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Economic Valuation of Geosystem Services in Agricultural Products: A Small-Sample Pilot Study on Rotella Apple and Moscatello Wine

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Abstract

Soils are critical natural resources, yet their abiotic contributions to ecosystem services remain largely unexplored in valuation studies. This pilot study represents, to the best of our knowledge, the first attempt to assess the perceived value of geosystem services (GSs) from a consumer perspective. Using a discrete choice experiment with 200 respondents, we evaluated preferences for Rotella apples and Moscatello wine through mixed multinomial logit and latent class models. Results show that attributes related to soil use and soil control were consistently significant drivers of consumer utility (e.g., odds ratios of 9.38 and 5.78 for Moscatello wine and 8.46 and 5.56 for Rotella apples, respectively; $p < 0.01$). These attributes align more closely with the concept of a "geological fingerprint" than with existing geographical labeling schemes such as the Protected Designation of Origin. Price effects were statistically insignificant, indicating virtually no influence on choices. Both estimated models revealed preference heterogeneity and a substantial number of no-buy responses. This suggests both limited consumer familiarity with GS concepts and a limitation of our attribute descriptions, which likely failed to convey information needed for effective purchasing decisions. This study is exploratory and limited by its convenience sample, imperfect price specification, and inability to estimate willingness-to-pay measures. Nevertheless, it provides empirical support for introducing geological footprint labeling and highlights the need for improved consumer information, policy tools, and public campaigns to promote recognition and sustainable management of geodiversity in agriculture.

Keywords: consumer choice experiment; geosystem services; mixed multinomial logit; latent class models; geological fingerprint

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1. Introduction

Human activities have caused extensive environmental degradation, including biodiversity loss, overexploitation of natural resources, and ecosystem damage [1].

Over the past two decades, awareness of the importance of conserving natural capital for human well-being has increased, leading to major international agreements and policy frameworks—such as the Convention on Biological Diversity, Nagoya Protocol, Sustainable Development Goals (SDGs), Paris Agreement, EU Agenda 2030, G20 Summit in Rome, and EU Green Deal—aimed at conserving and restoring ecosystem services [2–5].

Research on the economic valuation of ecosystem services has expanded, particularly in connection with the SDGs, aiming to introduce environmental–economic accounting and integrate natural capital valuation into policies to guide decisions on managing human–environment relationships at global, regional, and local levels [6,7].

Daily et al. [8] define ecosystem services as “the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life”. Although the abiotic and biotic components of nature are strongly interconnected and included in ecosystem definitions, most studies assess only biotic ecosystem services, largely disregarding abiotic contributions [9]. Similarly, most economic valuations of Earth’s diversity focus on biodiversity, disregarding geodiversity [10].

Building on the development of the geodiversity concept and its application in conservation strategies, the International Union for the Conservation of Nature (IUCN) established the Geoheritage Specialist Group in 2013, focusing on all aspects of geodiversity and protected area management [11].

Gray [9,12] introduced the concept of geosystem services, defining it as “the goods and functions associated with geodiversity,” after defining geodiversity as “the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landforms, processes), and soil features, including their assemblages, relationships, properties, interpretations, and systems”. Recognition of geodiversity and geosystem services has provided a holistic and integrated understanding of ecosystems and laid the foundations for more effective management and conservation strategies [9,13]. Among the various definitions of geosystem services [9,10,12,14–16], we adopt Gray’s meaning [9], which defines geosystem services as “all services associated with geodiversity independent of interactions with biotic nature”. More recently, researchers have applied the geosystem services framework in several contexts, particularly urban environments and spatial planning [17,18].

