UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
FACULDADE DE AGRONOMIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ZOOTECNIA

URSULA DA SILVA MORALES

SÍNTESE EMERGÉTICA COMO AVALIAÇÃO DA SUSTENTABILIDADE NA PRODUÇÃO DE JUVENIS DE PEIXES

Porto Alegre
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Tese apresentada como requisito para obtenção do Grau de Doutora em Zootecnia, na Faculdade de Agronomia, da Universidade Federal do Rio Grande do Sul.

Orientador: Prof. Dr. Danilo Pedro Streit Jr.

Coorientador: Prof. Dr. Marco Aurélio Rotta.

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SINTESE EMERGÉTICA COMO AVALIAÇÃO DA SUSTENTABILIDADE NA PRODUÇÃO DE JUVENIS DE PEIXES

Autor: Úrsula da Silva Morales
Orientador: Danilo Pedro Streit Jr
Coorientador: Marco Aurélio Rotta

A expansão acelerada aquicultura pode levar a problemas econômicos, sociais e ambientais. Quanto a produção de espécies nativas, embora venha crescendo no Brasil e pareça ser uma atividade bem estabelecida, faltam estudos que demonstrem sua sustentabilidade, principalmente sobre a produção de alevinos que está nos elos iniciais e são fundamentais na cadeia produtiva aquícola. Nesse sentido, o trabalhou objetivou utilizar a emergia para avaliar a produção de juvenis de espécies nativas. O objetivo do primeiro estudo foi realizar uma revisão sistemática sobre a aplicação desse método na aquicultura mundial nos últimos dez anos. Na revisão sistemática foi possível identificar 17 artigos utilizando a análise emergética para avaliar a sustentabilidade nos aspectos ambiental, econômico e social. De acordo com esses estudos, os sistemas de produção avaliados variam entre diferentes espécies, monoculturas e policulturas em diferentes níveis de produção (intensivo, semi-intensivo, extensivo). Com os resultados obtidos nesse estudo foi possível identificar limitações e tendências para novas pesquisas, além de confirmar que a avaliação emergetica permite quantificar os recursos da natureza e da economia, tornando uma ferrementa util para avaliar o manejo ou sistema de produção mais sustentável. No segundo estudo, o obejtivo foi aplicar a emergia para comparar dois sistemas de produção de juvenis, considerando uma empresa com dados hipotéticos e outra com dados obtidos em um laboratório de reproduçao no Estado de Mato Grosso. Os resultados identificaram o sistema de produção de juvenis de espécies nativas altamente dependem dos recursos da economia, com destaque para a a raçao comercial como o principal responsável. Os indices emergéticos EYR, ELR e ESI, indicam características de uma produção com baixa sustentabilidade evidenciando que gestão e planejamento adequados podem contribuir para a redução da dependência de recurso da economia e aumentar a utilização de recursos renováveis tornando a aquicultura mais eficiente.

Palavras-chave: Produção animal, alevinos, tambaqui, desempenho ambiental

EMERGETIC SYNTHESIS AS ASSESSMENT OF SUSTAINABILITY IN FISH JUVENILE PRODUCTION

Author: Úrsula da Silva Morales
Advisor: Danilo Pedro Streit Jr
Co-advisor: Marco Aurélio Rotta

Accelerated aquaculture expansion can lead to economic, social and environmental problems. As for the production of native species, although it has been growing in Brazil and seems to be a well-established activity, there is a lack of studies that demonstrate its sustainability, especially on the production of fingerlings, which are in the initial links and are fundamental in the aquaculture production chain. In this sense, the work aimed to use emergy to evaluate the production of juveniles of native species. The aim of the first study was to carry out a systematic review on the application of this method in world aquaculture in the last ten years. In the systematic review, it was possible to identify 17 articles using emergy analysis to assess sustainability in environmental, economic and social aspects. According to these studies, the production systems evaluated vary between different species, monocultures and polycultures at different levels of production (intensive, semi-intensive, extensive). With the results obtained in this study, it was possible to identify limitations and trends for further research, in addition to confirming that the emergy assessment makes it possible to quantify the resources of nature and the economy, making it a useful tool to evaluate the management or more sustainable production system. In the second study, the objective was to apply emergy to compare two juvenile production systems, considering a property with hypothetical data and another with data obtained in a reproduction laboratory in the state of Mato Grosso. The results identified the production system of juveniles of native species highly dependent on the resources of the economy, with emphasis on the commercial breed as the main responsible. The EYR, ELR and ESI emergy indices indicate characteristics of a production with low sustainability, showing that adequate management and planning can contribute to reducing the economy's resource dependence and increasing the use of renewable resources, making aquaculture more efficient**.**

Keywords: Animal Production, fingerlings, tambaqui, environmental performance.

