Bioeconomy Accounting: Methods and Pilot Application to 13 Latin American Economies

Abstract

We propose a practical methodology to estimate Bioeconomic Satellite Accounts following the rules outlined in the System of National Accounts for analytical extensions. This methodology reaggregates classifications within the Supply and Use tables of this system to highlight the economic contribution of inputs and outputs driven by biological resources for all economic activities. In contrast to similar studies, we suggest that an *a priori* classification of economic activities as either “bioeconomic” or “non-bioeconomic” underestimates value added by biological resources that fall outside the predetermined activities. Instead, we assess the economic contribution driven by biological resources for all activities and propose direct and indirect methods to rank them according to their importance for bioeconomic policy. We exemplify the methodology with the case of Guatemala and Costa Rica, and we provide estimates for 13 economies of Latin America and The Caribbean.

## Introduction

In 2018, the Costa Rican Government published that country’s National Bioeconomy Strategy, following an internationally agreed definition crafted in the context of the German Bioeconomy Council (German Bioeconomy Council, 2018), which states that the Bioeconomy is:

“The production, use, conservation, and regeneration of biological resources, including the knowledge, science, technology, and innovation related to these resources, to provide information, products, processes, and services to all economic sectors, with the goal of advancing toward a sustainable economy (Gobierno de Costa Rica, 2020).”

Additionally, this strategy defines “biological resources” within the framework as **i)** biomass cultivated to produce food, fodder, fibers, and energy; **ii)** biomass from marine resources and that produced through aquaculture; **iii)** forest biomass, especially that cultivated for use in the forestry and paper industries, as well as that legally extracted from natural ecosystems; **iv)** residual biomass from the agricultural, fishing and aquaculture, forestry, and agro-industrial sectors; **v)** biomass that can be recovered from urban waste; **vi)** liquid waste from livestock and human activities; and **vii)** terrestrial and marine biodiversity, including the biodiversity of inland waters.

Public policies informed by data have been shown to provide opportunities to build upon what works and understand why it works (Bowers & Testa, 2019). While Costa Rica has a long tradition in the production of environmental accounts (BCCR, 2021b) following the System of Environmental and Economic Accounts—SEEA—(European Commission, Economic Cooperation, Development, United Nations, & World Bank, 2013), their Environmental Accounts Council identified a gap in the assessment of the direct and indirect contribution of biological resources to the economy that officials needed to close to design better policies around the subject.

Given the richness of information regarding biological resources that is collected to assess the economic performance of the country, we were granted the opportunity to close this gap by extending the System of National Accounts (SNA), the framework with which Gross Domestic Product (GDP) is measured, among many other indicators, to highlight the contribution of those resources through Bioeconomy Sataellite Accounting (BSA) for Costa Rica (Vargas, Alvarado, Rodríguez, Rodríguez, & Wander, 2022). The SNA manual (European Commission et al., 2009, p. 523) provides clear guidelines on how to develop analytical extensions—specifically *Key Sector Accounts* and *Satellite Accounts*—and we chose to adhere to those guidelines to avoid deviations from SNA’s concepts and accounting rules and mantain comparability with traditional economic indicators. In particular, we focused on reaggregating classifications of the Supply and Use Tables (SUTs) that provide detail for what is known as the production account within SNA.

This strict adherence to the principles of SNA and the standarization procedure developed to handle SUT data in the case of Costa Rica, allowed us to readily extend this exercise to 13 Latin American economies. This was possible because these economies have made their Supply and Use tables publicly available and this information has been centralized in a repository (ECLAC, 2021). Relying on the SNA principles, definitions, classifications, and accounting rules also gave us an opportunity to express results related to the Bioeconomy using concepts that are easily understood by policy-makers because of their widespread use in economic performance communications and analysis.

