researchers assigned an intermediate economic value of US$ 4,029,902,444.4. Finally, cluster (3) granted a monetary valuation of US$ 774,163,167.16; and was made up of workers from decentralized institutions of the regional government of Apurimac in the sector: Foreign Trade and Tourism, Chamber of Commerce and Industry; officials of the offices of economic development and environment environment of local government and by the farmers of the communities of Lliupapuquio, Chumbao and Chihuampata, respectively. The amounts described, in general, represent an average of 51.78% of the Direct Use Value and 48.21% is the Non-Use Value of the TEV.

Among the UV components: the option value had a higher weighting that was assigned by clusters 1.0 and 2.0. Meanwhile, cluster 3.0 assigned greater weight to the direct use value. On the other hand, among the NUV components: the existence value had a high weighting and was assigned by clusters 3.0 and 2.0; instead, group 1.0 preferred and weighted the highest scoring bequest value.

5. Discussion

For the economic valuation of natural resources, whether tangible or intangible assets, we have a series of tools that allow us to quantify their importance through different approaches, some from the usufructuary point of view and others with a more protectionist approach to the resource. Ecological economics warns that it is not possible to separate the economy from nature, in reality we are facing an open system that exchanges matter, energy and information with its environment, and its constituent elements that go beyond the definition of goods and services that circulate in markets, that these form an interrelated and interdependent whole (Martinez and Dimas, 2013). In this complex scenario, the concept of Total Economic Value of a natural space becomes relevant, including both commercial and environmental benefits, these include direct and indirect benefits (Hernández et al., 2014). It is known that, when evaluating the VET, not only the current use value of a good or tangible asset is considered but also the future use value and the existence value of that good (Aznar and Estruch, 2015). From this concept, it is possible to initiate the discussion on the complexity of valuing an environmental good or service (Almeida et al., 2018). It is possible to use multi-criteria evaluation systems, where multiple assessment languages with hedonic, ethical, cultural, religious connotations, among others, must take place (Martínez and Dimas, 2013). In this context, the economic valuation of the ecosystem of the high andean water basins is still scarce and those that were reported are valued with traditional methods, which in general do not contain all the intangible aspects of natural resources; in the case of the monetary valuation of the Coata river basin in Puno determined the amount of 45 935.44 nuevos soles per month and 551 225.28 nuevos soles annually, using the method of disposition to pay (DTP), in that estimation the variables that influenced this amount was when the person or head of family as his age increased, were more willing to make the payment (increased by 2.77%), the same happened, when the person has a higher degree of education or instruction the probability of DTP increased by 3.1%; on the other hand, the greater the usufruct of ecosystem services, the value of EPD decreased by 2.3%. Thus, these values express the degree of environmental insensitivity (Quispe-Mamani et al., 2021); in this environment we consider it essential to intensify actions to disseminate environmental education to achieve social empowerment about the usufruct of nature and conservation of the ecosystem functions of the basins (Iwan et al., 2017). In the case of the valuation of the wetland of the padres Lagoon in Argentina, the monetary quantification of ecosystem services was carried out using the technique of production costs referred to the availability of water, where it was estimated at 138 million pesos per year, equivalent to 4.6% of the municipal budget of Padres in Argentina for fiscal year 2014; this value when compared with other municipal investments, such as the education sector and health, investments were allocated up to 28.0% and 21.23% of the total budget of the municipality, respectively; so it is evident that the environment sector is relegated to the health and education sectors; in that sense, it gives us to understand that the people residing in the municipality of Padres still do not perceive that nature plays the fundamental role in the development of a society (Iwan et al., 2017). Similarly, for the production of drinking water from Estero Llancahue, the estimation of the monetary value using the productivity change method ranged from US$ 11 to 25 per cubic meter, which in total is equivalent to US$ 83,742,593.00 to 190,324,075.00 respectively; but in situations where changes in production occur that involve significant reforms in the markets, the monetary amount may incur a bias that would cause damage to substitute services or goods and to those complementary to the valued asset (Braglia et al., 2004). It´s suggested to those who carry out an economic valuation to consider methodologies with approaches that incorporate both tangible and intangible ecosystem services, because as you have noticed in the studies described above they generally exclude the ecosystem functions of regulation and culture, that is, most traditional methods do not fit or are not applicable to all the biophysical elements of nature, for these reasons, multi-criteria models are chosen.

As for the marine coastal strip "La Safor de Valencia", when economically valued using the AMUVAM multicriteria model, they found values ranging between 2478.00 – 4479.00 USD / ha / year at a rental update rate of 3.04%. Of the group of experts, the group of researchers prioritizes regulatory services, while the group of fishermen prioritizes supply services (Gómez-Aguayo and Estruch-Guitart, 2019). In this way, the preferences detected in this study are similar to those we have found in the present research, where the collective group surveyed preferred the existence value that groups the regulatory ecosystem service.

