Watershed-Scale Environmental-Economic Accounting: Bridging SEEA-CF and SEEA-EA in a Data-Scarce Developing Country

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Abstract

This paper presents a watershed-scale methodology for bridging the System of National Accounts and ecosystem accounting, developed for discussion at the London Group on Environmental-Economic Accounting. It disaggregates national GDP to watershed and sub-watershed levels using nighttime light imagery, land use, and national accounts data, extending the authors' prior work, and integrates water-related ecosystem services, modeled with InVEST, across Guatemala's 62 river basins. A cluster analysis of these variables produces five basin typologies proposed as Ecosystem Accounting Areas (EAAs), operationalizing an underspecified SEEA-EA concept. Its original contribution is an industry-level water supply and use table and water-use intensity indicators for each EAA, serving as dependency proxies for ecosystem service flow accounts. Results show that Supply and Use Table data can be disaggregated to non-administrative units such as watersheds, supplying the monetary counterpart linking SEEA-CF flow accounts to SEEA-EA extent and condition accounts. The indicators further link SEEA-CF supply and use tables to the pressure and dependency accounts envisioned in the SEEA-CF update. A validation against Guatemala's official regional GDP accounts confirms strong overall correspondence alongside a capital-region bias. Guatemala's ecological wealth, socioeconomic disparity, and limited statistical capacity make it a demanding test case for a replicable methodology for data-scarce countries.

Keywords: Ecosystem Accounting Areas; water use intensity; SEEA Central Framework; watershed accounting; nighttime lights; System of National Accounts

1. Introduction

Guatemala has built environmental-economic accounts for two decades. The Sistema de Contabilidad Ambiental y Económica (SCAE) began in 2006 through an interinstitutional agreement between the Banco de Guatemala (Banguat) and the Instituto de Investigación en Ciencias Naturales y Tecnología at Universidad Rafael Landívar (IARNA-URL). The Instituto Nacional de Estadística and the Ministerio de Ambiente y Recursos Naturales joined the agreement later (Castañeda, 2026). The SCAE Central Framework component has included land and ecosystem accounts since its inception, alongside forest, water, energy, and emissions accounts. This trajectory was strengthened between 2014 and 2019 through the WAVES partnership, which produced Guatemala's first physical and monetary ecosystem service accounts (Banco Mundial et al., 2021). This institutional continuity places Guatemala among the more advanced implementers of the System of Environmental-Economic Accounting (SEEA) in Central America, yet it also exposes a structural limitation that this paper addresses directly.

The limitation is spatial. The SEEA Central Framework (SEEA-CF) measures environmental assets and their stocks, typically at the national level, while the SEEA Ecosystem Accounting standard (SEEA-EA) extends this measurement to the flows of ecosystem services entering the economy (United Nations et al., 2021). Compiling that extension requires a spatial unit that the System of National Accounts (SNA) does not supply. National accounts report Gross Domestic Product (GDP) for the country as a whole, while ecosystem services and disservices are generated and experienced basin by basin, shaped by topography, land cover, and hydrology rather than by administrative boundaries (Castañeda, 2026). Without a spatial unit shared by the economic and the ecological sides of the ledger, SEEA-EA's flow accounts cannot be linked to the SEEA-CF and SNA accounts that already exist for Guatemala.

This is not a Guatemala-specific observation. It is, at the time of writing, an open and dated item on the international statistical agenda. The SEEA Central Framework is undergoing a structured revision mandated by the United Nations Statistical Commission in 2024 and expected to conclude in 2028, organized around 29 update issues under the oversight of the United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA, 2025a). Issue A4 of that update, "spatial accounts," is scoped in explicit terms. The July 2025 Technical Committee review note states that "there is no conceptual definition of a spatial or spatially explicit account in SEEA CF, nor any guidance on methods for spatial accounts" (UNCEEA, 2025a, p. 1). It identifies river basins as the paradigmatic case in which "integration of physical data on water at relevant spatial levels... may not align with available spatial detail for economic data" (UNCEEA, 2025a, p. 3). The London Group on Environmental-Economic Accounting reached a parallel conclusion the previous year. A position paper on water accounting recommended developing "integrated physical and monetary supply-use tables linking Central Framework and Ecosystem Accounting" and flagged spatial explicitness as a cross-cutting requirement for that work (Vardon et al., 2024, Recommendation 5).

This paper responds to that open agenda item with evidence from two linked studies conducted in Guatemala. The first disaggregates national GDP for 2020 to the department, municipality, watershed, and sub-watershed levels. It combines VIIRS nighttime light imagery with national land use and land cover data and Guatemala's Supply and Use Table (Reyes et al., 2026). The second models water yield and sediment retention for Guatemala's 62 river basins using the

InVEST suite. It links these ecosystem services to GDP at the basin level and derives a five-cluster basin typology proposed as a set of Ecosystem Accounting Areas (Pinillos et al., 2025). This paper's own contribution builds on both. It reclassifies the physical water yield estimated in the second study onto the industry classification of Guatemala's Supply and Use Table within each Ecosystem Accounting Area. This produces an industry-level physical water supply and use table and a water-use intensity indicator that functions as a dependency and pressure proxy in the sense currently being scoped under Issue B6 of the same SEEA-CF update (UNCEEA, 2025b).

The remainder of the paper is organized as follows. Section 2 situates this paper's Ecosystem Accounting Area concept within the SEEA-EA measurement hierarchy and within the SEEA-CF update's parallel spatial accounting discussion. Section 3 describes the methods of the two underlying studies and the industry-level water supply and use table developed for this paper. Section 4 presents the results, including a validation of the watershed-level GDP estimates against Guatemala's official regional accounts. Section 5 discusses the contribution to the SEEA-CF/SEEA-EA bridging agenda and its limitations, and Section 6 concludes.

2. Conceptual framework

SEEA-CF and SEEA-EA measure different, complementary objects. The Central Framework records stocks and flows of individual environmental assets, mostly in physical terms, organized so that they can be linked to the SNA production boundary (United Nations et al., 2014). Ecosystem accounting instead treats the ecosystem itself as the unit of analysis, recording its extent, its condition, and the flows of services it supplies to the economy and to society (United Nations et al., 2021). To operationalize this, SEEA-EA defines a nested spatial hierarchy. Basic Spatial Units (BSUs) are the fine-grained geometric building blocks, typically pixels or small polygons, at which biophysical data are collected. Ecosystem Assets (EAs) are contiguous areas of a given ecosystem type with distinctive biotic and abiotic conditions. Ecosystem Accounting Areas (EAAs) are the larger, typically fixed, management-relevant territories, such as river basins or protected areas, for which a full ecosystem account is compiled by aggregating the EAs they contain (United Nations et al., 2021).

The two studies underlying this paper implement that hierarchy for Guatemala. BSUs are defined as the raster pixels used by the InVEST water yield and sediment retention models. EAs are the intersection of land use and land cover categories with the economic activities recorded against them in the Supply and Use Table. EAAs are the five basin clusters that emerge from a factor and cluster analysis of GDP, water yield, and sediment dynamics across Guatemala's 62 basins (Pinillos et al., 2025). This paper adopts that Ecosystem Accounting Area terminology throughout, in the SEEA-EA sense just described, and does not use the term to refer to any other spatial concept.