## Data and Methods

### Supply and Use Tables as data sources

The main source of information for BSAs are SUTs from SNA (European Commission et al., 2009), which are multi-dimensional matrices that show in great detail the production and import of goods and services by economic activities in a country and how those are used, either in the production process itself as inputs, by other agents in the economy, or by the rest of the world. The different areas of these tables describe a flow of transactions in the economy. All transactions (columns) show detailed information for all products (rows) identified in a given economy. The production transaction in the Supply Table and the intermediate consumption transaction in the Use Table are further disaggregated by economic activities (columns). The detail of products is arranged according to national adaptations of the Central Product Classification—CPC—(United Nations, 2015) and economic activities are arranged according to the International Standard Industrial Classification of All Economic Activities—ISIC—(United Nations, 2008).

In the case of the Supply Table, the sequence of those transactions (columns) describes a flow where different products (rows) are produced by economic activities at basic prices (i.e., the price at the farm gate, factory, or commercial establishment). This output is then combined with imports free of insurance and freight costs to form the supply at basic prices. However, this is not the price paid by economic agents. In its way to market, taxes on products are added to the basic price supply, minus any subsidies received, followed by distribution margins (transportation and trade costs). This results in the total supply at purchaser’s or market prices, found in the last column of the table, which represents what is available for purchase by the same economic agents in the use table. For these additional columns of transactions, the product detail (rows) is mantained, but not the economic activity detail.

The Use Table shows how the supply from the last column of the Supply Table is purchased by economic agents for various purposes at market prices, expressed in the form of different transactions. Similar to the production above, this table shows Intermediate Consumption, which refers to the purchase of inputs by economic activities used to produce the goods and services in the first table (essentially, the production recipe for each economic activity). The portion of the supply that does not become an input in the production process remains available on the market for other domestic and foreign economic agents. The other transactions in the remaining columns illustrate that these goods and services can be exported; consumed by households, nonprofit institutions serving households (NPISH), and the general government; or they can be used as durable goods in gross capital formation; moved in or out of storage to be consumed in a different accounting period (changes in inventories); or get sold as valuable items. It is important to note that, row by row (product detail), the Total Use column equals the last column of the Supply Table, adhering to the economic principle of equality between supply and demand.

### Characterizing the Bioeconomy using product classifications: a two step procedure

Countries use adaptations of the international classifications of economic activities and products to focus on those elements that are important to their economic structure. In most cases, there is a one-to-one correspondence between international classifications and their national adaptations. However, this is not always the case, because there might be key national activities and products unique to the country that do not have an international counterpart. In other cases, there could be a match at one level of disaggregation but not at another, due to the way some categories are combined. This is reflected, for example, in the vertical integration of certain industries where the same economic activity produces a primary sector good while it also provides services related to that production in a manner that’s indistinguishable in their financial statements, making it practically impossible to separate them. This, for example, could result in a product category comprising a mix of codes from an agricultural division and a services division. For this reason, it is necessary to follow a two-step procedure:

* In the first step, we compare the different products from the CPC classification against the internationally agreed definition of the Bioeconomy shown in the introductory paragraphs (German Bioeconomy Council, 2018), in general, and that of biological resources in particular (Gobierno de Costa Rica, 2020), and we decide whether the product matches any of its parts conceptually. It should be clarified that, at the highest levels of disaggregation, certain services, which may not initially appear to be directly related to the Bioeconomy, have been taken into consideration in this first step, based on the argument that they could not exist without the prior existence of a Bioeconomic product. For example, the category *62123 Retail trade services of meat, poultry, and game in non-specialized stores* refers to a trade service, but its purpose and existence are so closely tied to bioeconomic products that it could not exist without the prior production of *21111 Fresh or chilled beef* or *21121 Fresh or chilled chicken* one step back in the supply chain, as well as *02111 Cattle* and *02151 Chickens* two steps back in the production chain. For this reason, these have been categorized as Characteristic of the Bioeconomy. This is also consistent with the Bioeconomy definition, which includes services. Nevertheless, national adaptations in the following step do not have this level of disaggregation and thus a binary approach, even with these caveats, is impossible and we resort to the creation of a partial category termed Extended Characteristic of the Bioeconomy. Resulting equivalence tables are included in the Supplementary Information (SI) section.
* In a second step, we analyze each element of the national product classification and evaluate how each corresponding code aligns with the binary identification from the international classification of previous step. Often, national classifications bundle together product categories at a level that is sensible for field or record data collection. This results in three possible outcomes 1) 100% of the products within the national category belong to the Bioeconomy, according to the international classification (Bioeconomy products); 2) only some of the products within the national category belong to the Bioeconomy, according to the international classification (we call those Bioeconomy Extended products); and 3) none of the activities or products within the category belong to the Bioeconomy, according to the international classification (Non-Bioeconomy Products).