Within the broad concept of geodiversity, soils are among the most important and complex components of both ecosystem and geosystem services, as they form the critical interface between the lithosphere, hydrosphere, atmosphere, and biosphere [19,20]. Despite their importance, soils are among the most exploited natural resources, with approximately 33% of the world’s soils already being degraded due to human activities [21]. Historically, soils were regarded primarily as a medium for agricultural productivity. However, over the past two decades, a growing body of literature has emphasized their broader ecological and economic value [19,20]. In this context, the Millennium Ecosystem Assessment [22] identified soil-related ecosystem services to highlight the essential role of soils in supporting human well-being. Although the Common International Classification of Ecosystem Services (CICES (Table S1) V5.1; [23]) explicitly distinguishes abiotic from biotic services, most valuation studies focus primarily on biotic services, highlighting soils mainly in relation to biodiversity maintenance [24]. While the debate on these issues remains open, it is widely acknowledged that humans benefit significantly from the abiotic components of soils, particularly in food production, where geosystem processes contribute to numerous functions supporting human nutrition and well-being [25]. For instance, more than 99% of the calories of human food derive from soils [26], which also provide drinking water through filtration processes and supply essential nutrients necessary for plant growth [8].

Food and drink provisioning is among the twenty-five geosystem services identified by various researchers, which also include mineral water and salt used in drinking and food production [9,27]. Many essential macro-, micro-, and trace elements—such as iron, sodium, potassium, calcium, manganese, copper, and zinc—play critical roles in human health. These elements originate from rock-forming minerals, are mobilized into soils through natural weathering processes, and are subsequently taken up by plants, ultimately entering the food chain through agricultural products [28].

Among the few studies on soil service valuation, most address biotic services linked to biodiversity [24]. Research connecting geodiversity and pedodiversity to food production has focused mainly on the production side, including geographical traceability of products [29–31] and geological fingerprints of a territory [32–36]. Initiatives like Geofood (Magma Geopark, Norway; [37]) and the concept of terroir [38–40] also emphasize geological influences but remain supply-side-oriented.

While consumer behavior research has extensively examined biotic ecosystem attributes in agri-food products, such as organic and biodiversity labels [41–43], few studies have analyzed consumer valuation of ecosystem service-related attributes in food products [44]. Research explicitly addressing abiotic components, particularly geosystem services, is virtually absent, despite long-standing certification schemes such as DOC/DOCG having been in use since the 1960s and being more widespread in Italian agri-food markets than organic labels (Regulation EEC No. 2092/91; Regulation EC No. 834/2007).

In recent years, environmental economics has shifted from a generic focus on "the environment" to explicitly integrating ecosystem services (ESs) and natural capital (NC) as foundational pillars of economic systems. This transition, driven by the EU Biodiversity Strategy for 2030 and the broader climate neutrality targets set for 2050, has elevated biodiversity and ES to central components of sustainability policies.

Ecosystem services represent the flows of functions ecosystems provide, which humans appropriate for productive, recreational, or cultural purposes [6,45]. According to the Joint Research Centre (JRC) report by [45], Europeans increasingly recognize biodiversity and ecosystem services as public goods that should be preserved and enhanced through targeted policies.

To address this largely unexplored topic, the present study provides the first empirical investigation into consumer perceptions and valuations of geosystem services embedded in agricultural products. Specifically, it contributes to filling this gap by estimating the non-market value that consumers assign to geosystem service-related attributes of two Italian niche agricultural products—Rotella apple and Moscatello wine—through a pilot discrete-choice experiment analyzed with mixed multinomial logit and latent class models.

2. Materials and Methods

This exploratory pilot study addresses a largely overlooked topic: consumer perceptions and valuation of geosystem services embedded in agricultural products, along with associated consumption behaviors. The analysis focuses on two niche products from the Italian regions of Tuscany and Liguria, namely, the Rotella apple and Moscatello di Taggia wine.

The Rotella apple is a traditional cultivar originating from Lunigiana, a historic region spanning the provinces of Massa Carrara (northern Tuscany) and La Spezia (eastern Liguria). It is characterized by its round, slightly flattened shape and a distinctive sweet–sour flavor with a pronounced aroma when fully ripe. Notably, the Rotella apple is well known for its long storage potential. Average annual production is approximately 220 quintals, primarily destined for self-consumption and direct sale [46].

The Moscatello di Taggia is a historic aromatic wine from western Liguria that belongs to the Muscat family [33]. It experienced widespread and long-standing diffusion during the late Middle Ages, reaching prestigious destinations such as the papal cellars and the markets of Flanders and England between the 15th and 17th centuries [47]. In 2011, the "Taggia" sub-zone was recognized within the "Riviera Ligure di Ponente" DOC, encompassing the historic production area in the Argentina and Armea valleys and the coastal strip between Ospedaletti and Santo Stefano al Mare (Province of Imperia). Four varieties are currently produced—dry, sparkling, late harvest, and "passito," the latter closely resembling the ancient version of this renowned wine [48].