That terminological choice needs to be made explicit because a second, adjacent concept has entered the SEEA vocabulary since Pinillos et al. (2025) was written. The SEEA-CF 2028 update's draft guidance note for Issue A4 proposes a spatial-unit typology distinguishing administrative, natural or ecological, demographic, and economic boundaries. Within it, the note introduces a new unit it calls an “Environmental Accounting Area,” defined as “the geographical territory for which an environmental account is compiled” (UNCEEA, 2025c, para. 97-vi), and explicitly seeking “consistency between spatial elements of SEEA CF and SEEA EA”

(UNCEEA, 2025c, para. 21). The SEEA-CF draft concept and the SEEA-EA Ecosystem Accounting Area used here share an acronym and a family resemblance, but they originate on different sides of the framework and have not yet been reconciled by the UNCEEA Task Team responsible for Issue A4. This paper takes no position on how that reconciliation should proceed. It uses “Ecosystem Accounting Area” exclusively in its established SEEA-EA sense. It offers Guatemala's five empirically delineated basin-cluster EAAs, together with the industry-level water supply and use table constructed in Section 3.3, as a concrete case the Task Team may wish to draw on once that reconciliation is taken up.

The SEEA-CF update also touches this paper's contribution through two further issues. Issue B6, “inclusion of residual flows to ecosystem type,” proposes extending the Central Framework's physical supply and use table so that flows to the environment are recorded “by location, e.g. by ecosystem asset.” The rationale is that doing so would provide “a very tangible link between the accounts of the SEEA CF and the accounts of the SEEA EA” (UNCEEA, 2025b, paras. 2, 7). The proposal is framed around residual and pollution flows rather than resource demand, but the underlying accounting move, attributing a physical flow between the economy and a specific ecosystem type by industry and by location, is the same one this paper makes for water use. Issue D7, “valuation of water,” cross-references Issue A4 directly, noting that because “water resources are ideally accounted for on a catchment basis, the valuation of water will need to consider the ways in which methods can be applied at sub-national level” (UNCEEA, 2025d, para. 12b). This paper does not attempt to value water. It supplies the physical, spatially explicit scaffolding that a future valuation exercise conducted under Issue D7 would need.

Finally, the paper's bridging argument sits within a wider set of recent contributions to the London Group on Environmental-Economic Accounting. A comparable effort links SEEA-EA, SEEA-CF, and the SNA in Namibia through descriptive “bridge tables,” a looser mechanism than the quantitative supply and use table constructed here (Kavezepa, 2025). A general “Sudoku” method for reconciling SEEA-CF and SEEA-EA tables offers a broader frame that this paper's industry-by-EAA table can be read as a worked, single-country instance of (La Notte, 2024, 2025). Ecosystem accounting for land, water, riparian, and mineral resources at the basin scale in a semi-arid setting is the closest prior methodological parallel to the approach used here (Lin, 2024). The use of ecosystem accounts in decision-making across governmental levels is examined elsewhere (Randen & Grimsrud, 2025). This paper returns to that question in Section 5, when discussing the policy relevance of the EAA typology for Guatemalan territorial governance.

3. Materials and methods

3.1 Watershed-scale income accounting

Guatemala's 2020 GDP, as recorded in Banguat's Supply and Use Table, is disaggregated to the department, municipality, watershed, and sub-watershed levels. This four-phase procedure is summarized in Figure 1 (Reyes et al., 2026). The method prepares VIIRS Day/Night Band nighttime light (NTL) imagery for Guatemala and joins it to departmental (IGN) and 2020 land use (MAGA) layers through area-weighted zonal statistics. It then uses NTL intensity as the spatial proxy for non-agricultural economic activity. Unlike the University of Colorado framework it builds on, it omits a separate population layer, on the argument, following Ghosh et al. (2010), that nighttime light emissions already implicitly incorporate the population factor (Reyes et al., 2026).

Figures

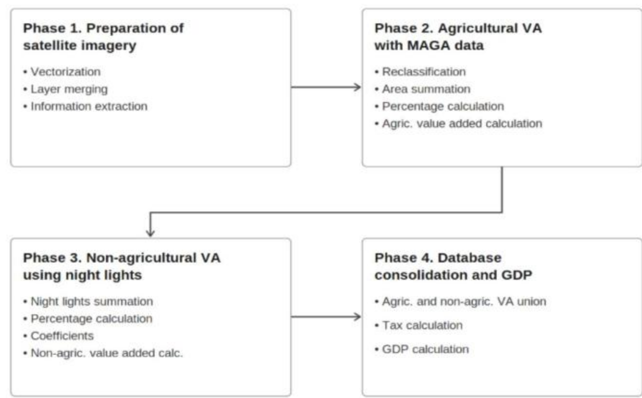

Figure 1

Methodology for GDP Disaggregation Using Nighttime Lights and Land Use Data

Figure 1

Methodology for GDP disaggregation using nighttime lights and land use data

Note. Reproduced from Reyes, Goyzueta, and Castañeda (2026), Figure 1, distributed under a CC BY 4.0 license.

Value added is then distributed across this spatial layer in two steps. Agricultural value added is allocated by matching MAGA land use categories to Supply and Use Table activities through an expert crosswalk, then distributing each activity's value added across polygons in proportion to the polygon's share of that land use category (equation 1).

$$VA_{pa} = A_p \times VA_t \quad (1)$$

where VApa is the polygon's agricultural value added, Ap is the polygon's share of the total area under that activity's land use category, and VAt is the activity's total national value added.

Non-agricultural value added is instead allocated using nighttime light intensity as the spatial proxy, computing each activity's national economic weight and distributing it across polygons in proportion to their share of national luminosity (equations 2 and 3).

$$C = VA_e \,/\, VA_t \quad (2)$$

$$VA_{pna} = NTL_p \times C \times VA_t \quad (3)$$

where C is the activity-specific economic coefficient, NTLp is the polygon's share of national nighttime light intensity, and VApna is the polygon's non-agricultural value added.

Net taxes on products are then allocated in proportion to each polygon's share of total value added, and the resulting polygon-level GDP is aggregated to departments, municipalities, watersheds, and sub-watersheds using the corresponding boundary layers. Figures 2 and 3 show the two spatial layers this procedure combines: national nighttime light intensity, and the resulting distribution of agricultural and non-agricultural economic activity.

