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Valuation of water production: an application of the replacement cost and opportunity cost methods

Valoração da produção de água: uma aplicação dos métodos de custo de reposição e de custo de oportunidade

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Abstract: The valuation of Environmental Services (ES-env) related to water yield is a relevant topic for the sustainable use of water in food production and the improvement of State policies. This study aimed to estimate the value of ES-env for water yield within the context of public policies in Brazil, based on a case study in an Agroforestry System (AFS) located in the Cerrado/Atlantic Forest biome. The objectives were: to monetarily measure the ES-env of water yield in a consolidated AFS; and to evaluate two valuation methods, the Opportunity Cost Method (OCM) and the Replacement Cost Method (RCM), both applied to water production. Using the proposed methodological strategy, financial and accounting data were identified, organized in spreadsheets, and processed using IBM SPSS Statistics. Subsequently, the aforementioned methods were applied: first, the OCM, based on five equations supporting the economic valuation of water production; then, the RCM, which involved another five equations enabling the construction of the monetary valuation of the same production. Based on the results obtained from the RCM within the AFS studied, the Water Production Value (WPV) proposal was established, with an estimated value of US$317.42 per hectare per year. Regarding the results found in the application of the OCM, it was proposed to apply the Water Production Value Index (WPVI) in the analysis of economically viable scenarios for the site. Thus, it was concluded that adopting the WPV in Payment for Environmental Services (PES) programs makes water yield more attractive. Moreover, when comparing scenarios, the WPVI was effective in the analysis and decision-making for public policies.

Keywords: water resources; agroforestry systems; environmental services; ecosystem services; payment for environmental services.

Resumo: A valoração dos Serviços Ambientais (SAs) voltados à produção de água é pauta relevante para o uso sustentável da água na produção de alimentos e na melhoria de políticas de Estado. Esta pesquisa teve por objetivo estimar o valor do SA para produção de água, no contexto das políticas públicas do Brasil, a partir do estudo de caso em um Sistema Agroflorestal (SAF) no bioma Cerrado/Mata Atlântica, em que se buscou: mensurar monetariamente o SA de produção de água em um SAF consolidado; e avaliar dois métodos de valoração, o Método do Custo de Oportunidade (MCO) e o Método do Custo de Reposição (MCR), ambos aplicados à produção de água. Com a aplicação da estratégia metodológica, foram identificados dados financeiros e contábeis, inseridos em planilhas e tratados com uso do IBM SPSS Statistics. Após isso, foram aplicados os métodos citados: primeiramente, o MCO, embasado em cinco equações que corroboram a valoração econômica da produção de água; depois, o MCR, que contou com outras cinco equações, desta vez possibilitando a construção da valoração monetária da mesma produção. Mediante os resultados obtidos com o MCR dentro do arranjo SAF investigado, foi constituída a proposta do Valor da Produção de Água (WPV) com valor estimado em US$ 317,42 por hectare ao ano. Quanto aos resultados encontrados na aplicação do MCO, foi proposta a aplicação do Índice de Valoração da Produção de Água (WPVI) na análise dos cenários economicamente viáveis para o local. Assim, foi possível concluir que a adoção do WPV em programas de Pagamento por Serviços Ambientais (PSA) torna a produção de água mais atrativa. Ademais, ao comparar cenários, o WPVI foi eficaz na análise e tomada de decisão junto a políticas públicas.

Palavras-chave: recursos hídricos; sistemas agroflorestais; serviços ambientais; serviços ecossistêmicos; pagamento por serviços ambientais.

1. Introduction

The increasingly evident scarcity of natural resources compels humanity to seek adaptive strategies and sparks intense debate regarding their sustainable utilization (Desta & Lemma 2017; Ndzabandzaba & Hughes, 2017; Del Vecchio & Barone, 2018), with water emerging as one of the most critical topics of discussion. A case in point is the Universal Declaration on the Rights of Water, promulgated by the United Nations (UN), which underscores the vital importance of this resource for humanity (Universidade de São Paulo [USP], 1992).

Given the unequal global distribution of freshwater, the UN has raised alarms regarding the finite nature of this resource (Agência Nacional de Águas e Saneamento Básico [ANA], 2021). This reality drives the scientific community to investigate innovative solutions, such as sustainable extraction, to ensure universal access to water (Garcia et al., 2017; Salem et al., 2017; Chiodi & Marques, 2018; Karandish & Šimůnek, 2018).

Holding approximately 12% of the planet's freshwater, Brazil stands as one of the nations most endowed with water resources (Matsuoka, 2019). This prominence is reflected domestically and demands constant monitoring by the ANA.

In its technical studies, the ANA indicated that irrigation accounts for the largest share of water consumption in Brazil, representing approximately 49.8% of the total (ANA, 2021). However, consumption is rising, and projections for 2035 indicate substantial real losses to the agricultural and industrial chains, estimated at US$ 111.5 billion. These figures were derived from the economic dimension of the Water Security Index (WSI), within a water crisis scenario projected from historical data (ANA, 2020; 2023).

To promote sustainability within the agro-industrial sector, various measures are being adopted, including the diffusion of innovative technologies (Ribeiro et al., 2017). Integrated Systems (IS) and Biodiverse Agroforestry Systems (Biodiverse AFS) exemplify initiatives that synergize agriculture with nature conservation (Gil et al., 2015; Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA], 2017).

AFSs are agroecology-based production systems that combine different crops and species, thereby enhancing the provision of Ecosystem Services (ES-eco) (Padovan et al., 2017; EMBRAPA, 2018; Oliveira et al., 2018), defined as "relevant benefits to society generated by ecosystems in terms of maintenance, recovery, or improvement of environmental conditions" (*Lei nº 14.119*, 2021, p. 1).

Here, further challenges arise – gaps that these services open from an economic perspective, such as their valuation (Paiva & Coelho, 2015; MacDonald et al., 2016; Katko, 2017; Natyzak et al., 2017). Currently, several schools of thought exist, most notably ecological economics, which employs valuation methods and tools such as Payment for Environmental Services (PES).

PES schemes are transaction mechanisms aimed at provisioning Environmental Services (ES-env) – defined as "individual or collective activities that favor the maintenance, recovery, or improvement of ecosystem services" (*Lei nº 14.119*, 2021, p. 1) – through the promotion of incentives based on the provider-receiver model, in favor of the sustainable use of natural resources (Wunder, 2015).

Among the range of options for applying PES, Payment for the Water Provision Service (Water PES) stands out. This involves remunerating rural producers who ensure conditions for water production, such as spring maintenance (Santana & Alvarenga, 2006; Lino, 2009), seedling planting, fencing of springs, and increasing vegetative cover areas, among other strategies.