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CAPITULO I

1. INDRODUÇÃO GERAL

Dentro da concepção de novos modelos de desenvolvimento, destaca-se a necessidade de fortalecimento de sistemas de produção menos degradantes, mais eficientes, geradores de trabalho e renda e que garantam saúde, qualidade de vida e dignidade àqueles que delas dependem. A aquicultura como atividade economicamente emergente, apesar de sua origem milenar, encontra-se hoje diante do desafio de moldar-se ao conceito de sustentabilidade (ASSAD; BURSZTYN,2000). Isso implica agregar novas dimensões à racionalidade que move a produção de conhecimentos e os sistemas de cultivo do setor.

Dentre as metodologias existentes para avaliar a sustentabilidades de uma produção agrícola, destaca-se a síntese emergética definida por Odum, (1996) como a disponibilidade de energia que é utilizada em transformações diretas ou indiretas para produzir um produto ou serviço. Conforme Kamiya (2005), os índices fornecidos pela análise emergética permitem que sistemas agrícolas, com modelos de produção diferentes, sejam comparados. Deste modo, pode-se obter o modelo de produção que apresenta os melhores desempenhos ambientais, econômicos e sociais.

Para a aquicultura a utilização desta análise pode contribuir como ferramenta capaz de mensurar os diferentes impactos ecológicos causados pelos díspares modelos de produção. Quanto ao cultivo de espécies nativas, embora a produção venha crescendo no Brasil e pareça ser uma atividade bem estabelecida, faltam estudos que demonstrem sua sustentabilidade, principalmente sobre a produção de juvenis que está nos elos iniciais e são fundamentais na cadeia produtiva aquícola. Sem boas práticas de manejo adequadas na produção, não há juvenis de boa qualidade, toda a cadeia fica comprometida, as taxas de conversão caem e não há padronização.

Partindo desse princípio, este estudo buscou responder as seguintes perguntas: A produção de juvenis de espécies nativas são sustentáveis? A metodologia de síntese emergética permitirá identificar os possíveis entraves da sustentabilidade na produção de juvenis? Com isso, o presente estudo visa atender as necessidades citadas acima por meio de diferentes abordagens.

Para colaborar com o entendimento e aprofundamento do tema quanto aos aspectos relacionados ao uso da emergia na avaliação de juvenis de espécies nativas, a presente tese foi subdividida em três capítulos; *O capítulo I* contendo a Introdução, abordando basicamente a estrutura da tese e os conceitos.

O *Capítulo II* buscou-se através de uma revisão sistemática realizar o levantamento de estudos disponíveis na literatura nos últimos 10 anos utilizando a síntese emergética como avaliação da sustentabilidade na aquicultura, descrevendo as principais espécies e sistemas de produção avaliados. Com base nas informações observadas procurou-se identificar as limitações e as tendências para pesquisas futuras através dos resultados observados.

Já o *Capítulo III* traz o estudo comparativo aplicando a emergia para avaliar dois sistemas de produção de juvenis de espécies nativas, a primeira com dados hipotéticos e a segunda com dados reais de uma piscicultura localizada na região de Sorriso, Estado de Mato Grosso. A aplicação da análise emergética proporcionou reflexões referentes ao uso dos insumos advindo da natureza e da economia, visando a comparação com outros sistemas de produção de peixes nos estágios iniciais da produção aquícola. E por último, as Conclusões à que se chegaram e as Considerações Finais da presente pesquisa.

2. REVISÃO BIBLIOGRÁFICA

Neste tópico será fundamentado as discussões e análises propostas no decorrer do trabalho. Conceitos teóricos de bioeconomia e suas relações com a aquicultura, sua aplicabilidade junto ao objeto de pesquisa – sustentabilidade da produção de peixes, que serão discutidos de forma inter-relacionada e apresentados em duas seções: discussões sobre analise emergética e bioeconomia.