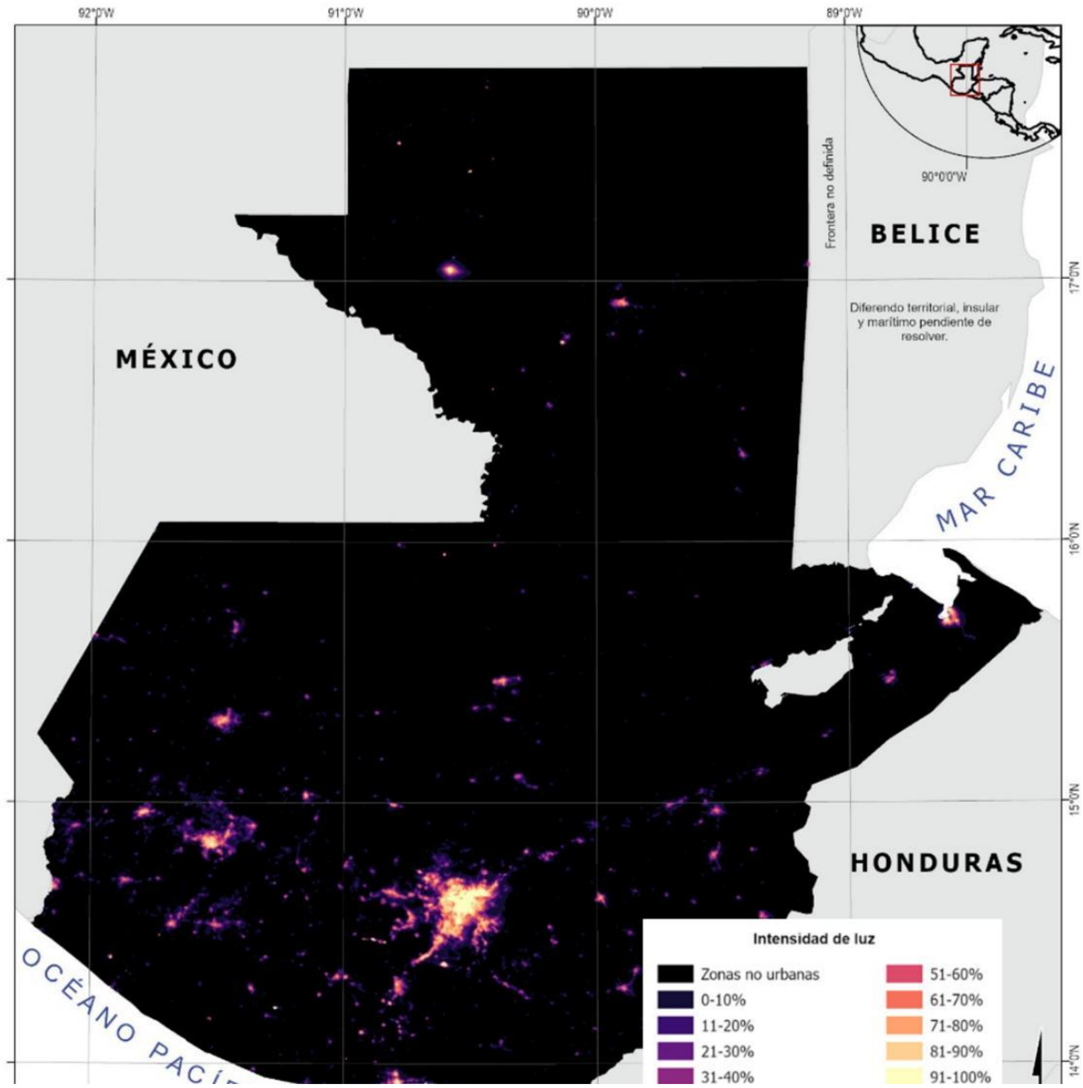

Figure 2

Distribution of nighttime light intensity across Guatemala, 2020

Note. Reproduced from Reyes, Goyzueta, and Castañeda (2026), Figure 2, distributed under a CC BY 4.0 license. Own elaboration based on VIIRS Day/Night Band annual composite imagery (NASA/NOAA, 2020).

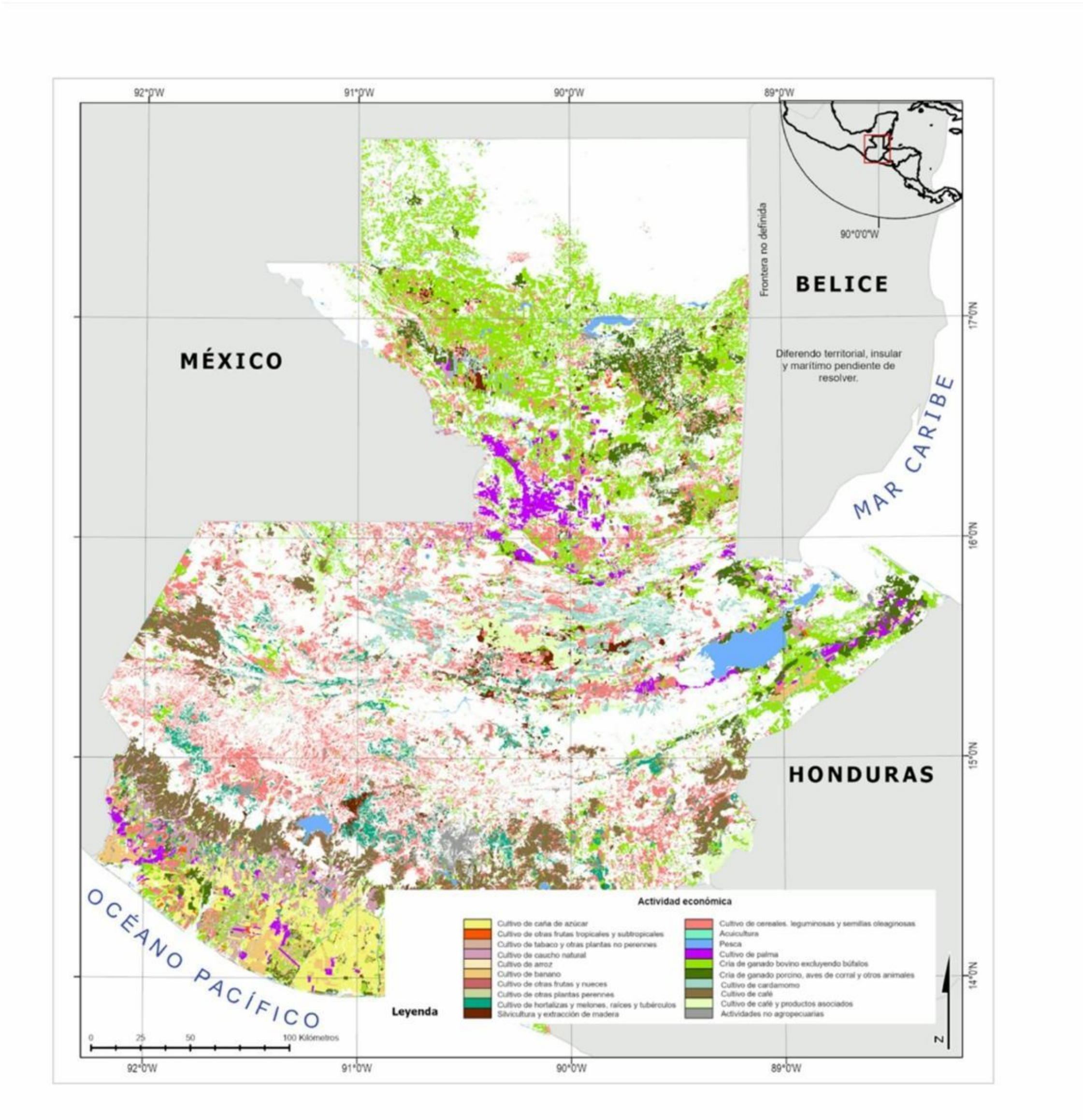

Figure 3

Distribution of agricultural and non-agricultural economic activities in the territory, 2020