From this context, demands emerge for more appropriate alternatives to value the water production service (Vilar, 2009; Paiva & Coelho, 2015; Caetano et al., 2016; Chiodi & Marques, 2018), alongside questions such as: which of these could be applied in the context of Biodiverse AFSs (Silva, 2014; Nascimento et al., 2016; Padovan et al., 2017)

This research aimed to estimate the monetary value of the water production environmental service within a Biodiverse AFS situated in the Cerrado/Atlantic Forest biome under the scenario of Brazilian public policies, considering the application of the Replacement Cost Method (RCM) and the Opportunity Cost Method (OCM).

2. Literature Review

2.1. Environmental valuation methods

Initially, upon identifying and classifying Ecosystem Services (ES-eco), the Millennium Ecosystem Assessment (MEA) defined them as nature's contributions to society (Millennium Ecosystem Assessment [MEA], 2005; *Lei nº 14.119*, 2021). In this classification, ES-eco are divided into four categories: Provisioning Services, which refer to goods such as food, water, and energy; Regulating Services, including pest control, flood regulation, and maintenance of the hydrological cycle; Cultural Services, encompassing spiritual, recreational, and aesthetic values; and Supporting Services, which are essential ecological processes like soil formation and nutrient cycling (MEA, 2005).

Consequently, new debates have arisen, for example regarding how to measure and value Environmental Services (ES-env) and Ecosystem Services (ES-eco). This is a complex task that traverses various barriers, including economic, political, and market factors.

Kooten (2018) argues that it is possible to monetarily value every externality. In some cases, the market fails in this valuation, as occurs with ES-eco. However, instruments exist to remedy this, such as economic incentives like PES (Bezerra, 2020).

According to Garcia and Romeiro (2015), attributing value to non-measurable assets like diverse natural resources is complex. Researchers such as Pavan Sukhdev have broadened this horizon with the work The Economics of Ecosystems and Biodiversity (TEEB) and ecosystem asset accounting (Matsuoka, 2019).

Pioneers in the valuation of biosphere ES-eco, Costanza et al. (1997) estimated such services at an average of US$ 33 trillion/year, updating this figure to US$ 125 trillion/year in 2014 and US$ 145 trillion/year in 2019 (Matsuoka, 2019). Costanza et al. (1997) further defend that environmental valuation should be statistical and that each ES-eco has a specific value.

Odum and Odum (2000) goes further, arguing that when valuing an ES-eco, it is necessary to analyze this natural capital in monetary terms.

Authors such as Motta (1997) and Machado (2011) have contributed to the systematization of natural resource valuation. The former sought to classify these natural resources by their use and non-use value. The latter defined several valuation methods, such as the Replacement Cost Method (RCM). The literature contains numerous valuation methods. Machado (2011) lists seven methods and divides them into two major groups: indirect methods, which assess, among other items, degradation and productive capacity; and direct methods, which evaluate market characteristics in greater depth. By way of example, the Travel Cost Method (TCM) is generally used in recreation destinations, being a direct method based on indirect Willingness to Pay (Indirect WTP) (Machado, 2011).

Still according to Machado (2011), in Use Value (UV), valuation is based on the existence of similar goods priced by the market, which can be direct (DUV), indirect (IUV), and option (OV). Like the RCM, DUV is given by visitation, IUV derives from ES-eco such as biodiversity, and OV stems from the option for future use (Machado, 2011). Conversely, Non-Use Value (NUV) represents the existence value of a certain resource, containing Existence Value (EV), which is not associated with use but rather with ethical, moral, and legacy values (Motta, 1997).

For Motta, monetary valuation concerns the price associated with a heritage, service, and/or natural resource, whereas economic valuation is linked to real value. He further argues that “determining the economic value of an environmental resource is to estimate its monetary value in relation to other goods and services available in the economy” (Motta, 1997, p. 227). Therefore, economic valuation is preceded by monetary valuation.

For Viana et al. (2012), this process is reversed; however, for both (Motta, 1997; Viana *et al.,* 2012), valuation stems from the application of specific methods.

Another viewpoint was addressed by Adam Smith (1983), who divided value by its power of use and exchange. For him, a resource with greater use value possesses lower exchange value, and vice versa.

Smith (1983, p. 117) exemplified this relationship with the Water Paradox, where "there is nothing more useful than water". But because it is, in theory, abundant, its exchange value is small compared to a diamond, which "has almost no value regarding its use, but a great quantity of other goods will frequently be found in exchange for it" (Smith, 1983, p. 117). This paradox elucidates that utility and importance are defined by value, not price.

In the context of environmental resources, economic value exists in the tenuous difference between the level of production of these resources and their consumption by society (Motta, 1997). In the case of ES-env and ES-eco, monetary valuation navigates through market gaps, generally allowing for value or price proxies.

In this scenario, valuation models suffer criticism because, by seeking backing from market instruments, they end up being useful as parameters but open up questions and even moral claims (Matsuoka, 2019).

Studies such as those by Spash (2007) propose a new classification, introducing Deliberative Monetary Valuation (DMV), a hybrid model between economic and political approaches.

Along these lines, Ortiz (2018) classifies the main methods into: Revealed Preference (travel cost, hedonic pricing); Stated Preference (contingent valuation, discrete choice); and Avoided Costs and Replacement Costs.

Finally, for Jax et al. (2018), there is no single linear approach to applying methodologies such as valuation, which encompasses the very concept of ES-eco itself.

Given this context, this research offers a broader perspective for the search for solutions, focusing on the valuation of the environmental service.

2.2. Replacement Cost Method (RCM)

The Replacement Cost Method (RCM) is part of the set of indirect methods based on the market for substitute goods. The RCM captures the minimum value of a given environmental resource, providing a snapshot of the cost related to restoring that resource to its original characteristic, under possible conditions (Vergara et al., 2014; Bezerra, 2020).

According to Marques et al. (2005), the RCM can be applied to calculations for restoring eroded soil, since expenditure on nutrients, such as commercial Nitrogen (N), can be measured. Furthermore, initiatives such as Trends in Ecosystem Services (TESE), by the Getúlio Vargas Foundation (FGV), applied the RCM in the valuation of ES associated with CO_2 emissions, with results that corroborate the method in valuing externalities (FGVces, 2019).

In Brazil, the RCM is used in various Water PES programs, which rely on the measurement of indicators, such as reforestation, in the supervision and remuneration of their producers. The RCM opportunely lists expenses internalized by producers, quantifiable through financial and accounting data (Vergara et al., 2014).

2.3. Opportunity Cost Method (OCM)

Like the RCM, the Opportunity Cost Method (OCM) is part of the indirect valuation methods. It is important to emphasize that the concept of Opportunity Cost (OC) was coined by Friedrich von Wieser (1851–1926), who defined it as “the net income generated by the factor in its best alternative use” (Beuren, 1993, p. 1).