2.1. Choice Experiment Setup

The choice experiment was designed to elicit consumer preferences for product attributes associated with geosystem services. Four non-price attributes were included, each with multiple levels, representing key soil- and geology-related features identified through a literature review and consultation with local producers. The price attribute was defined based on market references for comparable products (e.g., Moscato d'Asti sparkling wine). As we will discuss later in the Results section, the price definition was not accurately tailored to the different variants of the product, which can be processed either in a style similar to Moscato d'Asti or as a late-harvest passito wine. These variations involve substantial price differences that may not have been clear to respondents. This is certainly a limitation of the study. Future research should provide a more precise description of the wine type and its packaging (e.g., whether sold in half bottles, as typical for passito wines, or in standard 750 ml bottles) and, consequently, select reference prices that better reflect comparable products.

Table 1 summarizes the attributes and levels used in the experiment. Specifically:

(*i*) Use of the soil (two levels) refers to sustainable soil use, which is fundamental to habitat provisioning and the supply of nutrients and minerals essential for healthy product growth; (*ii*) Location of the product (two levels) reflects consumer knowledge about the geographical origin of the product (similar to a Protected Designation of Origin label) versus more detailed information on the geological characteristics of agricultural soils (comparable to a geological label); (*iii*) Soil control (two levels) addresses consumer awareness of chemical substances present in the soil; (*iv*) Traditional product (three levels) relates to cultural aspects of products, including their cultivation history; (*v*) Price (four levels) is based on market benchmarks.

Both Rotella apple and Moscatello wine were described using combinations of predefined attributes and levels. Using STATA software (v. 16-2019), we first generated the full factorial design, resulting in 96 unique product profiles ($2 \times 2 \times 3 \times 4$). From these, all possible profile pairs [$(96 \times 95)/2$)] were randomly generated to form potential choice sets. The choice sets were not fully optimized or balanced, except for the partial balance achieved through random selection.

To improve realism, we filtered the randomly generated pairs in Microsoft Excel for Mac (v. 16.99.2), removing implausible alternatives (e.g., combinations where price was unrealistically low relative to other high-quality attribute levels) and dominant alternatives (e.g., profiles with universally low attribute levels but high price, or vice versa) which would present no rational trade-off.

While this manual filtering helped to maintain internal validity, the absence of a fully optimized experimental design likely reduced statistical efficiency, increasing the variance of coefficient estimates and limiting our ability to derive robust willingness-to-pay (WTP) measures. Nevertheless, the use of random selection—although not optimized through an efficiency criterion such as D-efficiency—ensured a broad and unbiased coverage of attribute combinations. This approach is particularly suitable for exploratory pilot studies, where the primary goal is to identify relevant attributes and capture preliminary patterns in consumer preferences rather than achieving maximum statistical efficiency.

Finally, for each respondent, two random profile pairs (e.g., Table 2) were selected for each product. In cases of dominance or implausibility (as defined above), the pairings were manually adjusted to ensure plausibility and internal consistency. Thus, each respondent was given a total of four choice tasks (two for Rotella apple and two for Moscatello wine), with each task presenting two alternative product profiles and a no-purchase option to reflect realistic market conditions. In total, 400 choice sets (2 × 200 respondents) were constructed.

Table 1. Attributes and levels considered in the choice experiment for Rotella apple and Moscatello wine, based on geosystem services.