Once this rearrangement is completed, we describe the Bioeconomy using traditional macroeconomic aggregates like output, intermediate consumption, imports, exports, taxes on products, and gross capital formation disaggregated for Bioeconomy products, Bioeconomy Extended products, and Non-Bioeconomy products.

### Bioeconomic Value Added and GDP: a divergence from other studies

The output of every economic activity less its intermediate consumption (its inputs) leaves a remainder called Value Added, which is then available for distribution among the owners of capital, laborers, and the government. Value Added is similar in business accounting to the concept of profits, which are what remains after deducting costs from total sales. The only difference is that in National Accounts, payments to employees are not deducted as costs. The sum of the individual Value Added of all economic activities, plus taxes, less subsidies, equals GDP. One important fact about Value Added is that it is calculated by economic activity and not by product and this poses a challenge for the Bioeconomy.

Initial efforts in the nascent gray literature classify economic activities as Bioeconomic or Non-Bioeconomic *a priori* based on whether their primary production is a bioeconomic product or not, as defined in the previous section. Then they add together, either all, or a fraction of their Value Added (VA) as a proxy for the “Bioeconomic GDP”. We understand that this approach as a necessary compromise, because “biological resource” is a quality of products, but VA and GDP are aggregates that are estimated at the economic activity or total economy level. While these first approximations have provided valuable estimates of the size of the Bioeconomy, this *a priori* determination of bioeconomic activities has at least three important limitations.

1. Within SUTs economic activities can produce more than one product and, in turn, any product in the Economy can be produced by more than one activity. Bioeconomic products could be part of the secondary production of activities that have not been deemed as Bioeconomic. Since the value added of these activities is not included in the estimation of the Bioeconomy, this would lead to an under estimation of the contribution of bioeconomic products.
2. Secondary production of Non-Bioeconomic products within an activity classified as Bioeconomic *a priori* could be a non-trivial share of its output. Taking that activity’s entire Value Added as Bioeconomic would lead to an over estimation of the contribution of bioeconomic products to the total economy.
3. *A priori* classification of economic activities as Bioeconomic is based on observed values at the time of compilation. There are activities in the present that might not have biological inputs or outputs, but which could have them in the future. For example, in a given country, there might be zero biological resources used in construction, rendering that activity as non-bioeconomic, but with the advent of biomaterials and other innovations, this could change in the future and housing could be constructed with “live” materials. Not belonging to the Bioeconomy at the time of first compilation, these future developments would be overlooked. Alternatively, reclassifying them as Bioeconomic o Bioeconomic Extended in the future would introduce inconsistencies to time series.

Instead, we propose that the Bioeconomy within an economic activity is a continuum. All economic activities might use, as part of their production recipe between 0 and 100 percent of bioeconomic inputs for the production of its output, which can itself be between 0 and 100 percent bioeconomic. We can then estimate the direct fraction of economic value that is enabled by biological resources by adjusting Value Added by any of these percentages. This leads to a more accurate estimation of the Bioeconomy by minimizing the sources of under or over estimation discussed above.

This is a criteria that we developed only after trying the first approach and finding these pockets of under or over representation of the Bioeconomy outside *a priori* determined bioeconomic activities. Our original estimates for Costa Rica (Vargas et al., 2022) showed that the bioeconomy described with this first method was of about 12.0% of Gross Value Added. Using our proposed approach allowed us to correct our under and overvalued estimation of the Bioeconomy, which resulted in a contribution of 15.7% of Gross Value Added in the case of an output based fraction estimation and 17.2% in the case of an intermediate consumption based fraction estimation.

## Results

This section presents a comparative series of results that highlight the contribution of biological resources to 13 economies of Latin America and the Caribbean, focusing on several macroeconomic aggregates. As an example of the information generated for each country, we provide a compact version of the Bioeconomy SUTs with data from Guatemala for the year 2019—the most recent year available in ECLAC’s repository (ECLAC, 2021)—and insights at economic sector level from the Costa Rican case.