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3.2 Water-related ecosystem services and EAA delineation

Two water-related ecosystem services and one landscape disservice are quantified for each of Guatemala's 62 river basins using the InVEST modeling suite (Sharp et al., 2020), for the reference year 2020 (Pinillos et al., 2025). The Water Yield model estimates the annual runoff generated by each pixel as precipitation minus actual evapotranspiration, following the Budyko curve. This runoff is summed to the basin level (equation 4). The Sediment Delivery Ratio model estimates sediment export and retention from the Revised Universal Soil Loss Equation. Soil loss, export, and avoided export, the regulating ecosystem service of sediment retention, follow equations 5 through 7.

$$Y(x) = \left(1 - \frac{AET(x)}{P(x)}\right) \times P(x) \quad (4)$$

where Y(x) is the annual water yield of pixel x, P(x) is total annual precipitation, and AET(x) is actual evapotranspiration, estimated from potential evapotranspiration following Budyko (1974) and Zhang et al. (2004).

$$usle_i = R_i \times K_i \times LS_i \times C_i \times P_i \quad (5)$$

$$E_i = usle_i \times SDR_i \quad (6)$$

$$AEX_i = (RKLS_i - USLE_i) \times SDR_i + T_i \quad (7)$$

where Ri, Ki, LSi, Ci, and Pi are the rainfall erosivity, soil erodibility, slope length-gradient, cover management, and support practice factors for pixel i. SDRi is the sediment delivery ratio, RKLSi is potential soil loss before management and practice factors are applied, and Ti is the upslope sediment trapped on pixel i (Borselli et al., 2008).

Guatemala's 62 basins were then grouped using a factor analysis followed by Ward's hierarchical cluster method. This clustering was applied to GDP, water yield, and avoided, exported, and deposited sediment. Three factors explained 87.5% of the variance among basins: slope (40.2%), vegetation and land cover (34.7%), and economic output (12.5%). The resulting five clusters, summarized in Table 1, are proposed as Ecosystem Accounting Areas (Figure 4 through Figure 6).

Table 1

Basin cluster typology proposed as Ecosystem Accounting Areas, Guatemala 2020

Cluster	Name	Avg. slope (%)	Main land use / cover	GDP (US$ M) / share	Urban area share
1	Boca Costa and southeastern basins	28.8	Annual crops (16%); pastures (15%); forest (15%)	14,729 / 19%	3%
2	Metropolitan, highly urbanized basins	32.3	Coffee (18%); low shrub (17%); pastures (13%)	47,168 / 61%	12%

Cluster	Name	Avg. slope (%)	Main land use / cover	GDP (US$ M) / share	Urban area share
3	Dry shrubland basins	37.6	Low shrub (25%); forest (20%); annual crops (19%)	6,464 / 8%	2%
4	Forested upland basins, low economic activity	43.4	Forest (34%); annual crops (20%); low shrub (16%)	4,848 / 6%	0.8%
5	Forested lowland basins, low economic activity	18.6	Forest (29%); pastures (27%); flooded areas (14%)	4,385 / 6%	0.6%

Note. Adapted from Pinillos et al. (2025), Table 4. GDP shares are of national GDP. Averages of slope and urban area are unweighted basin averages within each cluster. See Pinillos et al. (2025) for the full list of basins in each cluster.