Machado (2011) alleges that the OCM is based on the burden of preserving a certain environmental resource vis-à-vis the economic viability or inviability of its use or exploitation.

Maia (2002) analyzes it from another perspective: for him, the OC is generated by the conservation of these resources and can generate financial losses if not exploited.

The OC has been studied under two perspectives: from economics, based on Friedrich von Wieser’s concept, where OC is measured by the income of its best use; and from accounting, which presupposes that OC can be measured by profit, revenue, cost, etc. Both converge on the decision-making aspect of the OCM, preceded by financial data and multifaceted analysis regarding indices and interest rates (Pereira et al., 1990).

For Chodorow-Reich & Karabarbounis (2016), the OC is cyclical and volatile over the course of business. In turn, Post et al. (2016) state that the OC can be abruptly altered in anomalous situations, such as wars and pandemics. Guedes & Seehusen (2011) argue that the OC can be less onerous provided that economic instruments like PES balance this dysfunction and that compensation increases preservation.

The adoption of the OCM is grounded in the literature, given its use in various PES and Water PES programs. Because it relies on quantitative aspects, the OCM allows for the measurement of financial and accounting data, thus aiding decision-making based on price and profitability mechanisms (Secretaria Especial de Produtividade, Emprego e Competitividade, 2020).

Indeed, the OCM is addressed differently in certain areas, such as the aforementioned accounting with its sometimes objective view, or finance in not comparing investments with different risks, and even economics by allowing for subjective questions and themes. Even within these apparent divergences, the conceptual and even operational aspects of OC blend with the concept defined by Friedrich von Wieser (Beuren, 1993).

3. Methodological Procedures

3.1. Identification and analysis of opportunity costs

To enable the use of the OCM in the monetary measurement of the water production service, shadow price projections of relative revenues from this production were used based on three forms of soil exploitation common in the studied territory, namely:

a) Extensive livestock farming (beef production – fattening of beef cattle);

b) Grain production (unfolded into two annual crops: soybean and corn);

c) Land leasing – soybean (commercial leasing of land for soybean production).

Regarding the identification of productive costs, secondary sources were used, such as accounting and financial statements of the three mentioned activities, selected for being direct demanders of water production in the local economic chain.

Thus, for comparison purposes, the OCM was applied without considering the risks of each option; therefore, subjectivity was chosen in preference to the ecological economics perspective. A calculation roadmap for the OC was adopted, structured and based on available literature.

The data for each form of land use is presented below.

3.1.1. Extensive livestock farming

The first option analyzed was beef production, specifically the fattening of beef cattle. For this, production dimensioned the studied area to allow a proxy; however, areas unsuitable for animal management were excluded from the calculation. Consequently, the maximum quantity of heads per hectare and their annual return were calculated, multiplied by the period of AFS implementation. To this end, Equation I was elaborated according to Leitão (2021).

Equation I

Livestock Return:

$$\sum \mathbf{RP} = \left\{ \left[\left(\mathbf{Qt.} \times \mathbf{A} \right) \times \mathbf{Lpa} \right] \times \frac{\boldsymbol{n}}{\boldsymbol{Pe}} \right\}$$

The Livestock Return (LR) results from the multiplication of the Quantity of animals per hectare (Qt) by the Area destined for this production in hectares (A). The result is multiplied by the Net Profit per animal (NPA). Finally, this product is again multiplied by the ratio between the AFS Period (n) and the Fattening Period (Fp).

This configuration can be improved with the adoption of fertilization and management, associated with other grass species. For calculation purposes, an area of 30 hectares of Brachiaria was projected, thus inserting 43 heads of cattle with an estimated target of 34 arrobas (a unit of weight) per animal, resulting in about 1,462.0 arrobas at the end of the cycle (Gonsalves Neto, 2020).

For Fp, pastures with Brachiaria without fertilization were considered, supporting about 1.43 oxen per hectare in the fattening cycle. The fattening cycle would correspond to approximately 24 months (Gonsalves Neto, 2020).

When scaling these data to the studied AFS period of 10 years, and considering the fattening cycle, there are five productive cycles. To determine these costs, data from the National Confederation of Agriculture (CNA) were used, selecting values relative to the region where the research was applied (Confederação da Agricultura e Pecuária do Brasil [CNA], 2021).

Values referring to the arroba were collected from the historical data of the Center for Advanced Studies in Applied Economics (CEPEA-Esalq/USP), considering the years 2011 to 2020, without monetary adjustment (Centro de Estudos Avançados em Economia Aplicada [CEPEA], 2021).

3.1.2. Grain production

The second option, grain production, was unfolded into two other productions: soybean harvest (summer) and corn "*safrinha*" (winter harvest). Thus, the calculation of the Corn Production Return (CPR) took into account average productivity data for the region available in the CEPEA database and the Agriculture and Livestock Federation of Mato Grosso do Sul (FAMASUL).

The property area is part of a highly productive region, reaching averages of around 93.5 bags of corn per hectare, this being the arithmetic mean of the periods obtained after analyzing the historical averages of bags, available in the mentioned databases, within the 2011–2020 timeframe (Federação da Agricultura e Pecuária de Mato Grosso do Sul [FAMASUL], 2019; CEPEA, 2021).

Information regarding production costs was collected from CNA data specifically for the studied region. This data was supplemented with information listed in the National Supply Company (CONAB) database, including average net profit percentages per harvest. Other parameters were obtained as subsidiary sources of information, proof, and counterproof (EMBRAPA, 2018; Richetti et al., 2018; CNA, 2021; Companhia Nacional de Abastecimento [CONAB], 2021). Equation II represents the corn production values.

Equation II

Corn Production Return:

$$\sum \mathbf{RPM} = \left\{ \left[\left(\mathbf{Qt.} \times \mathbf{A} \right) \times \mathbf{Lsc} \right] \times \frac{\boldsymbol{n}}{\boldsymbol{Ps}} \right\}$$

The calculation of the Corn Production Return (CPR) was given in current currency (US$), obtained by multiplying the Possible Area (A) for this production on the property in hectares and the Quantity Produced (Qt), estimated via the region's average productivity, given in bags per hectare (bags/ha). The product of this initial calculation was multiplied by the Net Profit (NP), given in US$/hectare and based on historical average values from CONAB. The result was multiplied again, this time by the quotient of the Harvest Period (Hp), one harvest per year, by the AFS Period (n), of 10 years (Leitão, 2021).

As a third calculation, and still within the second OC option, is the Soybean Production Return (SPR), in which the same parameters as the CPR were adopted regarding A, Hp, and n. However, the average productivity identified for the region was 61.29 bags per hectare, values obtained from CEPEA databases and compared to FAMASUL bulletins and reports. Total costs and net profit percentages were obtained from CONAB databases (FAMASUL, 2020; CEPEA, 2021; CONAB, 2021). Equation III represents the soybean production values.