### Bioeconomy SUT: The case of Guatemala

In the Supply Table ([Table 1](#tbl-gtm19-sup)), the most important categories correspond to the output (OP) or the production of goods and services, which are divided into bioeconomy, extended bioeconomy, and non-bioeconomy. For presentation purposes, all 152 products and services from the Guatemalan economy, as published in the ECLAC repository (ECLAC, 2021), are aggregated into these three categories. In the case of the use table ([Table 2](#tbl-gtm19-use)), the same three bioeconomic aggregations are displayed, but this time they represent the intermediate consumption and final consumption of the same 152 products (row data). In other words, purchases of inputs by activities for production (intermediate consumption); purchases of households, nonprofit institutions, and the government as consumers; gross capital formation (i.e. the purchase of durable goods, valuable objects, and changes in inventories); and exports.

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| Table 1: Guatemala: Condensed Bioeconomy Supply Table (Million GTQ at current prices, 2019) |

Transactions: OP. Output; IM. Imports; C/F. CIF/FOB Adjustment; T/S. Taxes less subsidies; MR. Trade and transport margins. Groups of Activities: A. Agriculture; B. Mining; C. Manufacturing; D-E Other Utilities & Water; F. Construction; G. Wholesale and Retail Trade; H-S. Other services.

The flow of information from left to right in [Table 1](#tbl-gtm19-sup) shows output (OP) at producer prices (i.e., the price at the farm gate or factory), to which we then add imports free of insurance and freight costs to form the supply of goods and services in the economy at basic prices. The transactions in the following columns add detail on insurance and freight costs, taxes less subsidies on products, and distribution margins (i.e., transportation and marketing costs), which are added to bring these products to consumers. The last column shows, row by row, the availability of each good and service in the economy at market prices in the case of supply ([Table 1](#tbl-gtm19-sup)), which is equal to total use (in [Table 2](#tbl-gtm19-use)) row by row.

[Table 1](#tbl-gtm19-sup) shows an output of 324.2 billion QTQ in bioeconomic products, which corresponds to 28.7% of the total supply at purchaser’s prices, amounting to 1.128 trillion GTQ. Products from the extended bioeconomy accounted for 152.3 billion GTQ, or 13.5% of the total supply, while non-bioeconomic products represented 651.7 billion GTQ, or 57.8% of total supply. Since SNA operates on the economic principle that supply equals demand, [Table 2](#tbl-gtm19-use) shows that the consumption of each category of products matches those of the Use Table. Taxes (less subsidies) on bioeconomic products amounted to 9.4 billion GTQ and represented 26.1% of total taxes on production (36.1 billion GTQ); extended bioeconomic products accounted for 17.0%, and non-bioeconomic products made up 56.9%.

In absolute terms, non-bioeconomic products represent the largest source of tax revenue, but it is interesting to estimate the implicit tax rate for each type of product. This is done by dividing the taxes collected by the output value of each type of product. This reveals that the implicit tax rate for bioeconomic products is 4.8% of production (9.4 billion / (197.9 billion + 7.8 billion + 0.9 billion), 6.8% for extended bioeconomic products, and 3.2% for non-bioeconomic products. It is important to clarify that this estimated tax rate is not the result of an explicit fiscal policy decision targeting bioeconomic products, but rather the aggregate impact of all the different fiscal policy decisions that have been made in the country over time. Notably, the implicit tax rate is higher for bioeconomic and extended bioeconomic products compared to non-bioeconomic products.