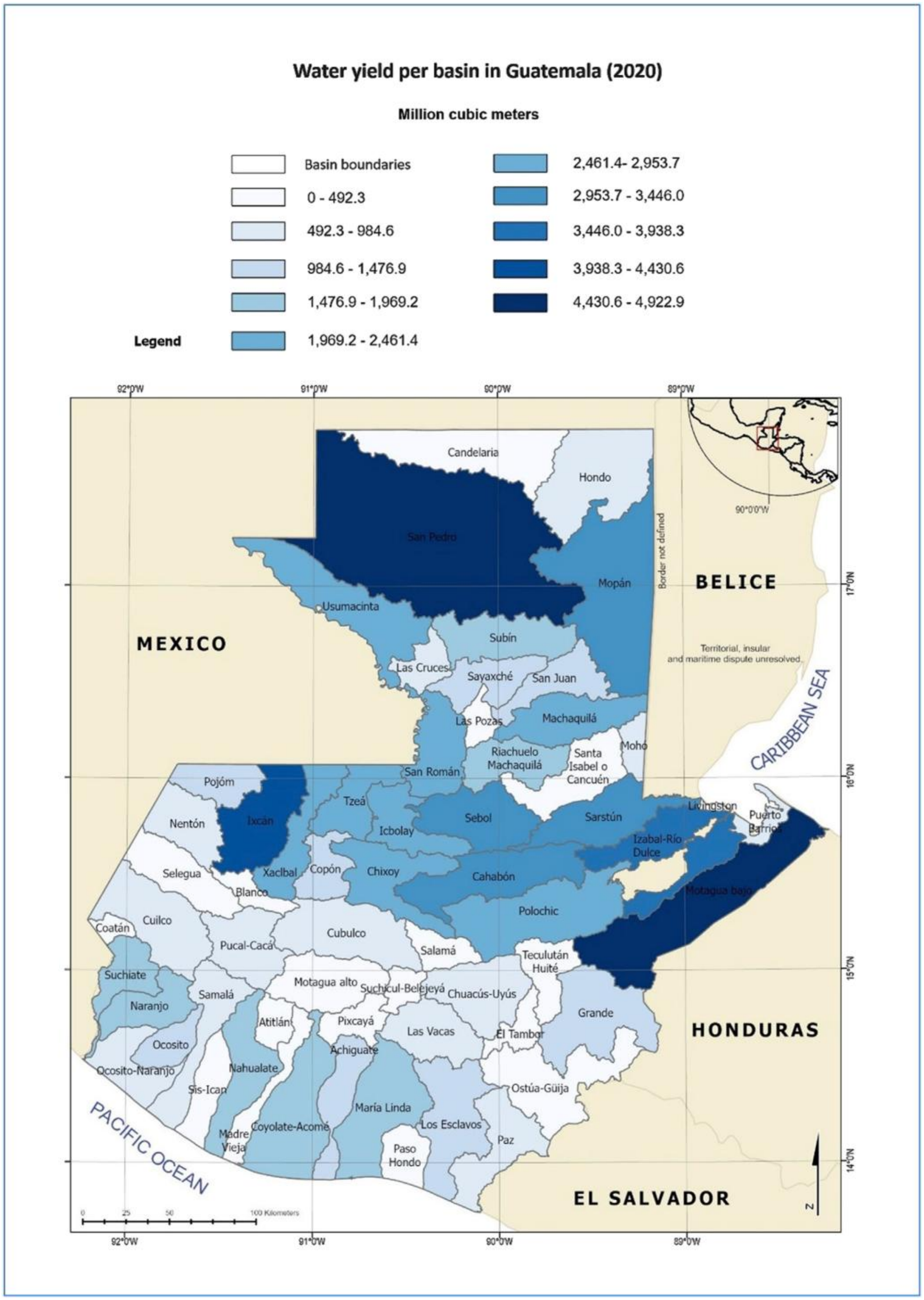

Figure 4

Water yield per basin in Guatemala, 2020

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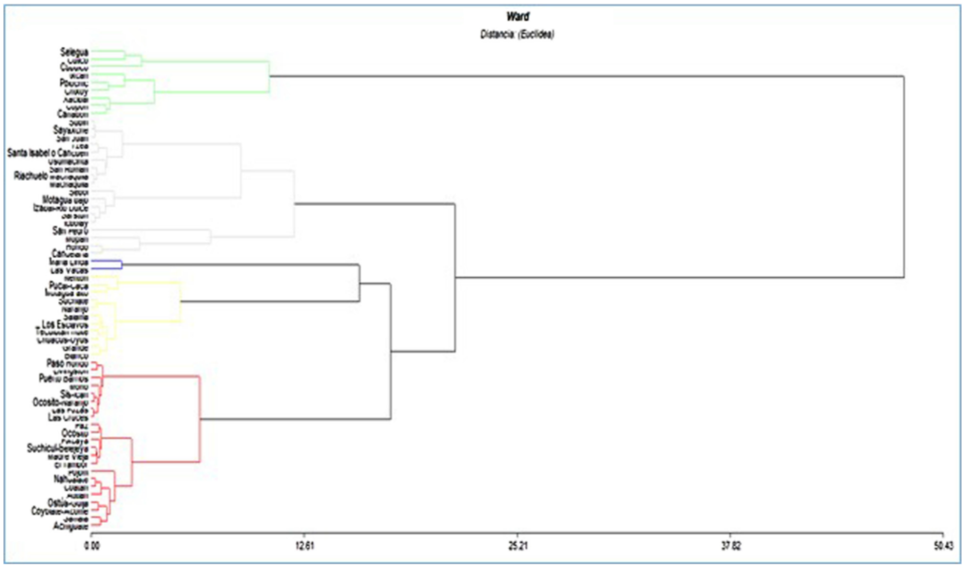

Figure 5

Dendrogram of Ward's method cluster solution for Guatemala's basins

Note. Reproduced from Pinillos et al. (2025), Frontiers in Environmental Science, Figure 5, distributed under a CC BY 4.0 license.

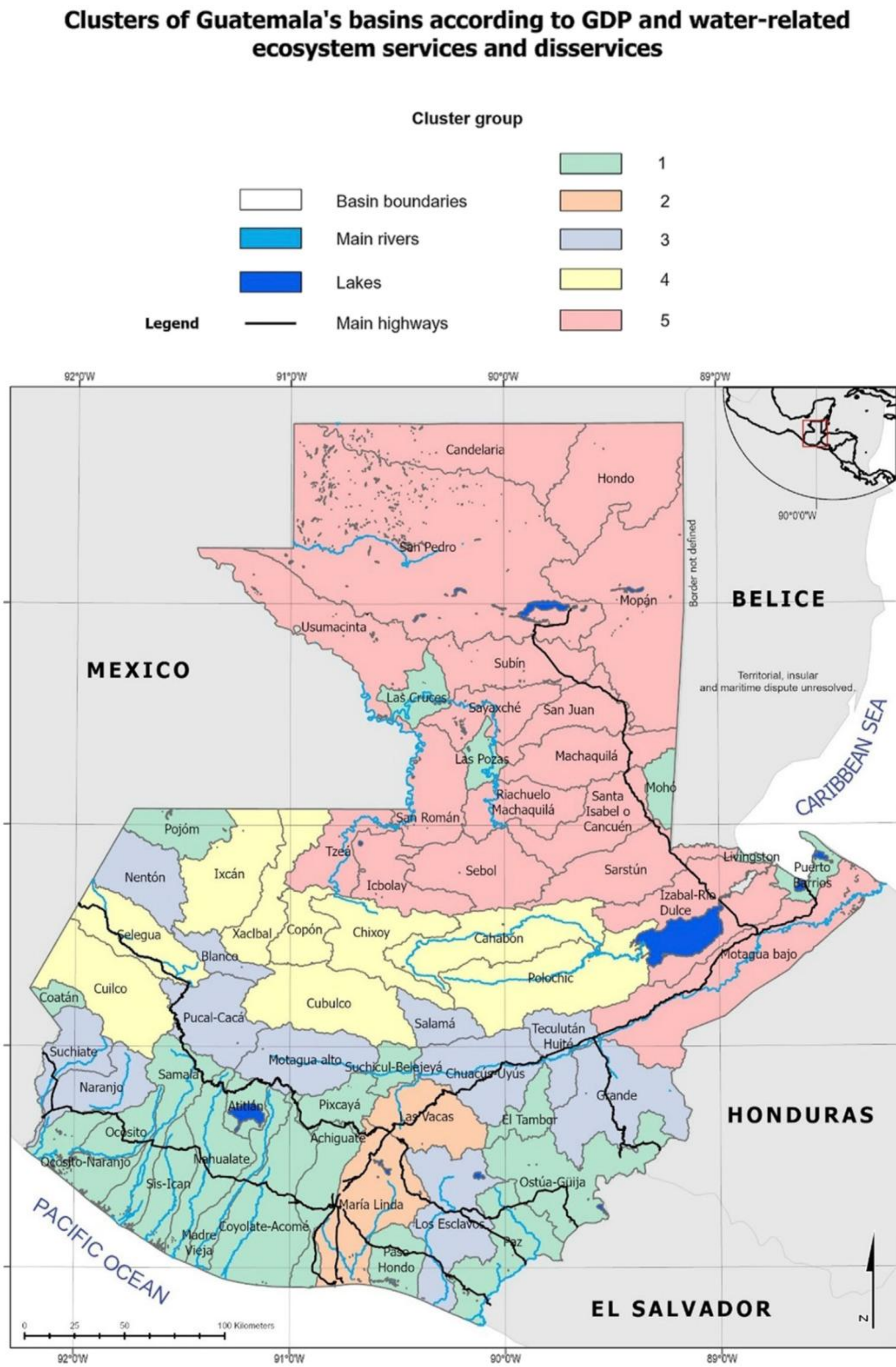

Figure 6

Ecosystem Accounting Areas: basin clusters by GDP, water yield, and sediment dynamics

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3.3 Bridging SEEA-CF and SEEA-EA: an industry-level water supply and use table

