

1 **Valuation boundaries in monetary ecosystem service**
2 **assessment: A logic-chain-based reporting framework with a**
3 **vineyard application**

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17 **Abstract**

18 Monetary ecosystem service (ES) valuations often diverge across studies and locations
19 even when similar valuation approaches are applied. A key reason is that applied
20 valuations frequently rely on opportunistic datasets and proxies, which implicitly
21 determine which biophysical, management, and demand-side drivers are represented
22 in the valuation workflow. Because this “valuation boundary” is rarely disclosed in a
23 structured way, readers and evidence users have limited ability to interpret differences
24 across estimates, assess comparability, or support evidence synthesis and benefit
25 transfer. We propose a logic-chain-based reporting framework that makes valuation
26 boundaries explicit through determinant coverage disclosure. The framework combines
27 an ecosystem-specific reference template that catalogues services and organizes
28 value determinants in service-specific logic chains spanning supply (nature and
29 management) and demand (beneficiaries and socio-economic modifiers), and a
30 reporting overlay that links each monetary estimate to the template by highlighting
31 represented determinants and listing key omissions. The approach is designed to be
32 feasible under real-world data constraints and to complement, rather than replace,
33 standard valuation guidance. We demonstrate the framework for vineyard
34 agroecosystems in Castilla y León (Spain). Using a data-driven valuation set-up based
35 on available regional information, we estimate monetary values (€/ha/year,
36 standardized to 2023) for a subset of provisioning, regulating, and cultural services and
37 report service-specific valuation-boundary profiles alongside each estimate. A small set
38 of vineyard-level observations illustrates how additional local information can narrow
39 reported boundaries and change interpretation of values. The outputs include a
40 reusable vineyard template, monetary results, and boundary profiles that can support
41 screening and stratification in valuation databases and synthesis exercises.

42 Keywords: ecosystem service valuation, monetary valuation, reporting framework, logic
43 chains

44 **1. Introduction**

45 Ecosystem services (ES), defined as the contributions of ecosystems to human well-
46 being(1) , are frequently used in environmental and resource economics to organize
47 evidence on nature's benefits and to inform policy appraisal and ecosystem accounting
48 applications(2,3) .Monetary valuation is often employed because it expresses diverse
49 benefits in comparable units (4,5),which can be useful in decision settings that require
50 explicit trade-offs(6,7) ,provided results are reported transparently and interpreted with
51 appropriate caution (8,9).

52 A persistent difficulty is that monetary ES values vary widely across studies and
53 locations(10). It is often unclear how much of that variation reflects genuine differences
54 in underlying biophysical service flows(11) opposed to methodological biases in
55 categorisation, ambiguous definitions or data limitations (12–14). This challenge
56 becomes more acute as valuation evidence is increasingly synthesized, used for meta-
57 analysis, and applied in benefit transfer. Recent work based on the Ecosystem
58 Services Valuation Database (ESVD) illustrates both the scale of the evidence base
59 and the continuing problem of interpreting heterogeneity across contexts (15). In
60 parallel, the benefit transfer literature has repeatedly emphasized that transfer validity
61 depends on explanatory variables capturing biophysical and socio-economic context,
62 and that missing or inconsistently reported covariates remain a major source of error
63 (16,17). In practice, methodological labels and headline valuation settings rarely
64 provide enough information to judge whether two reported values are meaningfully
65 comparable(18).

66 One reason is that many monetary valuations are produced under tight constraints of
67 time, budget, and data availability. Even when analysts follow established guidance on
68 valuation approaches(19), implementation is often data-driven, relying on opportunistic
69 datasets, proxies, and simplifying assumptions that differ across regions and studies.
70 These choices implicitly define a valuation boundary, the set of biophysical,
71 management, and demand-side determinants that the valuation workflow represents,

72 versus those it leaves unrepresented. Yet this boundary is seldom reported in a
73 structured, service-specific way(20).

74 This paper proposes a logic-chain-based reporting framework designed to make
75 valuation boundaries explicit through determinant coverage disclosure. The framework
76 has two components. First, it builds an ecosystem-specific reference template that
77 catalogues services for a given ecosystem type (21) and structures, for each service, a
78 logic chain of value determinants spanning supply (nature and management) and
79 demand (beneficiaries and socio-economic components). Logic-chain structures have
80 been used in ecosystem accounting and indicator development to connect ecological
81 processes, service flows and human outcomes (22,23). Second, the framework
82 introduces a standardized reporting overlay that links each monetary estimate to this
83 template by highlighting which determinants are represented in the valuation workflow.