Use of the Soil		
LEVEL 1 The product derives from an unsustainable use of the soil in which fertilizers are used to obtain the maximum yield of the product in terms of quantity.	**LEVEL 2** The product derives from a sustainable use of the soil without using artificial chemicals but only natural substances to respect the environment and consumer health.	
Location of the product		
LEVEL 1 The origin of the product is known only from the geographical point of view.	**LEVEL 2** The origin of the product is known only from the geographical and geological point of view.	
Soil Control		
LEVEL 1 product is grown on soil that is not checked or analysed. The presence of any toxic elements is unknown; the product could assimilate substances that might be harmful to human health.	**LEVEL 2** The product is grown on soil that is checked and analysed to determine the presence of potentially toxic chemical elements.	
Traditional product		
LEVEL 1 The product is not typical of the geographical area of production.	**LEVEL 2** The product is not typical of the geographical area of production.	**LEVEL 3** The product originates from the recovery of a historical local cultivar, preserving a connection with the past and keeping alive the tradition that links the soil, the product, and the local community.
Price		
The **Rotella apple** Level 1: 1.2 € Level 2: 1.5 € Level 3: 2.5 € Level 4: 2.7 €	**Moscatello wine** Level 1: 7 € Level 2: 10 € Level 3: 13 € Level 4: 17 €	

The experimental design was informed by recent methodological advances in the valuation of environmental goods and sustainability-oriented consumer studies [45,49–51]. However, no existing work has specifically addressed attribute selection for valuing geosystem services. Thus, while our design draws on standard discrete-choice experiment protocols, the definition of the attributes in our case was entirely exploratory. This pilot study was intended to test the feasibility of incorporating geosystem service-related attributes into consumer choice modelling and to provide a basis for future more refined research.

The final questionnaire comprised three sections: (i) an explanation of the survey's objective; (ii) socio-demographic questions (gender, age, education, occupation, and purchasing habits for wine and apples); and (iii) the discrete-choice tasks. The survey was administered online via Google Forms. A total of 200 respondents completed the questionnaire, yielding 200 valid responses.

Table 2. Example of choice task for "Rotella apple".

Apple A	Apple B	Apple C (Neither A nor B)
LEVEL 1 The product derives from an unsustainable use of the soil in which fertilizers are used to obtain the maximum yield of the product in terms of quantity.	**LEVEL 2** The product derives from a sustainable use of the soil without using artificial chemicals but only natural substances to respect the environment and consumer health.	--
LEVEL 1 The origin of the product is known only from the geographical point of view.	**LEVEL 2** The origin of the product is known only from the geographical and geological point of view.	--
LEVEL 1 The product is grown on soil that is not checked or analysed. The presence of any toxic elements is unknown; the product could assimilate substances that might be harmful to human health.	**LEVEL 2** The product is grown on soil that is checked and analysed to determine the presence of potentially toxic chemical elements.	--
LEVEL 1 The product is not typical of the place where it is grown.	**LEVEL 3** The product originates from the recovery of a historical local cultivar, preserving a connection with the past and keeping alive the tradition that links the soil, the product, and the local community.	--
1.50 €/kg	2.50 €/kg	--

Aside from a small number of participants who did not indicate their gender (because the option "prefer not to answer" was not included), all responses were complete. This omission will be addressed in future survey designs. The sample was not designed to be statistically representative and may therefore be subject to selection bias. Given the novelty of the geosystem services concept, the survey was primarily disseminated within an academic environment, targeting students as well as their families and acquaintances. This approach was adopted to ensure a minimum level of familiarity with the terminology used in the questionnaire. While this constitutes a limitation, it is important to note that the pilot study was explicitly conceived as a pre-test aimed at evaluating respondents' comprehension of the topic. We are currently working on an extension of this approach applied to geosites. As part of this development, we have planned a series of preliminary meetings aimed at clarifying key concepts related to geosystem services and refining the definition of product attributes for future discrete choice experiments.

2.2. Data Analysis

Responses were analyzed using two econometric approaches: (i) a mixed multinomial logit model (MMNL) and (ii) a latent class model (LCM). These models are widely applied in discrete choice analysis [52,53], under the assumption that consumers choose the alternative that maximizes their perceived utility.

Discrete choice experiments are grounded in Lancaster's characteristics theory of value [54] and random utility theory [55,56], where utility is derived from product attributes rather than the product itself. The classical MNL model remains a standard estimation method for discrete choice models and has been extensively used in environmental and consumer preference studies [55]. However, MNL assumes homogeneous preferences and the property of independence of irrelevant alternatives (IIA), meaning that adding or removing an option in a choice set does not affect the probability of choosing other options [49,57]. This assumption is often unrealistic in practice.