Equation III

Soybean Production Return:

$$\sum \mathbf{RPS} \;=\; \left\{\left[\left(\mathbf{Qt.} \;\; \times \mathbf{A}\right) \times \mathbf{Lsc}\right] \times \frac{\boldsymbol{n}}{\boldsymbol{Ps}}\right\}$$

The SPR is calculated from the product of multiplying the Quantity Produced (Qt) by the Area (A) where this production is possible, given in hectares. It is worth recalling that Qt corresponds to sc/hectare and relates to the region's average productivity. In turn, Net Profit (NP) was obtained based on CONAB information and is given in US$/hectare. Regarding Hp and n, the criteria are the same as for CPR (Leitão, 2021).

By obtaining the value for CPR and SPR, it is possible to arrive at the value of the grain production option. Consistent with the local practice of soybean monoculture in the summer harvest and corn in the winter harvest, this calculation is only possible due to the real possibility of the studied area producing two annual harvests in the system known as no-till farming. Thus, with these two parameters, Equation IV can be performed.

Equation IV

Grain Production Return:

$$\sum \mathbf{RPG} \;=\; \{\mathbf{RPM} \;+ \mathbf{RPS}\}$$

In this equation, the values of GPR, CPR, and SPR are expressed in current currency for example, in US dollars (US$). To calculate the GPR, one simply sums the CPR with the SPR (Leitão, 2021).

3.1.3. Land leasing – soybean

Finally, the third option suggested for calculating the OC is the commercial leasing of the area for grain production. For this calculation, annual remunerated contracting was considered based on an agreed percentage of the harvest yield.

The parameters of period, area, and productivity listed in the SPR calculation were also replicated, with average bag value data obtained from the CEPEA database, corresponding to the studied region (CEPEA, 2021). It is important to highlight that the mentioned percentage was based on contracts governed by Federal Law No. 4.504/1964 (Land Statute), which defines, among others, remunerations for leasing.

The cited law stipulates in Item XII of Article 95 that remuneration for leasing areas of intense exploitation and high profitability is 15% of the value of the property and its improvements. However, the usual practice in the region is the application of this percentage on average production (*Lei nº 4.504*, 1964). Thus, the calculation of the land leasing return (for soybean production) follows Equation V.

Equation V

Land Leasing Return – Soybean:

$$\sum \boldsymbol{RAS} \;=\; \{[(\boldsymbol{Qt.} \;\times \boldsymbol{A}) \;\times \boldsymbol{Vs}\,] \times \;\boldsymbol{\%}\;\} \times \frac{\boldsymbol{n}}{\boldsymbol{Ps}}$$

The Land Leasing Return – Soybean (LLR), given in current currency, is obtained by the product of the Quantity Produced (estimated via average regional productivity in bags/ha) (Qt), by the area in hectares (where this production would be possible on the property). This result must be multiplied again, but now by the Value of the bag (Vb) (in this case, 60 kg bags in US$, CONAB values).

The third part of the calculation occurs with the multiplication of the previous product by the contracted percentage (%) (in this case, 30% of soybean production). This value is multiplied again, but this time by the quotient of the Harvest Period (Hp), one harvest per year, by the AFS Period (n), of 10 years (Leitão, 2021). These calculations aim, even if simply, to identify the OCs of potential activities for the region.

By providing a broader analysis, the inclusion of complex variables, such as environmental preservation, assists stakeholders in the option of using or not using the environmental resource. Even if the valuation is not profound, at least there is a response to conjunctural economic pressures, given the comparison of the cited variable with exploitation options possessing a valued and priced market.

3.2. Identification and analysis of replacement costs

To identify and subsequently analyze the variables applied to the RCM, the premise must be the estimate of Replacement Costs for the location to be studied. However, this must be done taking into account the particularities of the location, such as management types and the different areas that may compose it, such as Legal Reserve Areas (LRAs) and Permanent Preservation Areas (PPAs).

Therefore, the Total Area Replacement Cost (TARC) was estimated, adopting four procedures, transcribed below:

1) Identification, analysis, and calculation of the Total Cost of Recovery of LRAs, PPAs, and those related to AFS implementation;
2) Identification, analysis, and calculation of the Soil Fertility Restoration Cost;
3) Identification, analysis, and calculation of the Soil Terracing Cost; and
4) Identification, analysis, and calculation of the Maintenance Cost.

The first procedure stems from the cost of planting seeds and seedlings, in addition to costs with fertilization, rental of machines and equipment, and labor for this stage. The second concerns the Soil Replacement Cost, where expenses with fertilizers and costs resulting from this process are brought to the fore. The third procedure refers to the Soil Terracing Cost, obtained from expenditures on physical soil treatment, such as costs in the construction of terraces and their composition. The fourth procedure estimates the Maintenance Costs (MC) of the AFSs that support water production.

The consolidation of the four procedures allowed estimating the TARC in the construction of an environmental valuation proposal focused on the Replacement Cost Method (RCM). By applying the RCM, aided by financial and accounting cost formation data, environmental valuation is possible starting from economic valuation.

In the studied case, backing was established with primary data obtained through questionnaires and interviews with two producers, in addition to subsidies with secondary data and consultations with researchers and consultants. Data relating to the 10-year period were inserted, the time of implementation and consolidation of the local productive system, the Biodiverse AFSs.

However, some indicators that could broaden the analysis, such as the history of surface water flow rainfall indices, which allow scaling the ES-eco provision, are not part of the listed calculations, given their non-existence for the studied area.

The calculations composing the replacement cost analysis are described below.

Equation VI

Total Cost of Recovery of PPAs, LRAs, and AFS Implementation

$$\sum \boldsymbol{CTRAPP} = \{[\boldsymbol{Ad}\, \boldsymbol{x}\ (\boldsymbol{Cp} \times \boldsymbol{Pep})] + \boldsymbol{Cat} + \boldsymbol{Cet} + \boldsymbol{Cmt}\}$$

The Total Cost of Recovery of PPAs, LRAs, and AFS implementation (TCRPLA) is given by the multiplication of the Developed Area (Da) in hectares, by the product resulting from the Unit Cost per Planted Specimen

(Pc), in US$/hectare, with the Proportion of Planted Specimens (Pps), in species/hectare.

In the composition of Pps costs, due to the absence of average Indirect Benefits and Expenses (BDIs) for shrub planting services, not foreseen in isolation in the study conducted by the Federal Court of Accounts, the minimum value among the average BDIs stipulated for various types of work was adopted (Vergara et al., 2014). This result is added to the Total Cost with Fertilization per hectare (TCF), the Total Cost of Rental or Acquisition of Equipment in Planting (TCE), deducting depreciation, and the Total Cost with Labor in Implementation (TCL), all in current currency (Leitão, 2021).