A supply table linking water-related ecosystem services to the land use categories associated with each economic sector is compiled in Pinillos et al. (2025, Tables 5 and 6). The same source compiles a water-use intensity index computed at the level of the land use and crop category. This paper extends that work one step further, toward the industry classification used in Banguat's Supply and Use Table itself, so that the resulting indicator can be read directly against gross value added by industry rather than against land use. For each of the 19 primary-sector industries of the International Standard Industrial Classification (ISIC) that could be matched to a specific MAGA land use category through the same crosswalk used in Section 3.1, the physical water yield attributed to that land use within each EAA was summed. This yielded the industry's physical water use. The corresponding industry gross value added within each EAA was drawn from the Supply and Use Table. The ratio of the two defines a water-use intensity index (equation 8), following the same logic as the index proposed by Pinillos et al. (2025) but computed at the industry rather than the crop or land-use level.

$$I_{i,c} = \frac{Wi,c}{Ei,c} \quad (8)$$

where Ii,c is the water-use intensity index for industry i in EAA c, Wi,c is the physical volume of water yield (m^3) attributed to industry i in EAA c, and Ei,c is the gross value added (GTQ) of industry i in EAA c. This index is an author calculation. Its inputs are the physical water yield layer and the industry gross value added figures from Guatemala's 2020 Supply and Use Table, both already used in Sections 3.1 and 3.2, and its full derivation by industry and EAA is provided in the accompanying data annex.

This land-use crosswalk covers only the 19 primary-sector industries whose economic activity maps to a specific MAGA land use category. It does not extend to manufacturing, construction, commerce, or services, since these are not tied to a single land use class in the same way. This is a material gap rather than a minor one. It coincides with Cluster 2, the metropolitan Ecosystem Accounting Area, where these uncovered industries generate the large majority of the 61% of national GDP concentrated there. Sections 4.4 and 5.2 return to what this gap implies for the index's usefulness in exactly the areas where economic weight and water pressure most need to be read together.

This construction performs, for water demand, the same location- and industry-specific attribution that Section 2 describes for Issue B6's pressure account, though it does not measure a residual or pollution flow, and it does not attempt the monetary valuation of water that Issue D7 is scoped around. It is offered as physical, spatially explicit evidence that this kind of industry-by-ecosystem-type attribution is feasible with the data typically available in a middle-income country's national accounts.

3.4 Validation against official regional accounts

Department-level GDP estimates are compared against Banguat's official regional and departmental GDP series, the first official subnational disaggregation of GDP in Guatemala's statistical history (Reyes et al., 2026; Banco de Guatemala, 2025). For this paper, that comparison was recomputed directly against the current published vintage of the Banguat series (2013–2024), matched to 2020, the reference year common to both sources. For each of Guatemala's 22 departments, the department's share of national GDP under the nighttime-light-based estimate was compared to its share under the official series, and the difference in percentage points was computed as an author calculation. The Pearson correlation across department-level GDP values and the Spearman rank correlation across department rankings were computed the same way. Because the two department-level series can diverge only in their internal distribution while both are calibrated to the same national Supply and Use Table total, this comparison tests the spatial allocation step of the nighttime-light method rather than its national control total.

4. Results

4.1 Watershed and sub-watershed concentration of GDP

Guatemala's 2020 GDP, estimated at GTQ600,727 million under the nighttime-light-based method, is highly concentrated in two watersheds. The Motagua watershed, which drains the central highlands and the entire Guatemala City metropolitan area to the Caribbean, accounts for 35.1% of national GDP, and the María Linda watershed, which drains the southern and southwestern metropolitan area and the Escuintla agro-industrial corridor to the Pacific, accounts for a further 32.2% (Reyes et al., 2026). Together, these two watersheds, covering a small fraction of the national territory, generate more than two-thirds of Guatemala's economic output. The Samalá watershed ranks a distant third at 4.5%, and the ten lowest-ranked watersheds together contribute less than 2% of national GDP. This concentration is sharper still at the sub-watershed scale. Within Motagua, the Las Vacas sub-watershed alone, encompassing Guatemala City and its immediate metropolitan fringe, accounts for 28.6% of national GDP, while the remaining Motagua sub-watersheds together contribute only 5.0%.

The spatial mismatch between economic output and territory is stark along every dimension examined. Urban areas, covering under 2% of the national territory, generate 90.2% of GDP, while agricultural land uses, covering 47.6% of the territory, generate only 9.8%. This is precisely the tension that motivates linking GDP to ecosystem accounting spatial units. The watersheds with the least economic weight in conventional national accounts, such as those draining the biodiverse Petén lowlands, are disproportionately significant for water yield and sediment regulation, a relationship examined directly in Section 4.3.

4.2 Validation against official departmental accounts

Table 2 compares the nighttime-light-based departmental GDP estimates of Reyes et al. (2026) against Banguat's officially published departmental GDP series for 2020. The two national totals are nearly identical, GTQ600,727 million against the official GTQ600,123 million, a difference of 0.1%, confirming that the nighttime-light method's control total is consistent with the national Supply and Use Table it is calibrated against. Department-level GDP values correlate strongly across the two sources (Pearson $r = 0.99$), and department rankings are also strongly, though less perfectly, preserved (Spearman rank correlation = 0.93).

The comparison also reveals a systematic bias that qualifies an earlier validation claim. Departmental estimates are described as showing “a high degree of correspondence” with the official series, with the Department of Guatemala reported to account for “approximately 55–60% of national GDP” in both datasets (Reyes et al., 2026). Against the currently published Banguat series, the nighttime-light method places the Department of Guatemala at 58.6% of national GDP, but the official series places it at 42.7%, a difference of 15.9 percentage points, the largest discrepancy of any department (Table 2). Because both series are calibrated to the same national total, this overstatement of the capital department's share is mirrored by an understatement in most other departments. Escuintla is understated by 3.3 percentage points (GTQ34,445 million against an official GTQ54,355 million), and Alta Verapaz, Chimaltenango, Quiché, and Suchitepéquez are each understated to between half and three-fifths of their official value. The direction of this bias, an overweighting of the primary urban core relative to secondary agro-industrial and agricultural departments, is consistent with the light-saturation effect that nighttime-light methods are known to exhibit in dense metropolitan cores (Nordhaus & Chen, 2015). This runs opposite to the effect anticipated in Reyes et al.'s (2026) own discussion of limitations. This paper reports the recomputed figures rather than the earlier validation language, and treats the discrepancy as a methodological finding relevant to any future application of the nighttime-light method to Guatemala's other reference years.