2.1. Bioeconomia e aquicultura

As discussões sobre as mudanças climáticas, escassez de recursos e a gama mundial de problemas ecológicos impuseram novas pressões na sociedade. Nesse sentido, criar um ambiente social que prospere dentro de seus limites biofísicos não é mais visto como um objetivo distante e utópico; agora é um assunto urgente que, se negligenciado ou mal administrado, trará consequências devastadoras para o planeta e a economia humana que vive nele. (CARADONNA, 2014).

Através dessas questões levantadas somado as oposições sobre as principais teorias da economia clássica e neoclássica, a bioeconomia se inseriu como um novo olhar para aspectos do processo econômico de fatores até então ignorados: a escassez de recursos e as instituições sociais (MAYUMI, 2009).

Assim, os teóricos da denominada economia ecológica se opõem a visão de valoração e baseiam-se principalmente numa análise de fluxo energético, considerando a economia ligada de forma inescapável aos processos biofísicos e energéticos. A economia ecológica além de se opor à economia do meio ambiente na solução do problema leva em consideração uma interdisciplinaridade, utilizando-se dos conceitos de biofísica, sobretudo o de entropia (WITT, 1999; BONAIUTI, 2013).

Esse grupo teria uma preocupação voltada mais para aquilo que se denominou sustentabilidade forte, em oposição à sustentabilidade fraca. A primeira definição trabalha com a ideia dos sistemas ambientais intactos, ou dito de outra forma trabalha com o conceito de capital natural fixo. Já a segunda definição admite a substituição entre capital natural e físico, logrando a sustentabilidade quando o total de capital, e não apenas o natural, permanece fixo (ROHDE, 2016).

Os pesquisadores que se preocuparam com a sustentabilidade forte foram marcados pelo pessimismo no que diz respeito ao alcance do desenvolvimento sustentável. Isso se justifica, principalmente, pelo fato de os mesmos serem fortemente influenciados pela análise pioneira de Georgescu-Rogen expressa na sua obra “The Entropy Law and the economic process” de

1971, que recorreu às leis físicas de entropia, enunciadas no século 19. Nesta obra, o economista romeno submeteu a economia aos limites físicos impostos pela natureza, uma vez que a primeira e a segunda leis da termodinâmica impõem conjuntamente a escassez à economia (MISSIMER, 2017).

Assim, fica evidente que as conceituações da Economia Ecológica se chocavam de frente com a tradicional economia ambiental, de inspiração neoclássica, que se limitava a observar apenas os aspectos econômicos, descolados de outros aspectos. Neste contexto, a bioeconomia começou a surgir como um novo paradigma para o desenvolvimento sustentável a longo prazo para o século 21. Onde envolve a ampliação das possibilidades trazidas pelas ciências biológicas e seus usos para resolver problemas e questionamentos referentes a utilização dos recursos não renováveis. (CNI, 2013).

O termo bioeconomia passou a ser utilizado na década 1970 no intuito de se reportar à origem biológica do processo econômico e, portanto, destacar o problema da existência da humanidade como uma loja finita de recursos acessíveis, localizados de forma irregular e desigualmente disponíveis (GOWDY & MESNER, 1998; MISSEMER, 2017).

Diante disso, seguindo a ótica da conceituação de bioeconomia, para Georgescu-Roegen entende que a entropia envolve tanto massa como energia, ambas sujeitas à degradação contínua na direção de menor entropia para maior entropia, de acordo com as duas leis principais da termodinâmica. O primeiro princípio é simples e diz que a energia não é criada, tampouco eliminada, mas transformada (FUNTOWICZ.; O'CONNOR, 1999; BIRCH; TYFIELD, 2013).

O segundo princípio, porém, enuncia que a matéria tende a evoluir no sentido dos estados de máxima entropia, isto é, estados onde a degradação é maior e estados onde a matéria tende a agregar-se em estruturas mais desorganizadas e de dispersão espacial. Portanto, o valor da entropia é mais baixo se a configuração por ela adotada é mais complexa e ordenada (FUNTOWICZ.; O'CONNOR, 1999).