The calculation lists costs with: planting of seedlings and seeds in the implementation of Biodiverse AFSs; recovery of PPAs and LRAs; organic fertilization; rentals and labor for this stage. The seedling planting calculation was adapted from Vergara et al. (2014) and can be observed according to Equation VI.

The TCRPLA is responsible for the largest outlays, whether in the implementation, expansion, and, depending on the arrangement and management, reimplantation phases.

Equation VII

Soil Fertility Restoration Cost:

$$\sum \mathbf{CRS} = \{[(\mathbf{Pf} \times \mathbf{Qt.})\ \mathbf{Ctlae} + \mathbf{Ctm}\,] \times \mathbf{Ad}\}$$

The Soil Fertility Restoration Cost (SFRC) is obtained with the product of the Price of fertilizers (Pf), by the Quantity of fertilizers (Qt), both in tons per hectare, expressed in US dollars. This product is added to the Total Cost of Rental or Acquisition of Equipment in soil treatment (TCRE), deducting depreciation, and the Total Cost with Labor in Application (TCL). Finally, this result is multiplied by the Developed Area given in hectares (Da) (Leitão, 2021).

For the calculation, macronutrients N, P, K, Mg, CA were included in current values at the time of acquisition, in addition to the cost of rentals, acquisitions of machines and equipment, and labor destined for this stage, using for this an adaptation of the equation proposed by Marques et al. (2005), as per Equation VII.

For Marques et al. (2005), the application of these calculations allows associating measures for improving soil quality with a productive cost and, consequently, assessing the economic value and the degraded soil.

Equation VIII

Soil Terracing Cost:

$$\sum \boldsymbol{CTS} = [(\boldsymbol{Ctlae} + \boldsymbol{Ctm}) \times \boldsymbol{Ad}] \times \boldsymbol{n}$$

The Soil Terracing Cost (STC) is the result of the sum of the Total Cost of Machine Rental in Soil Treatment (TCRE), with the Total Cost with

Labor for Soil Terracing (TCL). This result is multiplied by the Developed Area in hectares (Da) and subsequently by the Implementation Period (n) (Leitão, 2021).

The calculation considers the sum of the cost of machine rentals (in machine/hour), a practice observed in the studied case, and labor (in man/day) focused on soil treatment, as per Equation VIII.

The STC can raise initial financial outlays depending on the conditions of the area.

Equation IX

Maintenance Cost:

$$\sum \mathbf{CM} = (\mathbf{Ctlae} + \mathbf{Ctm} + \mathbf{Cti}) \times \mathbf{n}$$

The Maintenance Cost (MC) is the result of the sum of the Total Cost of Rental or Acquisition of Equipment in soil treatment (TCRE), the Total Cost with Labor in Application (TCL), and the Total Cost with Inputs for maintenance (TCI), all in current currency. The result of this sum was multiplied by the period of AFS implementation (n) (Leitão, 2021).

To find the MC, those related to rental and/or acquisition (duly depreciated) of equipment were listed, added to labor in this stage, which is the longest in the process, as per Equation IX.

The MC portrays costs often neglected or poorly dimensioned, given that they demand rigorous expense control and faithful recording.

Finally, the TARC calculation is elucidated in Equation X.

Equation X

Total Area Replacement Cost:

$$\sum \mathbf{CTRA} = \mathbf{CTRAPP} + \mathbf{CRS} + \mathbf{CTS} + \mathbf{CM}$$

The Total Area Replacement Cost (TARC) considers the summation of TCRPLA, SFRC, STC, and MC, all given in US dollars (Leitão, 2021).

The TARC compiles all previous calculations linked to replacement cost; thus, it portrays in monetary values the entire methodological apparatus of the RCM.

3.3. Identification and analysis of potential AFS revenue and water production

This item sought to analyze alternative revenues in the studied AFSs, how these can increase the property's cash flow and, from this, understand the gap that impacts the option for water production. For this, accounting data provided by the owners were used, corresponding to the 10-year period, from the implementation to the consolidation of the AFSs.

These data were processed in Excelâ spreadsheets and subsequently applied to Equation XI.

Equation XI
Total AFS Revenue:

$$\sum \mathbf{RTSAF} \;=\; \left[\left(\mathbf{Qt.}\;\times \mathbf{A} \times \mathbf{LL}\right)\right] \times \boldsymbol{\frac{n}{Ps}}$$

In this equation for Total AFS Revenue (TAFSR), the production of vegetables, seedlings, seeds, fruits, timber, and aggregate production of these products was considered, being the result of multiplying the Quantity Produced per Crop (Qt), the Productive Area Used per Crop (A), both in hectares, and the Net Profit per Crop (NP). The resulting product was again multiplied by the quotient of the Period in years of the AFS (n) and the Harvest Period (Hp), which can be dimensioned by cultivation or harvest, in years (Leitão, 2021).

TAFSR is an important metric, as it demonstrates the revenues generated by the AFS and impacts the valuation of the water production ES-env, as will be understood subsequently.

3.4. Water Production Value (WPV)

The Water Production Value (WPV) sought to demonstrate the fairest value to be applied in a Water PES, so that the water production option has viability vis-à-vis costs, debiting possible AFS revenues from these. The WPV is a proxy, calculated by the ratio between the productive area and the result of subtracting revenues from the replacement cost, as per Equation XII.

Equation XII
Water Production Value (WPV):

$$\sum \boldsymbol{VPA} \;=\; \boldsymbol{\frac{RTSAF - CTRA}{Ad}}$$

The WPV can be expressed in US$/hectare/year, and is the result of subtracting the Total AFS Revenue (TAFSR) from the Total Area Replacement Cost (TARC). This value is divided by the Developed Area in hectares (Da) (Leitão, 2021).

It is emphasized that the WPV is backed by the RCM, with TAFSR being a revenue of the case at hand; thus, the calculation can be adapted to other productive arrangements.

3.5. Water production valuation index (WPVI)

After finding the WPV for the area, it is possible to evaluate whether the water production activity is attractive. In the case of the possibility of remuneration by the obtained WPV, the local reality can be analyzed by the Water Production Valuation Index (WPVI). This index intersects the two economic valuation methods researched, the OCM and the RCM.

The calculation requires the TARC to be made negative, adding, one by one, the options listed by the OCM, and the result is divided by the TARC, this time positive. Subsequently, the new result is multiplied by 100, so that the percentage obtained allows a more faithful analysis of the possibilities of Water PES for the studied producers, equalizing the demands of Water PES program participants to the local reality, as observed in Equation XIII.