Outside the capital, the correspondence between the two series is close enough to be read as practically negligible rather than merely uncorrelated. For the 21 departments outside the capital, the mean absolute error is 0.9 percentage points, 71% of departments fall within ±1 percentage point of the official share, and 95% fall within ±2 percentage points. Lin's concordance correlation coefficient, a stricter agreement measure than Pearson's r because it penalizes shifts in scale and location as well as weak correlation, is 0.94 across all 22 departments and 0.77 once the capital is excluded, still indicating substantial agreement. A formal equivalence test (TOST) confirms this reading. Because the 22 departments constitute the full national territory rather than a sample drawn from it, a conventional test of the null hypothesis of zero difference mainly detects whether a directional pattern exists rather than whether it is large enough to matter. The more informative test is whether the mean difference among non-capital departments, -0.8 percentage points (SD = 0.8), is statistically equivalent to zero within a pre-specified margin. It is, at a margin of ±1.5 percentage points reflecting typical rounding and estimation tolerance in regional GDP disaggregation exercises ($p < 0.001$ for both one-sided tests). These statistics are author calculations derived from the department-level series reported in Table 2.

Table 2

Departmental GDP, 2020: nighttime-light-based estimate compared to official Banguat series

Department	NTL-based (GTQ M)	Official Banguat (GTQ M)	NTL share (%)	Official share (%)	Diff. (p.p.)
Guatemala	351,839	256,220	58.6	42.7	+15.9
Escuintla	34,445	54,355	5.7	9.1	-3.3
Quetzaltenango	25,557	25,961	4.3	4.3	-0.1
Petén	23,336	17,205	3.9	2.9	+1.0

Department	NTL-based (GTQ M)	Official Banguat (GTQ M)	NTL share (%)	Official share (%)	Diff. (p.p.)
Huehuetenango	21,263	22,116	3.5	3.7	-0.1
Izabal	18,428	19,187	3.1	3.2	-0.1
San Marcos	15,572	20,580	2.6	3.4	-0.8
Alta Verapaz	13,860	24,841	2.3	4.1	-1.8
Sacatepéquez	13,670	13,519	2.3	2.3	0.0
Chimaltenango	10,125	17,437	1.7	2.9	-1.2
Quiché	9,415	17,746	1.6	3.0	-1.4
Chiquimula	8,006	9,279	1.3	1.5	-0.2
Suchitepéquez	7,995	15,979	1.3	2.7	-1.3
Retalhuleu	6,448	11,824	1.1	2.0	-0.9
Zacapa	6,754	10,371	1.1	1.7	-0.6
Jutiapa	6,237	12,553	1.0	2.1	-1.1
Santa Rosa	6,188	12,065	1.0	2.0	-1.0
Sololá	5,377	8,525	0.9	1.4	-0.5
Jalapa	4,694	7,745	0.8	1.3	-0.5
El Progreso	4,400	8,412	0.7	1.4	-0.7
Totonicapán	3,996	7,529	0.7	1.3	-0.6
Baja Verapaz	3,122	6,477	0.5	1.1	-0.6
Total	600,727	600,123	100.0	100.0	0.0

Note. NTL-based estimates are from Reyes et al. (2026), Table 1. Official figures are from Banco de Guatemala (2026), Producto Interno Bruto Regional y Departamental, series 2013–2024, current 2020 value. Comparison (shares, differences, and the correlation statistics reported in the text) is an author calculation. Pearson r = 0.99 (department GDP levels). Spearman rank correlation = 0.93 (department rankings).

4.3 Water-related ecosystem services and basin typology

National water yield in 2020 was estimated at 90,204 million m³, and avoided sediment (sediment retention) at 3,179 million tons, against 306 million tons exported and 1,704 million tons deposited within basin boundaries (Pinillos et al., 2025). The five basin clusters summarized in Table 1 separate sharply along both the economic and the biophysical dimensions. Cluster 2, comprising only the María Linda and Las Vacas basins, occupies 4% of the national territory but generates 61% of national GDP. It is also the cluster with the lowest water yield per unit of area. Clusters 4 and 5, the forested upland and lowland basins with low economic activity, together cover 61% of the national territory and generate only 12% of GDP, while supplying 69% of national water yield and avoided sediment. This inverse relationship between economic weight and ecosystem service supply is the empirical basis for treating the five clusters as Ecosystem

Accounting Areas rather than as an incidental typology. Each groups basins that are similar in GDP and in the biophysical processes, principally slope and vegetation cover, that generate their water-related ecosystem services.

4.4 Industry-level water use and dependency indicators

Table 3 reports the water-use intensity index constructed in Section 3.3 for the 19 primary-sector industries that could be matched to a specific land use category, across the five Ecosystem Accounting Areas. Rice cultivation, cardamom, and the residual category of other animal farming and products show the highest national water-use intensity, each exceeding 5 m³ of water per Quetzal of gross value added, while banana and tobacco cultivation show the lowest, below 0.1 m³ per Quetzal. Pig farming is markedly more water intensive in Cluster 3, the dry shrubland basins, than elsewhere (41.2 m³ per Quetzal against a national figure of 2.8), consistent with that cluster's status as Guatemala's Dry Corridor, where livestock production draws more heavily on a comparatively scarce water supply. One value in Table 3, natural rubber cultivation in Cluster 2 (1,240.8 m³ per Quetzal), is an order of magnitude larger than any other entry in the table. It results from a very small denominator, since Cluster 2's two basins carry almost no rubber-sector gross value added, and it is reported for completeness rather than as a representative sectoral estimate.

Table 3

Water-use intensity index by ISIC industry and Ecosystem Accounting Area (m³ of water per GTQ of gross value added), Guatemala 2020

Industry (ISIC)	1	2	3	4	5	National
Poultry farming	1.52	0.20	0.30	1.36	0.06	0.30
Cattle farming (excl. buffalo)	0.41	0.90	0.93	0.45	0.03	0.21
Pig farming	6.49	12.98	41.20	8.81	0.63	2.78
Other animal farming and products	19.48	1.70	26.18	52.11	1.66	5.43
Rice cultivation	17.60	0.00	3.49	2.68	3.74	6.46
Banana cultivation	0.05	0.09	0.12	0.11	0.16	0.08
Coffee cultivation	0.68	0.55	0.94	0.26	0.62	0.60
Sugarcane cultivation	0.92	0.07	2.59	3.54	86.68	0.94
Cardamom cultivation	11.57	0.00	0.31	0.42	0.49	0.56
Natural rubber cultivation	1.66	1240.82	1.44	7.57	1.96	3.09
Cereal cultivation (excl. rice)	0.50	0.27	0.34	1.38	1.82	1.09
Vegetables, melons, roots and tubers	0.23	0.13	0.10	0.16	0.29	0.18
Other tropical/subtropical fruit	1.90	3.04	2.18	8.49	1.80	2.28
Other fruit and nuts	0.07	3.45	0.32	0.01	0.00	0.30
Other perennial crops	1.42	38.06	1.65	0.02	2.46	1.69

Industry (ISIC)	1	2	3	4	5	National
Oil palm cultivation	0.23	4.88	0.98	0.04	0.76	0.62
Tobacco and other non-perennial crops	0.24	0.55	0.25	0.27	0.32	0.25
Fishing	0.21	0.08	0.30	0.92	0.40	0.36
Forestry, logging and support services	1.00	0.32	1.30	0.30	0.78	0.68

Note. Author calculation. See Section 3.3 for derivation. Columns 1–5 correspond to the Ecosystem Accounting Areas defined in Table 1. Full underlying physical water use (m³) and gross value added (GTQ) figures by industry and EAA are provided in the accompanying Excel annex.