O meio natural está sempre caminhando uma direção de maior entropia, contudo influenciado pela presença do homem e por uma sociedade que procura atender as necessidades crescentes. Neste sentido, o processo entrópico tende a se acelerar e, no limite, a superar a capacidade de reorganização do sistema, condenando o homem e todo o ambiente a uma insustentabilidade permanente. (BUGGE et al., 2016).

A inevitabilidade e irreversibilidade destes processos, tendendo sempre a uma entropia máxima do universo, alertam para reflexões acerca das escolhas e investimentos tecnológicos e científicos das ciências que lidam diretamente com o uso destes recursos, como é o caso do agronegócio (ALEGRETTI, 2017).

O fluxo de energia solar aliado ao uso do recurso terra e seus estoques minerais determinam tanto a produção de plantas como de animais, dependentes direto das mesmas como alimento. A eficiência de utilização destes recursos naturais pelas diferentes espécies de plantas e animais deve ser um determinante na escolha das atividades agropecuárias na busca por processos menos entrópicos (WITT, 1999).

Outro ponto importante levantado por Georgescu-Roegen, além da escassez dos recursos de baixa entropia, diz respeito à geração de resíduos resultantes dos processos biológicos e econômicos. Atualmente, algumas atividades econômicas no mundo deixaram de ser praticadas não necessariamente pela finitude dos recursos, já percebida, mas sim pelo excessivo volume de resíduos gerados (GOWDY & MESNER, 1998).

De acordo com os relatórios de aquecimento global o aumento da mensuração da eutrofização de rios, contaminações de lençóis freáticos, dentre outros passivos ambientais, vêm obrigando a sociedade e os gestores públicos a aumentar o rigor das legislações ambientais interferindo, assim, diretamente em questões sociais relacionadas à geração de empregos, desenvolvimento regional e sistema econômico como um todo (MACEDO et al., 2010).

Portanto, entende-se que a bioeconomia é um termo multifacetado, que abrange muitos setores e significados permitindo aplicar biotecnologia aos bio-recursos a fim de colher novos produtos, possibilitando melhor compreensão dos ecossistemas em busca de soluções sustentáveis e conhecimentos que o permitam (BUGGE et al., 2016).

Aproximando a teoria proposta por Georgescu-Roegen, aquicultura é uma das atividades econômicas que contribui na produção de alimentos e vem se intensificando devido à demanda global crescente por produtos pesqueiros. Para isso, faz necessário o uso de práticas mais sustentáveis para reduzir os impactos ambientais associados a está atividade, incluindo o uso de recursos naturais, destruição de ecossistemas, eutrofização de rios, impactos devidos as práticas inadequadas de produção, entre outros (RABASSÓ; HERNÁNDEZ, 2015; GRANADA et al., 2018).

Dessa forma, percebeu-se a importância em criar condições econômicas para tornar viáveis tecnologias que fossem capazes de conciliar a produção animal e preservação ambiental. Nesse debate, a energia é um ponto central, pois tem grande importância econômica na medida em que serve de matéria-prima central para os processos produtivos, assim como na aquicultura, tendo seus impactos ambientais consideráveis (ANDERSON, 1985; VALENTI, 2008; FARMAKI et al., 2014).

Assim, de acordo com as discussões baseadas nos preceitos da Bioeconomia, as atividades econômicas, especificamente a aquicultura, podem alcançar a sustentabilidade energética desde que sejam incorporados processos e métodos que considerem a capacidade de suporte do meio ambiente. Desse modo, é possível orientar o desenvolvimento econômico para um novo modelo de produção.

2.2. Aquicultura e uso de metodologias de avaliação da sustentabilidade

A aquicultura é considerada o setor de produção animal que apresenta o ritmo de crescimento mais acelerado, devido em parte à intensa exploração dos recursos pesqueiros naturais. (Carvalho et al., 2010). Em 2016, a atividade foi responsável por aproximadamente 47% da produção mundial de pescado, já em 2018 forneceu 52% de todo o pescado utilizado para a alimentação humana (FAO, 2018).