84 We demonstrate the framework using vineyard agroecosystems in Castilla y León
85 (Spain). The case study is used to show implementability under opportunistic data
86 constraints and to provide a worked example of interpretive value. In vineyards, for
87 instance, management-related determinants affecting service flows (e.g., the presence
88 of cover crops) may be absent in regional datasets and therefore omitted or treated via
89 coarse assumptions, despite their documented impact on biodiversity and soil quality
90 (24,25). Vineyard-level observations can bring these determinants into the workflow,
91 changing the interpretation of values.

92 The paper contributes to the valuation and evidence-synthesis literature in three ways.
93 First, it provides a lightweight reporting structure that documents valuation boundaries.
94 Second, it offers ecosystem-specific templates as a scalable scaffold for consistent
95 reporting(26). Third, it clarifies an under-documented source of valuation heterogeneity
96 (differences in valuation boundaries induced by opportunistic evidence constraints)
97 without presenting the approach as a substitute for uncertainty analysis, but as a
98 complementary tool for transparency(27,28). To demonstrate these contributions, we
99 apply the framework to the aforementioned vineyard case study. This application

100 illustrates how contrasting regional proxy-based estimates with local refinements can
101 alter the interpretation of monetary outcomes. Finally, we discuss the implications of
102 this reporting layer for comparability and the future development of valuation
103 infrastructures.

104

105 **2. Materials and methods**

106 **2.1. A logic-chain-based reporting framework for valuation-boundary disclosure**

107 The framework proposed here is designed as a reporting contribution. It does not aim
108 to introduce a new valuation method or to replace existing standards for ecosystem
109 accounting and monetary valuation (3,8). Instead, it introduces a practical reporting
110 layer that links each monetary estimate to a structured disclosure of determinant
111 coverage, service by service. The central premise is that comparability not only
112 requires more than shared labels for valuation methods or reference years, but also
113 clarity about which determinants of service flows and monetary expression are
114 represented in the workflow, and which are not. By making this explicit, the framework
115 supports interpretation of divergence across valuations and provides information that is
116 typically missing when values are later synthesized or transferred, addressing the
117 ongoing problem of interpreting heterogeneity across diverse contexts(5,15).

118 To operationalize determinant disclosure, we organize determinants using service-
119 specific logic chains. Logic-chain thinking has become established in ecosystem
120 accounting and indicator development as a way to structure causal links between
121 ecological processes, service flows, and human outcomes(3).This approach aligns with
122 broader conceptual efforts to link ecosystem processes directly to service
123 provision(22). A closely related motivation appears in the “benefit-relevant indicator”
124 literature, which stresses that ecosystem service measures should make explicit how
125 ecological change connects to welfare-relevant outcomes(23). In the present
126 framework, logic chains serve as structured “maps” of the determinants that plausibly

127 influence a service's realized flow and its monetary expression, offering a consistent
128 scaffold for disclosure across services and studies(29).

129 The framework couples an ecosystem-specific reference template with a standardized
130 determinant-coverage overlay (Fig. 1). The conceptual reference template provides a
131 service catalogue for a given ecosystem type based on the typology(21), while
132 establishing service-specific logic chains that identify the value determinants expected
133 to influence both service flows and their subsequent monetary expression.

134 Determinants are structured along supply and demand. On the supply side, the
135 template distinguishes nature-related determinants (biophysical and ecological
136 conditions shaping capacity and flow) from management-related determinants (human
137 actions that modify ecological processes and flows). This distinction is critical in
138 agroecosystems where management intensity significantly drives both biodiversity and
139 service delivery(25). On the demand side, it records beneficiary characteristics and
140 relevant socio-economic modifiers that can influence monetary expression for a given
141 valuation approach. Rather than parameterizing site-specific models, the reference
142 template establishes a consistent structure and vocabulary to standardize the reporting
143 of applied valuations. This ensures that heterogeneous datasets can be disclosed
144 against a common scaffold, improving transparency across diverse assessment
145 contexts (30).