5. Discussion

The two studies synthesized here, taken together with the industry-level table constructed in Section 3.3, respond directly to the Issue A4 gap identified in Section 1. Guatemala's case shows that the two halves of that gap, economic data organized by administrative unit and ecosystem data organized by hydrological unit, can be reconciled without new primary data collection. The reconciliation draws on a Supply and Use Table, a national land use map, and satellite nighttime light imagery that are already standard inputs to national accounts and to InVEST-based ecosystem service modeling in most middle-income countries. The resulting Ecosystem Accounting Areas are the SEEA-EA-side spatial unit that Guatemala's SCAE can now use to compile ecosystem extent, condition, and service flow accounts. The industry-level water supply and use table is the SEEA-CF-side monetary counterpart that Issue A4 identifies as generally missing from country practice.

The industry-level water-use intensity index also speaks to Issue B6 without fully resolving it, performing the same industry-by-location attribution described in Section 2 for resource demand rather than a residual flow. Both face the same practical constraint, that the spatial detail available for physical environmental data rarely matches the spatial or sectoral detail available for the corresponding economic data. Guatemala's experience suggests that a land-use-based crosswalk, of the kind already required to compile agricultural value added under the nighttime-light method, is a workable bridge for both kinds of account. This holds at least for industries whose water use or environmental pressure is closely tied to a specific land use category. It works less well for industries, chiefly manufacturing, commerce, and services, whose economic activity is not land-use specific, an industry coverage limitation discussed further in Section 5.2.

The delineation procedure itself contributes to a second recurring theme in the London Group discussion, the operational definition of an Ecosystem Accounting Area. SEEA-EA, SEEA-CF, and the SNA are linked in Namibia primarily through descriptive bridge tables (Kavezepa, 2025). A general logical structure for reconciling the two systems' accounts is offered by the Sudoku framework (La Notte, 2024, 2025). The cluster analysis used by Pinillos et al. (2025) instead offers a specific, replicable statistical procedure, factor analysis followed by Ward's method applied to GDP and biophysical variables jointly. This procedure derives EAA boundaries from data a country is likely already to hold. Basin-scale ecosystem accounting for land, water, riparian, and mineral resources in a semi-arid setting is the closest available comparator (Lin, 2024). The Guatemalan case extends it by deriving the basin typology statistically rather than administratively. It also couples the typology to a nighttime-light-based GDP layer rather than to official subnational accounts, which in Guatemala's case did not yet exist when the underlying fieldwork began.

For territorial governance, the practical value of the EAA typology lies less in any single indicator than in the combination of Table 1 and Table 3. Cluster 2 concentrates 61% of GDP on 4% of the territory while supplying the least water per unit of area. Cluster 3's livestock sector is unusually water intensive precisely where water is scarcest. This combination gives planners a basis for setting sector- and basin-specific water-use thresholds, of the kind already used in multi-level ecosystem accounting decision processes elsewhere (Randen & Grimsrud, 2025). Guatemala's SCAE institutions, Banguat and IARNA-URL, already maintain the Central Framework accounts for land, water, forests, and biodiversity that such thresholds would draw on. What this paper adds is the spatial unit, the Ecosystem Accounting Area, that lets those accounts be read against economic output at a scale finer than the nation as a whole.

5.1 Issues for discussion

This paper closes with three questions for the London Group's consideration, each tied directly to an open point on the SEEA-CF 2028 update's agenda. The naming question comes first. Should the Task Team working on Issue A4 retain SEEA-EA's established term “Ecosystem Accounting Area” in its forthcoming guidance, rather than introduce the near-homonym “Environmental Accounting Area”? The two concepts sit on opposite sides of the framework and have not yet been reconciled, and this paper's own view is that the reconciliation should favor one established term over two similarly named ones. A second question concerns Issue B6. Does the industry-by-EAA water-use intensity index constructed in Section 3.3 offer a workable template for the pressure account envisioned there, or does attributing resource demand raise structural issues that attributing residual and pollution flows does not? A third question is one of transferability. Do member countries facing comparable data constraints, a national Supply and Use Table, a land use map, and satellite nighttime light imagery but little else, see this crosswalk approach as adaptable to their own basins and industries? Which national circumstances would most complicate that adaptation?

5.2 Limitations and further research

Several limitations bear on how these results should be read. The InVEST Water Yield and Sediment Delivery Ratio models operate on annual averages, so they do not capture the seasonal and event-driven variability that characterizes Guatemala's climate, including its pronounced rainy season and its recurrent extreme events, and the sediment model excludes gully, bank, and mass-movement erosion (Pinillos et al., 2025). The nighttime-light method used to disaggregate non-agricultural GDP is subject to light saturation in dense urban cores. Section 4.2's validation exercise suggests that this saturation biases the Department of Guatemala's estimated GDP share upward by roughly 16 percentage points relative to the current official series. This effect runs in the opposite direction from the one anticipated in Reyes et al.'s (2026) own discussion of limitations. Future applications of the method should test for this bias explicitly, including by comparing successive vintages of the official series as they are revised.

The industry coverage gap noted in Section 3.3, the crosswalk's silence on manufacturing, construction, commerce, and services, is the most consequential limitation for the metropolitan Ecosystem Accounting Area, where those industries dominate. Extending the crosswalk to them would likely require geolocated business registry or establishment-level data that were not available for this study, a constraint shared with Reyes et al.'s (2026) treatment of non-agricultural GDP more generally. Finally, this paper does not attempt to value water in monetary terms, in line with Issue D7's own assessment that this remains an open, and largely unresolved, area of SEEA methodology (UNCEEA, 2025d). The physical indicators presented here are offered as an input to that future work rather than as a substitute for it.

6. Conclusions

This paper has shown that Guatemala's national Supply and Use Table, its 2020 land use map, and satellite nighttime light and biophysical data can together fill the SEEA-CF spatial-accounts gap that motivated this paper. Together, they yield a set of Ecosystem Accounting Areas, delineated by a replicable cluster analysis of GDP and water-related ecosystem services, with a monetary economic counterpart disaggregated to the same spatial units through nighttime-light-based GDP estimation. It has extended that work with an industry-level water supply and use table and a water-use intensity index that perform, for water demand, the same industry-by-ecosystem-type attribution that Issue B6 envisions for residual and pollution flows. It has also validated the underlying GDP disaggregation against Guatemala's official departmental accounts, finding a strong overall correspondence alongside a specific, quantified bias toward overstating the capital department's share. Guatemala's combination of high ecological endowment, significant socioeconomic disparity, and limited statistical infrastructure make it a demanding test of whether this kind of integration is feasible in a data-scarce developing country. The results suggest that it is, and that the resulting Ecosystem Accounting Areas and water-use intensity indicators offer a replicable pathway for other countries advancing SEEA-EA and SEEA-CF implementation under similar constraints.

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