Equation XIII

Water Production Valuation Index (WPVI):

$$\sum \boldsymbol{IVPA} = \frac{(-\boldsymbol{CTRA})+\boldsymbol{MCO}}{\boldsymbol{CTRA}} \times 100$$

The WPVI is the result of the TARC added with a negative sign, summed with the alternatives proposed for the OCM. In this research, the options found were Livestock Return; Soybean Production Return; Corn Production Return; Grain Production Return; and Land Leasing Return – Soybean (Leitão, 2021).

By allowing the application of the OCM, the WPVI enables scenario analysis within the proposed land use alternatives.

Throughout this research, it was mentioned that, despite being indirect valuation methods, the OCM and RCM are guided by different variables. The literature demonstrates that both are used in different PES programs. The OCM is applied in the analysis of the options market, generally structured on income or profit. In turn, the RCM is recognized in the analysis of expenses, such as those listed in the recovery of degraded soil, in the case of reforestation of forest areas.

Thus, the WPVI instruments an analysis with these two methods and their various variables in favor of more assertive and realistic decision-making.

It is important to reinforce that this research did not study the AFS in the context of other ES-eco, such as carbon, nor the valuation of its credits. Tax advantages nor income generation via environmental easement (*servidão ambiental*), a modality in which the owner waives their exploration rights of native vegetation (excluding LRA and PPAs), were not included in the analyses (*Lei nº 12.651*, 2012).

Also not part of the investigation was the identification of Willingness to Pay (WTP), given, among other reasons, the case study character, a limiting factor in the adoption of Contingent Valuation Method (CVM) tools.

4. Results and discussion

4.1. Results of opportunity costs

Initially, for the calculations listed for OCM application, the Livestock Production Return (LR) was obtained. For this productive option, the net profit was approximately US$ 250.92[1] average per animal/fattening cycle. In the last cycle, the accumulated LR was US$ 53,946.98, for a total of 43 heads estimated at 1,462.0 arrobas, deducting from this total the replacement of animals for a future cycle; however, infrastructure expenses were not computed.

Subsequently, there is the calculation of the Corn Production Return (CPR), where the average net profit was given in bags per hectare per year, reaching the approximate value of US$ 1.54 (value for a total production of 2.805 bags per year). The accumulated return was about US$ 43,200.33 for winter corn harvests[2].

For the Soybean Production Return (SPR), the arithmetic mean found for net profit was US$ 3.57/sc/hectare/year. The total production for this result was approximately 1.838 bags per year. Thus, the accumulated SPR in the period was US$ 65,668.86, following the same guidelines as the CPR, with possible corrections.

Therefore, the sum of CPR and SPR demonstrated a Grain Production Return (GPR) of US$ 111,400.22 accumulated over 10 years. It is worth noting that these values refer to production in two harvests per year, winter (corn) and summer (soybean).

Finally, the last option proposed for Opportunity Cost, the Land Leasing Return – Soybean (LLR), given that the data are largely the same as those used in SPR, when applying the limit contractual percentage for contracts of this type in the studied region, was 15% on soybean production, according to the Land Statute (*Lei nº 4.504*, 1964), that is, an accumulated US$ 46,487.56.

Table 1 demonstrates the Opportunity Cost values for each economic activity in the considered area.

Analyzing Table 1, it is evident that the highest total return comes from GPR, as it involves the production of two crops per year (soybean in summer and corn in winter); and that the lowest value, CPR, represents about 41% of the highest value. The second lowest value refers to LLR, and the

Table 1 Opportunity Cost Values for each economic activity.

Production Options (OCM)	Total Accumulated Return
Corn Production Return (CPR)	US$ 45,731.36
Livestock Return (LR)	US$ 53,946.98
Soybean Production Return (SPR)	US$ 65,668.86
Land Leasing Return (Soybean) (LLR)	US$ 46,487.56
Grain Production Return (GPR)	US$ 111,400.22

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[1] Exchange rate for purchase: (R$) / US$) on 09/23/2024 (R$ 5.544). Available at: http://www.ipeadata.gov.br/ExibeSerie.aspx?serid=38590&module=M

[2] Value represents the accumulated in the period, with monetary corrections (IPCA).

second highest value is given by the SPR option, in the molds analyzed in this research.

However, despite portraying a period of a specific market, Opportunity Costs are not, by themselves, capable of valuing ES-eco as in the researched case, that of water production, which consists of a market failure. Thus, according to the proposed valuation, such failures can be minimized through the adoption of Replacement Cost.

These calculations may vary as they adapt to distinct research realities. Furthermore, they can be refined with the application of viability analyses, via Weighted Average Cost of Capital (WACC), a method utilizing the weighted average of the cost of debt and equity capital (Leitão et al., 2022).

4.2. Results of Replacement Costs

Replacement Costs were realized starting from the total costs of AFS implementation and recovery of LRAs and PPAs, through the adaptation of the equation by Vergara et al. (2014). From this first calculation, it was necessary to deduce the initial period of AFS implementation in the studied area (30 hectares).

This AFS implementation, despite being constant, peaked in the first three years, when investments were higher. Regarding the proportion of inserted species, the result was about 330.57 arboreal plants (trees and seedlings) per hectare, at an average value of US$ 5.20 per seedling, according to accounting data provided by the producers.

Total costs with fertilization were US$ 59.32 per hectare, a considerably low value given the analyzed period. The explanation lies in agroecological management, with the use of organic fertilizers produced on-site, allowing for improved nutrient cycling and reducing the need for external inputs (Padovan et al., 2016).

Total costs with acquisition or rental of machines and equipment for the seedling planting stage were US$ 1,201.42 in the first three years alone. The cost with labor in the implementation stage was approximately US$ 11,220.31.

That said, the Total Cost of Recovery of Permanent Preservation Areas (PPA), Legal Reserve Areas (LRA), and AFS implementation (TCRPLA) found was US$ 64,011.16.

The Soil Fertility Restoration Cost (SFRC) was estimated for the three-year period in the mentioned area. Fertilizers used in this stage were purchased at a cost of US$ 361.81 per ton. According to the data, approximately 1.18 tons were used.

Subsequently, within the SFRC equation, the Total Cost of machine rental in soil treatment (TCRE) and the Total Cost with labor (TCL) of this stage were calculated, resulting in US$ 52.23 and US$ 487.83 respectively, according to an equation adapted from Marques et al. (2005). Thus, the

Table 2 Replacement Costs (RCM).

Replacement Costs (RCM)	Total Accumulated Cost
Total Cost of Recovery of PPAs, LRAs, and AFS implementation – TCRPLA	US$ 64,011.16
Soil Fertility Restoration Cost – SFRC	US$ 901.87
Soil Terracing Cost – STC	US$ 839.38
Maintenance Cost – MC:	US$ 33,178.76
Total Area Replacement Cost – TARC	US$ 98,931.17

SFRC value was US$ 901.87 – a low value, stemming from management, as previously described.