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147 XXXXXXXXXXXXXXXX Figure 1 XXXXXXXXXXXXXXXX

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149 The determinant coverage overlay operationalizes the linkage between specific
150 valuation exercises and the reference template by mapping the underlying workflow,
151 including data inputs, modeling trajectories, and documented assumptions, onto the
152 logic-chain determinants. This systematic disclosure generates a valuation boundary
153 profile that integrates the monetary estimate with its corresponding technical settings
154 and a transparent account of determinant coverage. By anchoring results to a common

155 scaffold rather than relying on non-standardized narrative descriptions, this profile
156 ensures cross-study comparability and facilitates rigorous evidence
157 synthesis(15,17,26). To prevent the conflation of distinct variance sources, a persistent
158 challenge in applied valuation(10,13), the framework disentangles three critical
159 reporting dimensions. Value determinants characterize the contextual drivers shaping
160 service flows and monetary expression while valuation settings capture technical
161 parameters such as unit costs, discount rates, and price-year standardization. Finally,
162 the valuation approach denotes the specific economic methodology employed. The
163 framework remains intentionally method-agnostic, prioritizing the transparency of
164 represented determinants and the traceability of parameter choices over the
165 adjudication of specific valuation techniques, aligning with current best practices in
166 ecosystem accounting(3,8).

167 Determinant coverage disclosure inevitably involves interpretation, particularly when
168 workflows rely on proxies and simplifying assumptions. To support consistent
169 implementation across analysts and studies, the framework applies minimal operational
170 rules while maintaining a clear distinction between empirical parameters and gap-filling
171 assumptions(27,28). A determinant is treated as represented when the valuation
172 workflow includes an explicit variable, indicator, or model component intended to
173 capture that determinant. To avoid conflating empirical measurement with uniform
174 proxy use, a recognized challenge in ecosystem service assessments (20), we
175 differentiate within the framework. A determinant can be captured via explicit
176 representation (using site-specific data) or proxy representation (where uniform
177 assumptions, such as adopting a single management regime across all sites for lack of
178 data, are explicitly stated and operationally used in the valuation). Conversely, a
179 determinant is treated as unrepresented when it appears in the template logic chain but
180 has no corresponding workflow component. Crucially, merely documenting that a
181 variable was ignored or assumed to have zero effect without an operational justification
182 counts as an omission, not as representation. Among unrepresented determinants, the

183 framework highlights “key omissions”, determinants that are expected to have a non-
184 negligible influence on outcomes and plausibly vary across contexts. To reduce analyst
185 subjectivity, these key omissions should be identified based on established meta-
186 analyses(25) or the structural logic of the ecosystem-specific reference template(23).
187 These rules are intentionally lightweight. The aim is to ensure that reporting remains
188 feasible under real-world constraints, while still producing a consistent and auditable
189 valuation-boundary profile. More elaborate extensions such as controlled vocabularies,
190 reason codes for omissions, or graded quality descriptors can strengthen the
191 framework, but they are not required for basic implementation and are left for future
192 development. We implement the framework in a vineyard demonstration in three steps.
193 First, we construct a vineyard ecosystem-specific reference template comprising a
194 service catalogue and service-specific logic chains of value determinants. Second, we
195 produce data-driven monetary valuations using opportunistic datasets and
196 standardized procedures, reporting monetary estimates and the valuation settings
197 required for interpretation. Third, we apply the determinant-coverage overlay to each
198 monetized service, highlighting represented determinants and listing key omissions to
199 generate service-specific valuation-boundary profiles.
200 Full template logic chains and full overlays for all monetized services are reported in
201 the Appendices, while the main text provides a condensed template summary,
202 monetary results tables, and selected overlay extracts to illustrate how valuation-
203 boundary profiles support interpretation of heterogeneity under opportunistic evidence
204 constraints.

205 **2.2. Case of study: Vineyard agroecosystems in Castilla y León**

206 We demonstrate the reporting framework using vineyard agroecosystems in Castilla y
207 León (Spain), a region where viticulture has historically shaped both the rural economy
208 and the cultural landscape(31). As is common in multifunctional landscapes(32,33),
209 vineyards occur here as a spatial mosaic embedded in broader agricultural and semi-
210 natural land covers, creating heterogeneous patterns of service provision. The region