No Brasil o desenvolvimento da aquicultura apresenta inúmeras vantagens. Com mais de 6,5 milhões de hectares em lagos, reservatórios e represas, o país apresenta ampla capacidade de produção (MPA, 2013). A disponibilidade de água e terra, o clima favorável, a grande disponibilidade de insumos para ração e o baixo custo de produção são fatores que contribuem para esse crescimento

Segundo IBGE (2015), a produção de peixes se desenvolveu em todo território gerando em 2015 mais de R$ 4,39 bilhões, sendo quase 70% (R$ 3,64 bilhões) proveniente da criação de peixes (IBGE 2015). No entanto, a aquicultura no Brasil tem mostrado uma velocidade de crescimento muito inferior ao seu potencial. Países como Egito, Indonésia e Filipinas apresentaram um crescimento aquícola mais expressivo, ainda que com menos recursos naturais disponíveis (HALWART, 2007; MPA, 2013; RORIZ 2016).

Ainda assim, a produção de pescado saiu de 392 mil toneladas em 2013, para 483 mil toneladas em 2015, tendo um aumento de 18,8%, sendo a tilápia o peixe o mais produzido no Brasil, com 219 mil toneladas em 2015 (IBGE 2013; 2014; 2015). Hoje o Brasil encontra-se entre os maiores produtores de tilápias do mundo atrás de China (1,8 milhão/t/ano), Indonésia (1,1 milhão/t/ano) e Egito (800 mil/t/ano). Em 2018 a produção obteve um aumento de 11,9%, em relação ao ano anterior, alcançando 400 mil toneladas (PEIXE BR, 2019).

Apesar do Brasil apresentar um grande foco em espécies exóticas, o país conta com inúmeras espécies nativas algumas delas de grande importância para aquicultura brasileira como o tambaqui, sendo a segunda espécie mais cultivada, contribuindo com 39,84% do total da produção de peixes em 2018. Sua despesca foi de 287.910 toneladas. A produção de peixes nativos liderada pelo estado de Rondônia, com 72.800 t, seguida por Mato Grosso (52.000 t). Os cinco maiores produtores (199.700 t) representam 69,4% da oferta total (PEIXE BR, 2019).

Com o potencial de mercado a produção de peixes estimulou o aumento do número de produtores nos últimos anos. No entanto, para que os avanços sejam estáveis, é necessário que se adotem os preceitos da sustentabilidade (KUHLMAN; FARRINGTON, 2010; CARADONNA, 2014; HAVICE; ILES, 2015).

O aumento da produção de espécies aquáticas traz questões diretamente relacionadas ao seu desenvolvimento sustentável e demanda por estudos de sustentabilidade. Entre elas estão questões relacionadas aos impactos ambientais, viabilidade econômica, equidade social e ao conjunto de arranjos que constituem a governança do setor (LAZARD et al., 2011).

Entretanto, o grande desafio encontrado por pesquisadores em todo mundo é avaliar os vários sistemas adotados na produção de organismos aquáticos, dentro do contexto da sustentabilidade. Assim, a aquicultura sustentável pode ser definida como produção lucrativa de organismos aquáticos, interagindo com ecossistemas e comunidades locais e minimização de possíveis impactos ambientais, é a utilização racional dos recursos financeiros, naturais e humanos no processo de produção (GENTRY et al., 2018).

Uma aquicultura sustentável é uma atividade economicamente viável, que propicia melhoria da qualidade de vida das comunidades locais, sem degradar os ecossistemas nos quais se insere envolvendo três componentes: a produção lucrativa, a conservação do meio ambiente e o desenvolvimento social. Sendo estes essenciais e indissociáveis para que a atividade seja perene (VALENTI et al., 2018).

Dentre os principais métodos usados para medir a sustentabilidade da aquicultura no mundo destacam-se: Pegada Ecológica, Análise do Ciclo de Vida, Resiliência e Análise Emergética (TEIXEIRA, 2011; MUNGKUNG et al., 2013; WILFART et al., 2013; WILLOT et al., 2019). Cada um deles com características próprias.

Os métodos de Pegada Ecológica e Analise do Ciclo de Vida focam principalmente a sustentabilidade ambiental. A interpretação dos resultados é relativamente mais simples, no entanto, os dados são mais difíceis de serem obtidos (KIMPARA et al., 2010). Quanto a Análise de Resiliência permite avaliar a capacidade de um determinado sistema se perpetuem ao longo do tempo. Porém, até o momento, ainda não há um método adequado para medir a resiliência nos sistemas de aquicultura.