According to Pugliesi et al. (2011, p. 119), in the "conventional system, fertilizer and labor prices represented about 50% each in the composition of the final replacement cost". It is highlighted that the obtained data correspond to areas where the SFRC stage was developed.

Regarding STC, the area and period criteria are the same as SFRC; however, the values concern the acquisition or rental of machines for soil treatment and labor costs for this stage, resulting in US$ 351.55 and US$ 483.38 respectively. The STC value was about US$ 839.38.

MC were considered in the periods after implementation, as these data could not be discriminated given the history available for this research. In the equation regarding this, the property's largest expenditures are found, where TCRE, TCL (of the stage), and TCI were respectively US$ 779.56, US$ 3,673.31, and US$ 2,008.66. These values culminated in a MC of US$ 33,178.76.

The last equation referring to the RCM, the Total Area Replacement Costs (TARC), were summed, composing the complete panorama of the period in the studied area. The TARC reached the figure of US$ 98,931.17, equivalent to US$ 329.77/hectare/year, reflecting the total costs of AFS implementation in the studied area and, to a certain extent, revealing a parameter on the economic value of preservation, without fitting this into a specific market.

Table 2 demonstrates the resulting values of the Replacement Cost calculations.

4.3. AFS Revenue Results

Regarding Total AFS Revenue (TAFSR), respecting the period and studied area, the initial phases of the AFS did not generate significant revenues, among other reasons, because they are perennial arrangements. Therefore, data were weighted to a global average that allowed prorating.

The highest revenues were assessed from the 7th year onwards, partly due to the change in productive profile driven by local demand for food, which scaled the studied property's revenue by 200% between 2017 and 2018.

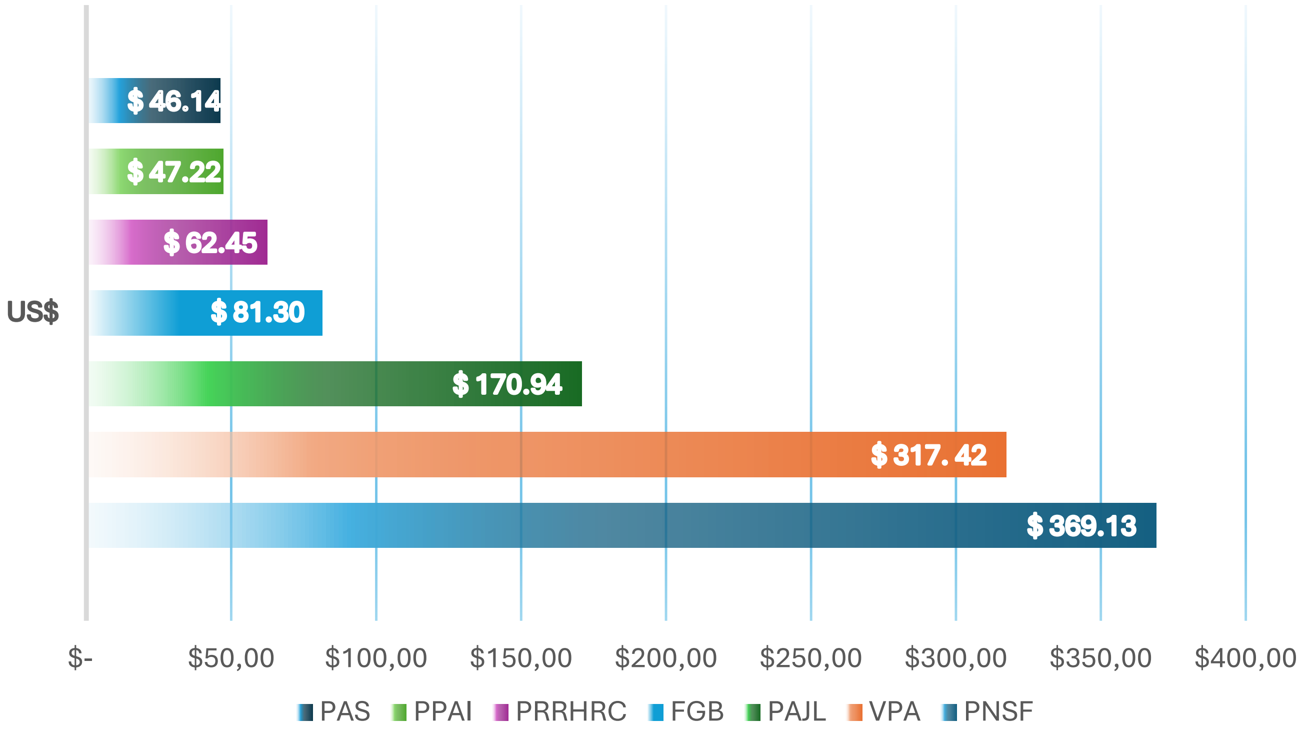

Figure 1

Comparative WPV with Water PES (Water Producer Program).

LEGEND: PAS – Salesópolis Water Producer; PPAI – Igarapé/MG Municipality Water Producer; PRRHRC – Preservation and Recovery of Capivari River Water Resources; FGB – Boticário Group Foundation; PAJL – João Leite/GO Water Producer; WPV – Water Production Value; PNSF – São Francisco Springs Project.

Fixed and variable production costs were treated, thus avoiding duplication. The accumulated TAFSR was US$ 3,705.48 – a value that can be estimated at US$ 12.35/hectare/year for the total period, with a productive basket of about 35 conventional foods, from fruit trees to fish.

4.4. Water Production Results (WPV)

The Water Production Value (WPV) was estimated from the annual values of TAFSR and TARC, US$ 370.55 and US$ 9,893.12, respectively. The resulting WPV was approximately US$ 9,522.57 per year for the total area, equivalent to the volume of water produced on the studied property.

This value represents part of the ecosystemic and biogeochemical effort/work to produce water. Such work, performed by nature, possesses an ecosystem cost and presents itself with an estimated value on the order of US$ 317.42/hectare/year.

The ecological gain provided at the location, with the increase in water flow, which, although not quantitatively verified, was recorded by the AFS implementation history. However, it became evident, at least under the financial aspect, that AFS revenues did not cover the costs of its implementation and consolidation. It is important to highlight that the parameter for water production is the average cost per hectare/year, a measure used in Water PES programs, such as Manancial Vivo, among others (Secretaria Municipal do Meio Ambiente e Gestão Urbana [SEMADUR], 2018).

Table 3 Values obtained by TAFSR and WPV.