211 encompasses an extensive vineyard area of over 83,000 hectares, with approximately
212 56,600 ha distributed across twelve formally recognized Appellations of Origin (AOs)
213 and a substantial share located outside these boundaries. This structural and
214 management heterogeneity makes the setting an ideal testbed, it mirrors the real-world
215 conditions of applied valuation where values vary spatially, and the opportunistic
216 evidence base differs drastically across services. To ensure comparability, the primary
217 unit of analysis is the vineyard area, with monetary results standardized to € ha⁻¹ yr⁻¹.
218 The valuation focuses on a subset of provisioning, regulating, and cultural services for
219 which monetization is feasible under the available evidence base. Other plausible
220 services recorded in the broader ecosystem template (Section 2) remain unmonetized
221 due to data limitations or because they are intermediate services whose value is
222 already embodied in final services, aligning with standard ecosystem accounting
223 principles. This intentional separation clarifies that the framework accommodates
224 partial valuation exercises and makes omissions explicit, rather than requiring
225 exhaustive monetization. (A concise cartographic description is included in S3). The
226 valuation exercise is deliberately designed to mirror common applied practice rather
227 than building a bespoke, data-optimal biophysical-economic model. We rely on
228 opportunistic evidence drawn from regional datasets, official statistics, and published
229 coefficients. This approach reflects the empirical reality that many monetary valuations
230 proceed with the best available data under tight constraints of time and budget, a
231 dynamic widely recognized in the literature where implementation choices significantly
232 drive value variation. Consequently, the workflow inevitably combines heterogeneous
233 inputs differing in spatial resolution and provenance. Within our framework, this
234 heterogeneity is explicitly disclosed rather than eliminated, directly addressing the
235 ongoing challenge of interpreting variance across contexts.

236 Monetary methods were selected to provide context-appropriate estimates,
237 standardizing all values to 2023 euros using a consumer price index adjustment (S2) to
238 maintain internal coherence. Importantly, the valuation approach itself is not the

239 methodological novelty; rather, the contribution lies in how these standard estimates
240 are reported.

241 To illustrate how valuation boundaries shift when higher-resolution data becomes
242 available, we complement the regional-scale valuation with a small set of case-study
243 vineyards (S3). Here, local observations allow the refinement of specific determinants
244 (e.g., ground cover) that must otherwise be treated uniformly at the regional scale. This
245 refinement does not claim to establish a "true" underlying value, but practically
246 demonstrates how incorporating local evidence alters determinant coverage and
247 affects the interpretability of the final monetary estimates.

248 The final step of the demonstration maps each monetized service onto its
249 corresponding template logic chain to disclose determinant coverage. For each service,
250 we report the monetary estimate, the key valuation settings required for interpretation,
251 and a valuation-boundary profile that highlights represented determinants and lists key
252 unrepresented determinants. By making explicit what each reported value conditions
253 on, this output provides a consistent basis to interpret differences across services and
254 between regional and locally refined estimates.

255

256 **3. Results**

257 **3.1. Vineyard reference template**

258 The vineyard reference template provides a structured catalogue of ecosystem
259 services and their associated value determinants, organized as service-specific logic
260 chains spanning supply and demand. The condensed template presented in Table 1
261 summarizes the services considered in this study and the main determinant categories
262 that are expected to influence each service flow and its monetary expression. Full
263 service-specific logic chains are reported in S1 Appendix A, which constitutes the
264 ecosystem-specific template artefact produced by the framework.

265 Two general patterns emerge from the template. First, vineyard services depend jointly
266 on biophysical conditions (e.g., soil properties, climate, topography) and management

267 determinants (e.g., ground cover practices, tillage intensity, landscape elements).
268 Second, for several services the monetary expression is sensitive to demand-side
269 context—either through beneficiary presence and use intensity (e.g., tourism-related
270 cultural services) or through socio-economic modifiers that affect unit values and
271 behavioural responses. These determinant maps provide the scaffold for reporting
272 valuation boundaries in the results that follow.

273

274 XXXXXXXXXXXXXXXX Table 1 XXXXXXXXXXXXXXXX

275

276 **3.2. Monetary valuation outputs under opportunistic evidence constraints**

277 Drawing on regional data and standardized valuation procedures, we estimated the
278 monetary value of a subset of vineyard ecosystem services. Table 2 presents these
279 values in € ha⁻¹ yr⁻¹ (adjusted to 2023 euros), alongside essential valuation settings
280 such as unit prices and discount rates. Comprehensive equations, parameters, and
281 data inputs are detailed in Supplementary Material S2. Rather than providing definitive
282 point estimates, these figures serve as data-driven approximations based on current
283 regional evidence. They are included to supply a realistic valuation output that
284 connects to our template, effectively illustrating the valuation boundaries discussed in
285 the following subsection.