For the Santa Elena Lagoon in Chile, the valuation through the AMUVAM method allowed to know the monetary unit of US$ 17,780,686.00 at a social discount rate equal to 6%; where, the panel of experts consulted gave greater weight to the indirect use value (IUV) as the highest valuation component with 36.39% of score, followed by the stock value (EV) with 26.72% and the legacy value (BV) with 26.64%, leaving the direct use value (DUV) (market) at 4.07% and the option value (OV) at 6.17%, respectively (Romero et al., 2020); the percentage scores expressed and ultimately show a clear preference for equality between existence value and legacy, this means that the surveyed experts have an ecological profile with a clear orientation to preserve natural resources for future generations. But when equating the weights assigned with our study, in our case, the stock value reaches 53,63% and is the score given by cluster 2.0; which expresses that the collective groups prefer to conserve environmental assets and possibly would be willing to declare as a protected natural area in the upper part of the chumbao river valley. The economic valuation also covered the natural parks. Thus, the ecosystem services generated by the Natural Park of Hoces de Cabriel, which has an area of 31446 hectares, was valued between 44,852,840.42 and 111,706,893.75 euros per year, since the collective group was classified into two clusters. In particular, both groups of experts agree that non-market services (non-use values) are more valuable than market services (use values), as support and cultural services have highly weighted valuations compared to the rest of the ecosystem service. This preference lies in the fact that experts associate them mostly with tourism, recreational and educational activities (Martin and Estruch, 2018). On the other hand, in the present investigation, the value of use was relatively better valued compared to the value of non-use (but only with 3.56% difference) for the high Andean water basin slope of the chumbao river. While, in the economic assessment of the aesthetics of the landscape of the albufera natural park in Valencia, Spain, using the analytical method of multicriteria assessment, the weights of TEV were derived from the responses of 43 experts, of which two clusters were formed. The utilitarian or materialist group (cluster 1, which corresponds to 62% of the participants) gave greater importance to the use values that represent 72% of the TEV, while the non-use values correspond to 77% of the TEV; the environmental group (cluster 2, corresponding to 38% of the participants). In this way, the TEV of the Albufera Natural Park of area 21000 hectares, ranges between 1,015 and 5,244 million euros, whose effective flow was updated applying a rate of 3% (Estruch-Guitart and Vallés-Planells, 2017). Although the number of members of cluster 2 is smaller compared to cluster 1; it is clear to us that UNV was rated better than UV, a situation that did not occur in the present investigation.

In another study, the economic values of ecosystem services associated with the Turia Natural Park, the values determined by the Multicriteria assessment (AMUVAM) range between 163,946,752.00 and 481,549,597.00 euros, the pivot value was updated to a social discount rate of 2.91%, as in previous studies, the group of experts were formed into two segmented or groups; however, the ecosystem services assessed have a greater specific importance in agriculture and hunting, climate regulation and recreational activities in relation to provisioning and cultural services, respectively (Estruch-Guitart and Valls-Civera, 2018). Meanwhile, in the case of the head of the chumbao river basin with an area comprising 133.67 ha, the value assigned ranges between 774,163,167.16 and 4,359,179,489.46 dollars, respectively (maximum and minimum value if two economic values were considered). The cash flow update was considered 3.77%. Overall, the component with high rating was the stock value of 53.63%, followed by direct use value 42.43% and so on, the IUV, OV and BV components were relegated. But it is also important to emphasize that Cluster 1.0 (made up of a miscellaneous of workers from the local water authority of the zonal office in Andahuaylas and a group of academic professionals of higher technician) gave high scores to both OV and BV; Cluster 2.0 (made up of academics and researchers) weighted EV highly; and Cluster 3.0 (made up of public officials and farmers) gave high scores to DUV and IUV; In this way the collective group expressed its consumerist or utilitarian and environmentalist profiles. As for the high weighting of EV, it is possibly justified by the concentration of wild flora and fauna, by the existence of the lagoons Pampahuasi, Antaccocha, Paccococha, Huachoccocha, Ccoriccocha, Ischuccahuanaccocha, Carioccocha, Tipiccocha, Suraccocha, Tinyanaccocha that supply as tributaries of the Chumbao River, and therefore, directly and indirectly supplies the socioeconomic development of the citizens of the districts of San Jeronimo, Andahuaylas and Talavera in the province of Andahuaylas, Apurimac region. As evidenced, it is reasonable to distinguish that the monetary values found by the aforementioned authors usually depend on the extension of the geographical area studied, the types of resources to be valued, discount rate assigned for each country, the methodology used since it takes into account various approaches and points of view (Gómez-Aguayo and Estruch-Guitart, 2019).

6. Conclusion

In this study, it has been possible to provide an estimate of the total economic value of the high andean ecosystem, which includes the tangible and intangible benefits of the environmental assets of the high andean basin on the slope of the chumbao river, of which the andahuaylina population operates in its productive activity. Where, we found three clusters that assigned the valuation differently; the first cluster assigned a weighting that quantifies an economic value of $ 4,35,179,489.46 as a high value; the second, an intermediate value of $ 4,029,902,444.41 and the third, a lower value of $ 774,163,167.16. This assessment has implications for both society and government management and policies. At the social level, the results obtained create an adequate perception about the importance of ecosystem functions and their contributions to people. Regarding government management and policy, it could serve as a tool that promotes the integration and formulation of environmental management plans for the high andean basins in order to make correct decisions associated with the use, exploitation and conservation of the natural space within the framework of the sustainable development goals.

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