To address this limitation, the mixed multinomial logit model (MMNL), introduced by McFadden and Train [58], was employed. The MMNL allows parameters to vary randomly across individuals, capturing unobserved heterogeneity in preferences [59]. The choice of the MMNL model is justified with the objective of capturing heterogeneity in preferences for attributes related to geosystem services.

As an alternative approach, a latent class model (LCM) was also estimated. The LCM assumes that heterogeneity arises from a discrete distribution of preferences. Respondents were segmented into n latent classes, each with class-specific parameters, while preferences were homogeneous within each class [60,61].

Model selection and evaluation were guided by standard information criteria, including log-likelihood (LL), the Akaike information criterion (AIC), and the Bayesian information criterion (BIC).

3. Results and Discussion

This section presents the estimation results obtained from the two econometric models described in the previous section: the mixed multinomial logit model (MMNL) and the latent class model (LCM). Both models were estimated using STATA software [62].

Table 3 illustrates the descriptive statistics of the survey sample, including respondents' socio-demographic characteristics and purchasing habits.

Table 3. Descriptive statistics of the survey sample.

Title	Results
Sex	Female = 64% Male = 35.5% Not specified = 0.5%
Age	16–18 = 0.50% 18–25 = 34% 25–40 = 32% 40–60 = 27% 60–75 = 6.50%
Education	Middle school diploma = 2% High school diploma = 31.50% Bachelor's degree = 20.50% Master's degree and higher (e.g., Ph.D.) = 46%
Profession	Self-employed = 0.50% Employee = 9.50% Student = 12% Retired = 3% Teacher = 2% Other = 73%
Consumption habit	Buy both products = 92.50% Buy only apples = 5.50% Buy only wines = 1% Buy neither apples nor wines = 1%

3.1. The Multinomial Logit Model

The estimation results of the mixed multinomial logit (MMNL) model for Moscatello wine are reported in Table 4. The model describes the probability of selecting different alternatives as a function of explanatory variables, including product attributes. Socio-demographic characteristics (Table 3) were initially included but were excluded in the final specificationm since none were statistically significant.

Table 4. MMNL of Moscatello wine.

Parameters	Estimate	Std.Error	Pr > ∣t∣
Mean			
No-buy	4177.33	4661.26	0.00 ***
Use of soil	11.85	3.89	0.00 ***
Location of soil	2.70	6.68	0.00 ***
Knowledge of soil	8.50	2.59	0.00 ***
Historical product conservation	1.54	0.28	0.01 **
Price	1.01	0.03	0.65
SD			
Use of soil	0.27	0.09	0.00 ***
Historical product conservation	2.69	0.69	0.00 ***

*** Statistically significant at 1%, ** Statistically significant at 5%. The respondents' socio-economic features are not reported due to their non-significance.

The model was estimated using the *mixlogit* command in STATA software, which accounts for preference heterogeneity by allowing coefficients to vary randomly across respondents. All attributes were initially specified as random; however, only Use of Soil and Traditional Product showed significant standard deviations, indicating unobserved heterogeneity. Estimated coefficients are expressed as odds ratios, representing the change in the probability of selecting a product for a one-unit increase in an attribute level.

Among 400 choice situations, 100 resulted in a no-purchase decision for Rotella apple and 105 for Moscatello wine—both relatively high shares. This could reflect either (*i*) short-term non-purchase behavior, where respondents might buy in the future but for a product profile not shown, or (*ii*) persistent non-purchase behavior, where respondents have no intention of buying either option now or later.

The model includes the no-buy option as a separate intercept ("label-specific constant"), capturing its intrinsic utility independent of product attributes. The very high odds ratio associated with this option suggests that, while based on the geosystem services (GSs) literature, the attribute descriptions may not have been meaningful from a consumer perspective. Instead of aiding choice, they may have caused confusion, leading respondents to opt out. This highlights a limitation of our exploratory design: attribute framing may not have conveyed information in a way consumers could use to differentiate products for purchase decisions.

Results show that all attributes except price are positive and significant. Use of Soil and Soil Control have the highest coefficients, reflecting consumer sensitivity to geosystem protection and geological product identification. The significant standard deviations for the first of these attributes further indicate heterogeneity: different consumer groups value these features differently. Overall, geosystem service–related attributes positively influence utility, with each attribute level increase making product selection more likely.