286

287 XXXXXXXXXXXXXXXX Table 2 XXXXXXXXXXXXXXXXXXXXXXXX

288

289 **3.3. Valuation-boundary sensitivity**

290 When we link our monetary outputs back to the vineyard reference template, a clear
291 pattern emerges: the coverage of value determinants varies significantly from one
292 service to another, even within the bounds of a single valuation exercise. To illustrate
293 what this reporting output looks like in practice, Table 3 presents overlay extracts for a
294 selected group of services. For each service, the table pairs the monetary estimate with

295 its corresponding logic chain, clearly highlighting the determinants we successfully
296 represented in the workflow. Alongside this, we provide a concise list of the key
297 determinants that had to remain unrepresented due to real-world evidence constraints.
298 The full reporting overlays for all monetized services can be found in S1b.

299

300 XXXXXXXXXXXX Table 3 XXXXXXXXXXXXXXXXXXXX

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302 Two findings are particularly relevant for interpretation and comparability. First, several
303 services rely on coarse regional indicators or literature defaults that represent only a
304 subset of the template determinants. In such cases, key supply-side management
305 determinants and some demand-side modifiers remain unrepresented and become
306 visible as omissions in the valuation-boundary profile. Second, the pattern of omissions
307 differs across services: for some services, the main limitations arise from missing
308 management and process determinants on the supply side. For others, beneficiary
309 context and use intensity are the binding constraints. This matters for cross-study
310 comparison because two valuations can share the same service label and broad
311 valuation approach while conditioning on different determinant sets.

312 The implications of these structural omissions become fully apparent when we shift
313 from regional proxies to site-level data. This local refinement subset clearly illustrates
314 the numerical impact of introducing higher-resolution information to the workflow. Table
315 4 provides a direct comparison between estimates derived from the broader regional
316 evidence base and those refined with actual field observations. At the regional level,
317 data constraints forced the workflow to rely on uniform management proxies (such as
318 assuming a standard no-tillage rate for climate regulation and a conventional tillage
319 factor for erosion control). In contrast, stepping down to the locally refined workflow
320 allowed us to incorporate observed, site-specific practices, explicitly noting the
321 presence of cover crops in organic vineyards.

322

323 XXXXXXXXXXXXXXX Table 4 XXXXXXXXXXXXXXXXXXXX

324

325 **4. Discussion and implications**

326 A recurring problem in monetary ecosystem service (ES) valuation is that differences

327 across studies are often interpreted as “method effects,” when in practice they

328 frequently originate upstream, in the way the biophysical flow is represented and in

329 how beneficiary and context conditions are incorporated or approximated through

330 available data(11,13). This issue becomes more visible when valuations are compiled

331 and compared across sites, ecosystems, and countries: even when studies converge

332 on broadly similar valuation approaches, they still rely on heterogeneous proxies,

333 spatial resolutions, and assumptions that can shift estimates substantially(10,18).

334 Large compilations such as the Ecosystem Services Valuation Database (ESVD)

335 illustrate both the promise and the limits of the current evidence base. Values can be

336 standardized to common units, but robust interpretation still requires attention to

337 context-specific determinants of value that are often only partially documented(5,15). In

338 that sense, the bottleneck is not only “more data” or “better methods,” but improved

339 traceability of what each estimate actually represents. The reporting framework

340 proposed in this paper addresses that bottleneck by coupling monetary estimates with

341 an explicit account of the value determinants represented in the modelling chain.

342 Rather than attempting to eliminate real-world heterogeneity, which is an unrealistic

343 goal in applied valuation, this approach is designed to make heterogeneity visible and

344 comparable. The core premise is that in many applied settings monetary valuation is

345 unavoidably data-driven, in the sense that analysts make defensible use of the best

346 available opportunistic datasets, proxies, and assumptions. That reality is recognized in

347 multiple strands of guidance. First, ecosystem accounting work emphasizes coherent

348 valuation concepts, notably exchange-value logic for accounting contexts, while

349 acknowledging practical constraints in compilation and data availability(8,72). Second,

350 best-practice syntheses for ES assessments repeatedly highlight gaps around supply