Values obtained by TAFSR and WPV	Annual value for area	Annual value per hectare
TAFSR	US$ 370.55	US$ 12.35
WPV	US$ 9,522.57	US$ 317.42

Figure 1 comparatively demonstrates some remunerations of Water PES programs listed by ANA, with the WPV found in this research.

In Brazil, Water PES programs are public and private initiatives favoring financial support to producers of ES-env. Figure 1 listed some of the programs supervised by ANA.

As Figure 1 demonstrates, the highest listed remuneration is that of PNSF, which remunerates 60 producers in Canindé de São Francisco/SE, with US$ 369.13 per hectare per year, who assist in supplying water to a population of 650,106 inhabitants (ANA, 2020). The second highest value, if applied, would be the WPV proposed in this research, and the third highest value was paid by PAJL, with values around US$ 170.94.

On the other hand, the lowest remunerations were paid by PAS, PPAI, and PRRHRC, remunerating US$ 46.14, US$ 47.22, and US$ 62.45, respectively.

In common, all these value proxies for water production encounter metric limitations stemming from the exact quantification of this production, seeing that this analysis should calculate, besides fluviometric flow, groundwater recharge and even water production via dew (Vilar, 2009). However, by associating this valuation with the adoption of conservationist systems, such as Biodiverse AFSs, the true financial expenditures to produce commodities, preserve, and improve ES-env, such as water production, are highlighted.

In the case study proposed in this work, the TAFSR and WPV values align and indicate the monetary viability of providing ES-env. Table 3 demonstrates these values.

4.5. Results of the Water Production Valuation Index (WPVI)

The spectrum of the WPV can be expanded and, thereby, improve analysis and consequently decision-making. Thus, there is the proposal of the Water Production Valuation Index (WPVI), which aims to cross-reference the two studied methods, OCM and RCM, and provide a holistic analysis that broadens the equity of Water PES, applying it to realities tied to the local market and its forces, having the WPV as a financial parameter.

The WPVI proposes comparing the TARC, categorized in this research as a financial expense, with the options listed for OCM, weighted in this research as revenue perspective.

Through the percentage index found by the equation cited in item 3.5, two scenarios open up: negative or positive WPVI. If the WPVI is positive, the PES is less attractive for engagement, given its viability; otherwise, the PES would cover costs and the producer, should they opt for service provision with AFS adoption, upon applying calculations and sketching comparisons with the five OCM options, as Table 4 demonstrates.

Table 4 presents the five calculations, their percentages, and the monetary value of the comparison. The first comparison projects the financial situation of the producer not remunerated by a PES based only on LR. In this scenario, costs to produce water would generate a loss of -45.47%, which would linearly represent a financial deficit of -US$ 149.95/hectare/year.

In the second comparison, the worst result is presented: if remuneration were measured only by CPR, the loss would be -53.77% accumulatively, and in hectares/year the value would be -US$ 177.33.

In the comparison with SPR, the WPVI is also negative: the percentage reached -33.62% and the accumulated financial loss would be -US$ 110.87/hectare/year.

The fourth comparison evaluated GPR, where the WPVI was positive, having a surplus of 12.60% and a financial result of US$ 41.56 per hectare per year – the best result among those analyzed and the productive model widely adopted in the studied region. This demonstrates a local challenge, as it makes the adoption of a PES less attractive.

The last comparison analyzed LLR and again the index was negative, this time at -53.01%, with a loss to the producer of -US$ 174.81/hectare/year.

The values found are referential and applicable to the case study region, but open discussions for the need for studies reflecting the local reality. Furthermore, they demonstrate that the value of the service performed by nature is not computed/accounted for in the agricultural cost production spreadsheet, and when this is done – which is correct – it demonstrates the real profit obtained, demystifying the Marxist theory of excluding nature in economic sciences and ratifying the appeal for a new perspective centered on the propositions of a new economic model, weighing the internalization of the value of ecosystem externalities.

Although tempting, the standardization and replication of values for Water PES impacted the performance, engagement, and continuity of programs and ES-env provided. This research found that, by applying the

Table 4 Analysis of the Water Production Valuation Index (WPVI).

WPVI Comparisons	Percentage	Value hectare/year
(TARC = LR)	(-45.47%)	(-US$ 149.95)
(TARC = CPR)	(-53.77%)	(-US$ 177.33)
(TARC = SPR)	(-33.62%)	(-US$ 110.87)
(TARC = GPR)	12.60%	US$ 41.56
(TARC = LLR)	(-53.01%)	(-US$ 174.81)

proposed methodology, it is possible to value water production so that its remuneration is not disconnected from reality.

It was also found that regardless of the region or biome, remunerations for provided ES-env will be more attractive and efficient when OC and RC are dimensioned in the study region. In the case of the studied region, it was evidenced that GPR is highly attractive, given the characteristics of the local agricultural chain, based on the Soil Map of the studied region (Amaral et al., 2000; Lombardi, 2013).

It is important to highlight that the association of WPV with WPVI has the merit of providing a more effective analysis, even with the limitations cited throughout the research. It is also worth noting that TAFSR entered the calculations as a possible data source, which does not prevent its modification or removal, without prejudice to the WPVI calculation.

5. Final considerations

This research concluded that the values obtained in the application of RCM and OCM can be adapted to realities distinct from this research. In the studied case, conservationist management impacted RCM calculations; however, the method allowed the monetary valuation of the water production ES-env. The OCM listed different aspects and their qualitative and quantitative comparisons and assisted in the monetary valuation of water production.

The TARC calculation revealed real costs in the implementation and maintenance of Biodiverse AFSs, and the need for revenues that cover these costs, such as PES. It was found that the WPV is capable of portraying the reality of the studied area and that in this case, the value would be the second highest among Water PES programs currently in force in Brazil.

It could also be concluded that the WPVI allows efficient comparisons and, in case its index is negative, the adoption of AFSs associated with a PES offering WPV values. Furthermore, in the studied case, the WPVI index for CPR was the worst result, showing that with the proposed WPV, a PES based on this is attractive for the studied region, as opposed to the WPVI index for GPR, in a context of profitable harvests.

It became evident that Water PES remuneration must be regionalized to allow for greater engagement of ES producers. Moreover, monetary valuation allows for a greater connection of PES remuneration to the reality of the local market.

Among the limitations found, it should be clarified that pluviometric flow was not listed, among other aspects, due to the lack of history prior to AFS implementation; and that risks inherent to each productive alternative were not considered in this analysis, although the WPVI enabled such simulations.

As a suggestion to Water PES programs, the WPV can be unfolded into two stages, implementation and maintenance, given that the former is more onerous to the producer. If this is not possible, bonus policies may help.

Finally, aiming to corroborate the strengthening of Water PES, this research opens space for new discussions, by provoking academia and society in the construction of policies that expand conservationist practices, improve natural infrastructure, and allow greater water security for all.

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