The comparatively lower odds ratio for Location of the Soil—the attribute most similar to current European geographical labels (e.g., PDO)—suggests that existing labelling does not fully meet latent consumer demand for information on soil characteristics. This implies a potential role for alternative labeling strategies, such as a "geological footprint", to better reflect geosystem services in agri-food value creation. This interpretation should, however, be taken cautiously given the high incidence of no-buy response.

These findings align with broader discussions on traceability and intrinsic product properties. Current efforts—ranging from EU regulations to blockchain systems—focus on improving product tracking, yet effective traceability requires reliable verification through audits and lab testing. Food products' chemical and elemental characteristics, which can identify origin and environmental context, are inherently linked to geosystem services and contribute to both intrinsic and market value. Transparent labeling that conveys soil use and production practices could therefore strengthen consumer decision making.

A key theme in current discussions emphasizes the chemical and elemental characteristics of food products, which can be identified through shared and validated methodologies to trace their origin. This focus on intrinsic product components is consistent with the concept of geosystem services; the value of these services is inherently embedded in the final product, contributing to both its intrinsic and market value. These considerations highlight the need for more transparent labeling policies that convey information on soil use and production practices to consumers.

Finally, the price attribute was not statistically significant, and its odds ratio was almost exactly 1, indicating that price had virtually no effect on consumer choices. This near-zero impact makes the positive sign inconsequential and does not warrant further interpretation. The lack of price sensitivity is likely due to misspecification; Moscatello wine spans multiple market segments with different price levels, yet only a single reference price (based on Moscato d'Asti sparkling wine) was used. Respondents may have perceived this as too low for the specific wine typology. Combined with the exploratory nature of the pilot design and high no-buy share, this further constrained our ability to estimate willingness-to-pay (WTP) measures.

The MMNL achieved a log-likelihood (LL) of −332.06, with AIC = 680.11 and BIC = 720.83, indicating a reasonable model fit for a pilot study. However, given the significant standard deviations and the unobserved heterogeneity they reveal, further investigation using a latent class model (LCM) is warranted to better capture distinct consumer preference segments.

The estimation results of the MMNL model for the Rotella apple are presented in Table 5 using the same format as that adopted for the Moscatello wine (Table 4). Three attributes—Use of Soil, Soil Control, and Traditional Product—were statistically significant and positive, suggesting that these characteristics enhance consumer utility. The interpretation of Use of Soil and Soil Control aligns with that discussed earlier for Moscatello wine, reflecting consumers' sensitivity to soil protection and awareness of chemical conditions affecting production.

The significance of the Traditional Product attribute, observed for both Rotella apple and Moscatello wine, further reinforces this interpretation. Tradition is among the easiest attributes for respondents to understand, as it conveys familiar messages commonly used in the marketing of similar niche products. This familiarity likely facilitates its positive influence on consumer preferences compared to less familiar attributes related to geosystem services.

The price attribute was not statistically significant but displayed the expected negative sign and a coefficient significantly below one, making it unlikely that price has no effect on consumer choice. Rather, this suggests limited statistical power due to the exploratory nature of the pilot sample.

Finally, the model achieved a log-likelihood (LL) of −340.99, with an AIC of 697.99 and a BIC of 738.71. These values are similar to those obtained for Moscatello wine, indicating a comparable overall model fit. However, the significant standard deviations for 'Use of Soil' and 'Traditional Product' confirm the presence of unobserved preference heterogeneity among consumers, which might be better captured using latent class modeling.

Table 5. MMNL for Rotella apple.

Parameters	O.R.	Std.Error	*p*-Value
Mean			
No buy	719.01	644.06	0.00 ***
Use of soil	8.12	2.22	0.00 ***
Location of soil	1.35	0.29	0.16
Knowledge of soil	6.90	1.80	0.00 ***
Historical product conservation	1.84	0.26	0.00 ***
Price	0.90	0.15	0.54
SD			
Use of soil	0.34	0.08	0.00 ***
Historical product conservation	0.17	0.33	0.01 **

*** Statistically significant at 1%, ** Statistically significant at 5%. The respondents' socio-economic features are not reported due to their non-significance.