351 and demand representation, spatial resolution, and uncertainty documentation(20).
352 Third, the benefit-transfer literature, where the re-use of prior evidence is routine, has
353 long stressed that credibility depends on transparent documentation of context
354 alignment and modelling choices(17). The contribution here is to operationalize those
355 expectations into a concrete reporting device that travels with each monetary estimate.
356 Conceptually, the framework aligns with the move toward causal, welfare-relevant
357 characterization of ecosystem services (22,29). This perspective argues that valuation
358 is more robust when it explicitly connects ecological processes and management to
359 outcomes for specific beneficiaries (23). While our proposal focuses specifically on
360 monetary valuation, it adopts a similar logic to ensure that estimates are interpretable.
361 By disclosing the coverage of both supply-side determinants (e.g., ecosystem condition
362 and management) and demand-side determinants (e.g., beneficiary exposure and
363 socio-economic context), the framework makes the 'black box' of the valuation
364 workflow transparent to the extent that available data allow.
365 A direct implication is that the framework improves the interpretability of differences
366 between valuations conducted with “the same method.” In practice, method labels do
367 not uniquely determine what has been quantified(18). Two studies may both claim a
368 replacement-cost approach while relying on different determinant sets, such as varying
369 management practices on the supply side or different beneficiary contexts on the
370 demand side. The framework makes these structural choices explicit , ensuring that
371 divergence is interpreted through the inclusion or omission of specific value drivers
372 rather than just method labels. Ecosystem accounting guidance explicitly cautions that
373 valuation outcomes depend on the scope and assumptions embedded in the
374 compilation chain and on the intended interpretation of monetary values(8). By forcing
375 the analyst to report which determinants were represented, the framework turns an
376 opaque comparison into a structured comparison that explains divergence through the
377 specific omission or inclusion of distinct determinant sets and proxies. This does not
378 eliminate uncertainty, but it clarifies where uncertainty and divergence are introduced.

379 The vineyards demonstration is useful precisely because it sits at the intersection of
380 strong economic relevance, strong cultural salience, and high heterogeneity in
381 management and landscape context(73,74). At regional scale, opportunistic datasets
382 necessarily flatten variation, sometimes through explicit assumptions when a
383 determinant is known to matter but is not observed. At local scale, field observation can
384 replace assumptions and narrow the gap between what is represented and what is
385 plausible for the specific sites. This is not presented as a comprehensive tiered
386 valuation architecture but a pragmatic illustration of how adding higher-resolution
387 information can change what the estimate represents. Importantly, the framework can
388 record that change without forcing the paper into a methodological treatise about model
389 uncertainty propagation.

390 There are at least three main limitations. First, the framework clarifies the presence or
391 absence of determinants, but it does not by itself standardize how a determinant is
392 quantified when it is present. Two studies may both include ground cover yet
393 operationalize it differently through distinct classification schemes, temporal windows,
394 or thresholds, yielding different monetary outputs. This is a genuine limitation and it
395 should be framed as such: the reporting framework is a necessary step toward
396 comparability, not a complete solution. Second, the approach can be criticized as
397 adding reporting burden. The defense is that it substitutes for long and inconsistent
398 narrative descriptions by compressing methodological heterogeneity into a format that
399 is easier to compare across studies and potentially easier to encode in databases(26).
400 Third, some will argue that the framework needs explicit integration with uncertainty
401 assessment. The uncertainty literature in ecosystem services is clear that uncertainty is
402 often under-assessed and under-communicated, and that feasible uncertainty practices
403 add value even when models are simple(27,28).

404 Finally, the link to evidence infrastructures such as ESVD is straightforward. Brander et
405 al. (2024)(15) emphasize that synthesized values can inform policy and transfers but
406 require careful consideration of context-specific determinants. A determinant-explicit

407 reporting layer is one way to make such consideration operational at scale, aligning
408 with recent calls for enhanced interoperability in ecosystem service
409 assessments(75,76). If future valuations were reported in a standardized determinant-
410 aware format, databases could become more than repositories of numbers and method
411 labels. They could support structured filtering, comparability screening, and more
412 defensible meta-analytic or transfer applications(16,17). In that sense, the principal
413 value of the framework is not that it produces new monetary methods, but that it makes
414 existing monetary estimates more interpretable, comparable, and reusable under
415 realistic data constraints.

416

417 **Supporting information**

418 **S1.** Framework implementation.

419 **S1A.** Vineyard ecosystem reference template, including the complete ecosystem
420 service catalogue and service-specific logic chains of value determinants.

421 **S1B.** Determinant-coverage overlays for all monetized ecosystem services, including
422 valuation settings, represented determinants, and key omissions.

423 **S2.** Valuation methods and parameterization. Detailed valuation equations, parameter
424 values, data sources, monetary standardization procedures, and assumptions used in
425 the monetary assessment.