[Table 2](#tbl-gtm19-use) shows a condensed version of the Bioeconomy Use Table, describing all possible destinations—row by row—for the total availability of products shown in [Table 1](#tbl-gtm19-sup). The first seven columns show Intermediate Consumption, with the eighth column showing the subtotal for that transaction. Intermediate Consumption describes the purchase of inputs for production by economic activities. In 2019, this transaction amounted to a total of 369.7 billion GTQ, of which 24.0% corresponded to the purchase of bioeconomic products, 13.5% to the purchase of extended bioeconomic products, and 62.6% to the purchase of non-bioeconomic products. Exports amounted to 95.3 billion GTQ (net of CIF/FOB adjustments), with 46.4% corresponding to bioeconomic products, 16.7% to extended bioeconomic products, and 36.9% to non-bioeconomic products. This is understandable for a country where a significant portion of exports consists of agricultural products. Finally, out of 578.3 billion GTQ corresponding to final consumption (net of insurance and freight costs), 32.8% accounted for bioeconomic products, 15.0% for extended bioeconomic products, and 52.2% for non-bioeconomic products.

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| Table 2: Guatemala: Condensed Bioeconomy Use Table (Million GTQ at current prices, 2019) |

Transactions: IC. Intermediate Consumption; EX. Exports; FC. Final Consumption; CF. Capital Formation. Groups of Activities: A. Agriculture; B. Mining; C. Manufacturing; D-E Other Utilities & Water; F. Construction; G. Wholesale and Retail Trade; H-S. Other services.

The remainder that results from subtracting intermediate consumption at purchaser’s prices from production at producer’s prices (which is technically known as gross output) is equal to gross Value Added (see [Table 2](#tbl-gtm19-use)). This is calculated for each economic activity (or column). Gross Value Added is similar to the profit that results from subtracting the cost of inputs (excluding labor) from total sales in a company, but at the level of the entire economy. The sum of the value added by all economic activities, plus total taxes on products, minus subsidies on those products, results in the Gross Domestic Product (GDP). In this case, 926.4 billion – 369.7 billion + 36.1 billion quetzales results a GDP of 592.8 billion GTQ for 2019.

If we were to abide by the *a priori* selection of Bioeconomic sectors, these would account for 17.0% of gross Value Added—i.e. the Bioeconomy’s GDP—, 4.6% for extended bioeconomic activities, and 78.4% for non-bioeconomic activities. However, we have explained the limitations that come with that approach. That’s why we suggest that biological resources, as the natural resource basis of production across *all* economic activities (not just some), can be seen as a spectrum. Each activity can make greater or lesser use of biological inputs. In other words, each activity may have a higher or lower share of bioeconomic products in its intermediate consumption structure and can also produce a mix of products with a higher or lower proportion of bioeconomic content. For this reason, estimating a bioeconomic contribution of 17.0% of Value Added, or 94.8 billion GTQ, overlooks in some way the 997.5 million GTQ in bioeconomic products and the 42.2 billion GTQ in extended bioeconomic products produced by non-bioeconomic activities. It would be more accurate to say that the value added across all sectors was based on 24.0% bioeconomic inputs (as explained earlier in the intermediate consumption analysis), which is a calculation that can be done individually for each sector (for example, agriculture, manufacturing, and trade), without relying on the three bioeconomic classification categories in the columns and instead focusing on the bioeconomic content of products in the rows. The conclusion is that all economic activities can be more or less bioeconomic, whether from the perspective of production or intermediate consumption.

[Table 2](#tbl-gtm19-use) also shows exports, which total 95.3 billion GTQ (excluding the CIF/FOB adjustments row), with 46.4% corresponding to bioeconomic products, 16.7% to extended bioeconomic products, and 36.9% to non-bioeconomic products. This is reasonable for a country where a significant portion of exports consists of agricultural products. Finally, of the 578.3 billion quetzales corresponding to final consumption (excluding CIF/FOB adjustments), 32.8% corresponds to bioeconomic products, 15.0% to extended bioeconomic products, and 52.2% to non-bioeconomic products.

### Disaggregation by Economic Activity

For a more detailed view of the Bioeconomy, we turn our attention to the example of Costa Rica. Bioeconomic SUTs include detailed information on hundreds of products and economic activities. Policy analysis can benefit from this level of disaggregation when conducting sectoral analyses. [Table 3](#tbl-cr18-pharma) shows an example of such a detailed view of the Bioeconomy for the case of the pharmaceutical sector of Costa Rica. [Table 3](#tbl-cr18-pharma) shows that 34.6% of the inputs of this economic activity by value depend on 24 bioeconomic products. An additional 17.5% of its Intermediate Consumption is catalogued as belonging to the extended bioeconomy, while 47.9 percent is accounted for by non-bioeconomic products.