3.2. The Latent Class Model

To further investigate preference heterogeneity and test the robustness of the MMNL results, we estimated a latent class model (LCM) for both Moscatello wine and Rotella apple. The motivation for using LCM lies in the exploratory nature of this pilot study: the high incidence of "no-buy" responses and significant standard deviations in the MMNL suggest substantial unobserved heterogeneity that a random parameter model alone may not fully capture. The LCM approach enables the identification of distinct consumer classes characterized by heterogeneous sensitivities to product attributes and price, potentially offering a clearer interpretation of consumer behavior than the aggregated MMNL estimates.

For Moscatello wine, the LCM identifies two distinct consumer classes presented in Table 6.

Table 6. LCM for Moscatello wine.

Parameters	OR	Std.Error	*p*-Value
		Class 1 (57.5%)	
Use of soil	11.13	4.59	0.00 ***
Location of soil	2.67	0.88	0.00 ***
Knowledge of soil	7.01	2.65	0.00 ***
Historical product conservation	2.07	0.43	0.00 ***
Price	1.02	0.03	0.41
		Class 2 (42.5%)	
Use of soil	1.92	0.55	0.02 **
Location of soil	0.49	0.13	0.01 **
Knowledge of soil	1.28	0.32	0.32
Historical product conservation	0.64	0.14	0.04 **
Price	0.94	0.04	0.26
No buy	1.35	0.24	0.09 *

*** Statistically significant at 1%, ** Statistically significant at 5%, * Statistically significant at 10%.

Class 1 (57.5%) is consistent with the MMLN estimates in Table 4 and shows strong and positive preferences for all geosystem service attributes, all statistically significant at the 1% level. Price is not significant, suggesting that for this class, utility is driven almost exclusively by qualitative product attributes rather than cost. This segment appears strongly engaged with geosystem service values and may reflect environmentally aware or niche consumers who are responsive to information on soil origin, protection, and tradition.

Class 2 (42.5%) is less responsive overall; the Soil control and Price attributes are not significant, and the remaining attributes, while significant, shows relatively small odds ratios. This may suggest that part of the sample may struggle to interpret or value geosystem-related information, possibly due to the novelty of the concepts or insufficient attribute framing in the experimental design. This second group may consist of price-sensitive or disengaged consumers who either do not consider the attribute information relevant or face challenges in interpreting it. The model achieved a log-likelihood (LL) of –355.45, an AIC of 732.90, and a BIC of 788.89. These results indicate a slightly less optimal fit compared to the MMNL model; however, they reflect a more nuanced segmentation, enabling a deeper understanding of consumer behavior.

The latent class model for Rotella apple identified two segments of nearly equal size (Table 7).

Table 7. LCM for Rotella apple.

Parameters	**OR**	**Std.Error**	***t*-Value**
Class 1 (50.5%)			
Use of soil	22.36	19.80	0.00 ***
Location of soil	1.79	0.78	0.18
Knowledge of soil	8.06	4.49	0.00 ***
Historical product conservation	2.96	1.02	0.00 ***
Price	0.83	0.27	0.58
Class 2 (49.5%)			
Use of soil	1.17	0.27	0.49
Location of soil	0.44	0.11	0.00 ***
Knowledge of soil	0.74	0.24	0.00 ***
Historical product conservation	0.85	0.14	0.35
Price	0.76	0.18	0.28
No-buy	1.01	0.23	0.94

*** Statistically significant at 1%.

Class 1 (50.5%) exhibits strong positive responses to Use of Soil (OR = 22.38) and Soil Control (OR = 8.06), with Traditional Product also significant (OR = 2.96). Price is not statistically significant but shows a negative sign, suggesting limited price sensitivity. This aligns with the MMNL findings and indicates consumers who strongly value geosystem-service attributes.

In contrast, Class 2 (49.5%) shows much weaker responses overall. Use of Soil is not significant, while Location of the Product and Soil Control are negative and significant, suggesting a possible aversion or confusion toward the attributes’ description. Traditional products, Price, and No-buy option are not significant.