426 **S3.** Study area and spatial data. Description of the study area, vineyard spatial
427 characterization, case-study vineyard selection, field observations, and supplementary
428 cartographic information.

429

430 **Declaration of Generative AI and AI-assisted Technologies in the Writing Process**

431 During the preparation of this manuscript, the authors utilized ChatGPT (GPT-4) to
432 assist in drafting and refining certain sections of the text. The authors have thoroughly
433 reviewed and edited the content generated by the tool to ensure accuracy and
434 coherence. The authors accept full responsibility for the content of this publication.

435

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440 **5. Bibliography**

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Table 1. Vineyard template: value-determinant logic chains for monetized ecosystem services.

Ecosystem service (subtype)	Supply-side determinants (Nature)	Supply-side determinants (Management)	Demand-side determinants	Unit price
Crop provisioning services	Vine age; variety; plant health; soil properties; climate (precipitation, temperature)(24)	Vine density and plantation system; soil management practices (e.g., conventional tillage, green cover, no-tillage, organic amendments); irrigation; natural edges; agricultural inputs(24,25,34)	Wine production(35,36)	Market valuation of AO wines(37,38)
Global climate regulation services	Vine age; variety (leaf area index); plant health; soil C concentration; soil fertility; climate(39)	Vine density; soil management practices (tillage/cover/no-tillage, amendments); irrigation; natural edges; agricultural inputs(40–47)	Carbon sequestration demand(3,48)	Carbon market prices(49–52)
Soil & sediment retention (soil erosion control)	Vine age; variety; plant health; rainfall pattern; soil erodibility; slope; slope length(53,54)	Vine density; soil management practices (tillage/cover/no-tillage, mulching, amendments, pruning residues); tillage orientation; irrigation; soil conditioners(40,41,45,55–59)	Demand for agricultural/wood biomass; location of managed water bodies at risk from sedimentation(60,61)	GDP per capita(3,38)
Water purification (water quality amelioration)	Vine age; variety; plant health; rainfall pattern; soil erodibility; slope; slope length(45)	Vine density/plantation system; soil management (tillage/cover/no-tillage, residues, amendments), irrigation; soil conditioners(40,55,56,58,59,62,63)	Demand for cleaner water for different uses(60,61)	GDP per capita(3,38)
Recreation-related services	Landscape quality; biodiversity; water and air quality(64,65)	Accessibility and site management; recreational forestry/green infrastructure; integration with planning(66,67)	Accessibility; location of users; demand for outdoor recreation(68–70)	GDP per capita; “uniqueness”(38,67,71)

Table 2. Monetary ecosystem service valuation in vineyards of Castilla y León by Appellation of Origin (AO) (EUR, 2023).

AO	Area_ha	Provisioning	Regulating and Maintenance			Cultural	Total_EUR	Total_EUR_yr
			<i>Climate regulation</i>	<i>Soil erosion</i>	<i>Water purification</i>			
Arlanza	314	405.4	290.1	27.9 – 1,120.4	2 - 37.3	347.9	1,242.8	390,264.4
Arribes	294	283.8	290.1	23.6 - 945.2	2.6 - 33	253.3	1,041.1	306,100.8
Bierzo	225	405.4	290.1	12.7 – 1,336.4	10.9 - 148.6	79.8	1,111.1	250,013.2
Cigales	1894	270.3	290.1	12.3 - 803.3	2.5 - 6.6	84.6	769.7	1,457,900.5
Ribera del Duero	25,568	601.3	290.1	11.3 – 3,685.8	1.3 - 34.8	232.5	1,368.1	34,979,561.3
Rueda	20,724	277.0	290.1	4.4 - 673.7	1.4 - 14.3	41	671.5	13,916,228.6
Sierra Salamanca	122	337.8	290.1	50.9 – 2,746.7	6.7 - 96	610.3	1,943.8	237,144.6
Tierra del Vino Zamora	604	297.3	290.1	18.2 - 310.4	1.9 - 6.2	123.3	806.1	486,927.6
Tierras de León	1,225	371.6	290.1	3.7 - 408	1.5 - 13.7	60.8	803.7	984,642.0
Toro	5,389	432.4	290.1	4.9 - 733.8	2.1 - 25.8	280.4	1,101.1	5,934,339.6
Valles Benavente	155	304.0	290.1	11.4 - 724.9	0.8 - 67.1	480.4	1,198.3	185,740.7
Valtiendas	100	540.5	290.1	16.2 - 724.9	3.2 - 17.2	744.6	1,752.6	175,269.3
Not an AO	24,399	270.3	290.1	9.7- 2,397.16	1.26 -168.8	3.1	866.9	21,152,636.1
Total							14,677.4	80,456,769.2

Table 3. Example of valuation workflows and determinant coverage disclosure for monetized services (carbon sequestration vineyard demonstration). In red, determinants represented in AO valuations; in blue, determinants also represented for the ten vineyard valuations (and not for the AO valuations).