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| Table 3: Costa Rica: Pharmaceutical Sector Bioeconomy Intermediate Consumption (Million CRC at current prices and percent, 2018)   | **Products** | **Value (CRC)** | **Percent** | | --- | --- | --- | | **Bioeconomy (subtotal)** | **30,307.1** | **34.61%** | | Pharmaceutical and medicinal products | 18,845.6 | 21.52% | | Other food products n.e.c. | 4,011.2 | 4.58% | | Prepared animal feed | 2,624.9 | 3.00% | | Paper and paper products | 1,124.2 | 1.28% | | Garments | 1,063.4 | 1.21% | | Food and beverage supply services | 996.0 | 1.14% | | Other milling products n.e.c., starches, and starch derivatives | 582.7 | 0.67% | | Soaps, detergents, perfumes, and toiletries | 253.7 | 0.29% | | Products from non-perennial and perennial plants | 198.5 | 0.23% | | Wood and cork, wood and cork products, except furniture; articles of straw and plaiting materials | 174.1 | 0.20% | | Support services for agriculture, livestock, and post-harvest activities | 133.8 | 0.15% | | Vegetable and animal fats and oils | 107.9 | 0.12% | | Leather and related products, except footwear | 64.1 | 0.07% | | Rubber products | 41.3 | 0.05% | | Cane sugar, molasses, syrups, and other sugars | 39.3 | 0.04% | | Ground coffee, soluble coffee, extracts, and concentrates | 31.5 | 0.04% | | Wastewater evacuation services | 9.5 | 0.01% | | Cocoa, chocolates, and confectionery products | 1.8 | 0.002% | | Wheat flour | 1.5 | 0.002% | | Products from forestry, wood extraction, and hunting | 1.0 | 0.001% | | Eggs | 0.7 | 0.001% | | Dairy products | 0.1 | 0.0001% | | Other fruits, nuts, and other oil-bearing fruits | 0.1 | 0.0001% | | **Extended Bioeconomy (subtotal)** | **15,298.4** | **17.47%** | | Basic chemicals and fertilizers, nitrogen compounds, pesticides, and other agrochemical products | 14,232.3 | 16.25% | | Other manufactured products | 555.7 | 0.63% | | Textile products, except garments | 237.9 | 0.27% | | Waste collection, treatment, and disposal services; material recovery | 107.4 | 0.12% | | Scientific research and development services | 65.6 | 0.07% | | Building cleaning and landscape care and maintenance | 46.7 | 0.05% | | Drinking water | 45.2 | 0.05% | | Waste and scraps | 6.8 | 0.01% | | Footwear | 0.7 | 0.001% | | **Non-Bioeconomy (subtotal)** | **41,960.0** | **47.92%** | | Remaining 68 Non-Bioeconomy products. | 41,960.0 | 47.92% | | **Total Use** | **87,565.5** | **100.00%** | |

Source: Own elaboration based on Costa Rica’s SUTs (BCCR, 2021a).

BSAs can be used to perform this type of exploration for sectors of interest in the context of an economic policy. For example, we can see that biological resources are very important in the case of the processed foods industry, both for *Meat Products* ([Figure 1 (a)](#fig-meat-products)) and *Milk and Dairy* ([Figure 1 (b)](#fig-dairy)) where Bioeconomy products make up 81 and 76 percent of their intermediate consumption, respectively. In contrast, Bioeconomic products account for only 4 percent of the value of intermediate consumption in the *Residential Construction* sector ([Figure 1 (c)](#fig-construction)). Given a policy that provides incentives for the use of innovative biological materials in construction, for example, policy-makers could focus on monitoring the increase or decrease of this share over time.

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| |  | | --- | | (a) Meat products | |  | |  | | --- | | (b) Milk and Dairy | |

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Figure 1: Bioeconomy, Extended Bioeconomy, and Non-Bioeconomy inputs for selected economic activities  (Costa Rica, percent, 2018)

### Comparative analysis for 13 economies of Latin America and The Caribbean

## Discussion

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