The model achieved an LL of –360.21, an AIC of 742.42, and a BIC of 798.41. Compared to the MMNL, the latent class model (LCM) offers a more nuanced view of consumer preferences for Rotella apple. While the LCM displays a weaker overall statistical fit—with higher log-likelihood, AIC, and BIC values—it provides valuable insights by identifying distinct consumer segments and revealing patterns of heterogeneity that the MMNL does not fully capture. This richer segmentation comes at the expense of statistical parsimony but enhances interpretability, particularly in an exploratory context. In this sense, the LCM complements the MMNL results, supporting the presence of differentiated attitudes toward soil-related attributes and no-buy behavior.

On the whole, the LCM estimates reinforce the key findings from the MMNL model, indicating a bimodal consumer structure. Across both products, Class 1 (about 50–60% of respondents) consistently values geosystem-service attributes, particularly soil use and control, and is relatively insensitive to price. This class shows a clear demand for geosystem information. Class 2 (about 40–50%) is less engaged, with some negative or null responses to these attributes, and shows no strong price sensitivity, indicating a low understanding or relevance of GS-related attributes.

The presence of negative coefficients and high no-buy rates likely reflects limitations in attribute framing; technical descriptions may have been difficult for general consumers to interpret.

4. Conclusions

This study represents, to the best of our knowledge, the first attempt to investigate the perceived value of geosystem services (GSs) from a consumer perspective, an aspect largely neglected in both academic research and sustainability debates that have predominantly focused on the contribution of GSs to production processes rather than on consumer valuation. The novelty of the topic, together with the lack of established references to geodiversity and GSs in sustainability discussions, justifies the exploratory and pilot nature of this analysis.

However, its pilot nature also comes with limitations. The use of a convenience sample, the imperfect description of certain product attributes (notably price), and the relatively high number of no-buy responses suggest that respondents experienced difficulties in fully understanding the attributes. These difficulties likely stem from both a lack of familiarity with the concept of geosystem services and from how scientific content was framed in the experimental design. The lack of a robust and significant price effect also prevented the estimation of willingness-to-pay (WTP) measures, which had been initially envisioned. Future research should address these limitations by refining attribute definitions, improving price specifications, and expanding sample representativeness.

Despite these shortcomings and acknowledging that nearly half of the sample appeared to misunderstand the attributes, the findings still provide clear and encouraging insights. Across both product cases, attributes related to soil use and control—interpretable as proxies for geosystem service values—emerged as significant and positive drivers of utility. These attributes do not align with traditional geographical labeling schemes (e.g., Protected Designation of Origin) but rather resonate with the notion of a "geological fingerprint," suggesting potential for alternative labeling strategies that reflect the ecological and geological identity of agri-food products.

The high number of no-buy responses also points to an important implication: we need not only to improve the availability of information on GSs but also to translate scientific content into a language that is both accessible and behaviorally relevant for consumers. The gap between the scientific understanding of GSs and their communicability in market settings highlights a key barrier. As such, this challenge should be recognized as a future line of research on how we might effectively reframe scientific knowledge about geodiversity into messages, labels, or signals that consumers can trust, interpret, and act upon.

From this perspective, our study not only reveals knowledge gaps but also opens up a path toward new research agendas, much like the development of ecosystem services (ESs) research, where cultural ESs and tourism have gradually gained relevance and weight within valuation frameworks.

Our results also reveal a significant gap between consumers' ability to fully understand the value of GSs and their willingness or ability to translate this understanding into purchasing decisions. This informational and knowledge deficit limits consumers' capacity to reward products embodying GS values. A key barrier lies in the high cost of producing and disseminating reliable information about environmental attributes, particularly for goods whose sustainability features are complex or not easily understood. Since these costs are challenging for private actors to bear alone, public funding and institutional support become essential.

Addressing these challenges will likely require institutional support. Public policy tools such as Payments for Ecosystem Services (PES), territorial marketing and branding strategies, and information campaigns can help to bridge the gap between scientific content and consumer understanding. Providing standardized, transparent, and reliable environmental information is essential for empowering consumers to make informed choices and reward products that embed GS values. Ultimately, improving how GSs are communicated and valued can support the broader goal of conserving and sustainably using geodiversity in agriculture and beyond.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/land14091718/s1, Table S1. Examples of geosystem services directly related to soil and food production.

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