SEEA (Subtypes)	Economic valuation						Determinants that define availability of the ecosystem service		Determinants that characterize demand	
	Valuation method (SEEA EA)	Proxy method	Spatial resolution	Economic valuation (Mean EUR ha ⁻¹ yr ⁻¹)	Factors included in the proxy method	Ecosystem service physical metric	Natural determinants	Management determinants	Use determinants	Unit price determinants
Global climate regulation services	Methods where the price for the ecosystem service is directly observable: Direct observed values	SOC rate and carbon market prices	Vineyard	290 EUR ha ⁻¹ yr ⁻¹	SOC rate; Emission price	Net carbon balance in t C eq	vine age, variety (different leaf area index), plant health, C concentration in soil , soil fertility, climate (precipitation, temperature)	Vine density and plantation system; Soil management practices : type (conventional tillage, green cover* , no-tillage , organic amendments), coverage, characteristics, years applied; rainfed/irrigated; natural edges; agricultural inputs	Carbon sequestration capacity	Carbon market prices

Table 4. Impact of valuation-boundary refinement on monetary outcomes: Contrasting regional proxy-based estimates with field-verified valuations. Note: CC: cover crop; C: conventional management.

ID	AO	Management	Climate Regulation (€/ha)		Erosion control (€/ha)	
			Regional (Proxy)	Refined (Local)	Regional (Proxy)	Refined (Local)
V01	Arribes	CC	290	368,8	213,59	250,46
V02	Arribes	C	290	290	93,38	93,38
V03	R. Duero	CC	290	368,8	65,41	76,7
V04	R. Duero	C	290	290	240,83	240,83
V05	R. Duero	C	290	290	31,84	31,84
V06	Rueda	CC	290	368,8	21,32	25
V07	Rueda	C	290	290	62,03	62,03
V08	Rueda	C	290	290	17,17	17,17
V09	Toro	CC	290	368,8	93,98	110,2
V10	Toro	C	290	290	26,6	26,6

Figure 1. Workflow of the reporting framework. A reusable ecosystem-specific template provides a service catalogue and service-specific logic chains listing value determinants on the supply and demand sides. A data-driven valuation produces monetary estimates using opportunistic evidence and standard valuation settings. The overlay maps each valuation workflow onto the template to disclose determinant coverage and key omissions, yielding a valuation-boundary profile reported alongside monetary estimates.

A. Ecosystem-specific template

Conceptual, reusable scaffold

A1. Ecosystem service catalogue

- List of services plausibly provided by the ecosystem type.
- Includes services monetized and not monetized in the demonstration.

A2. Logic chains with value determinants

- Supply-side: Nature determinants; Management determinants
- Demand-side: Beneficiaries; Socio-economic conditioners (Value relevant)

B. Data-driven valuation

Opportunistic evidence, standard settings

B1. Opportunistic inputs

- Spatial layers (e.g. vineyard extension)
- Published coefficients/literature values
- Official statistics (e.g. prices, tourism)

B2. Valuation settings

- Unit prices/unit costs; Discount rate (if applicable)
- Price-year standardization (CPI/HICP)

B3. Monetary outputs

- Service values reported as $\text{€ ha}^{-1} \text{ yr}^{-1}$
- Reported with key valuation settings

C. Reporting overlay

Determinant coverage disclosure

C1. Map valuation to template

- Link each service estimate to its template logic chain
- Trace which determinants are represented in the workflow

C2. Disclose determinant coverage

- Highlight represented determinants within the logic chain
- List key unrepresented determinants (omissions)
- Produces a service-specific valuation boundary profile

Example output (one service):

- $\text{€ ha}^{-1} \text{ yr}^{-1}$ + Logic chain with highlighted determinants
- Key omissions: management practice, beneficiary exposure

Outputs delivered by the demonstration (reported in main text + appendices)

Vineyard template artefact (S1, Appendix A)

Monetary results table (Main text)

Boundary profiles / overlays (S1 Appendix B)

Figure 1