O método da Análise Emergética, foco deste estudo, fornece uma visão holística do processo e considera as interações internas e externas da produção, possibilitando a análise de cada parte deste sistema produtivo em separado. Isso permite localizar os pontos fracos para correção (GUAN et al., 2016).

Esta metodologia permite entender como funciona a biosfera, os ecossistemas naturais, os ecossistemas antrópicos e suas inter-relações com a economia humana ao longo do tempo (ULGIATI et al. 2011). Quando empregada para avaliar um sistema produtivo, como na aquicultura, pode-se compreender claramente os pontos que desafiam um sistema aquícola e no ambiente que ele está inserido, realizando uma análise da sustentabilidade, econômica e a capacidade de suporte do ambiente: o saldo energético das fontes de energia (renováveis e não renováveis), a área de absorção de impacto pelo uso de energia não renovável.

2.3. Síntese Emergética

A contabilidade emergética pode ser definida como a disponibilidade de energia que é utilizada em transformações diretas ou indiretas para produzir um produto ou serviço (ODUM, 1996). A emergia, ou memória energética, permite o levantamento de todos os fatores que contribuem para a produção de bens e serviços num mesmo denominador: a energia da radiação solar equivalente ou necessária para o processo integral de produção que tem como medida o emjoule ou seJ (ODUM, 1996; BROWN; ULGIATI; 1997).

A síntese emergética se baseia nos princípios da termodinâmica, da teoria de sistemas e da ecologia de sistemas. Assim, fluxos de recursos que não são trocados no mercado, inclusive a radiação solar, o vento e a onda, podem ser internalizados na produção econômica e valorados pela emergia. Esses fluxos incorporam também a matéria, a energia, o dinheiro e a informação, além do trabalho necessário, a cultura e a informação, que podem ser agregados nessa metodologia a fim de se contabilizar as suas respectivas contribuições nos processos produtivos (BROWN; ULGIATI; 1997, 2002; ROHDE, 2003; HADEN; 2003; ULGIATI et al. 2011).

Dessa forma, a síntese emergética unifica os recursos da natureza e da economia em uma mesma medida, revelando a enorme e ramificada cadeia energética que une as partes do sistema (WANG et al. 2016). Por exemplo, o sol, o combustível, a eletricidade e os serviços humanos podem ser colocados em uma base comum, expressando-os todos em emjoules de energia solar que são necessários para cada um (ODUM, 2001).

A análise emergética permite, portanto, a quantificação e a valoração de suas contribuições, em fontes de energia renováveis e não-renováveis, o que outras técnicas geralmente não contabilizam ou contabilizam apenas de maneira parcial (ULGIATI; BROWN, 2002; ULGIATI et al., 2011). Os recursos renováveis (R) são extraídos do ambiente e têm a capacidade de renovação temporal e espacial mais rápida que o seu consumo (energia solar, energia dos ventos, energia da chuva etc.). Os recursos não renováveis (N) são armazenados na natureza, porém, seu consumo é mais rápido do que a sua capacidade de renovação (carvão, petróleo, florestas, água potável etc.). Os recursos provenientes da economia (F) são referentes a materiais e serviços provenientes de outras regiões que estão fora das fronteiras do sistema estudado (CAMPBELL et al., 2005; RODRIGUES et al., 2011).

O conjunto desses recursos fazem parte de uma hierarquia de energia universal e de uma rede de transformação de energia que englobam dos estes recursos (CAVALLET; ORTEGA, 2010). Por este ser um método que contabiliza a energia despendida nos processos de produção, é importante reconhecer a qualidade e a funcionalidade de cada tipo de energia que é utilizada para a geração dos recursos, tendo em vista a geração da hierarquia de energia e no resultado dessas transformações energéticas possam ser ordenadas hierarquicamente (BROWN; BURANAKARN, 2003).

Por exemplo, muitos joules de sol são necessários para fazer um joule de combustível; vários joules de combustível para se fazer um joule de energia elétrica; muitos joules de energia elétrica para suportar o processamento de informações em uma universidade, e assim por diante. Dessa forma, pelo fato de os tipos de energias não serem iguais em contribuição, o método de análise emergética expressa cada transformação em unidades de uma forma de energia anteriormente exigida (YANG et al., 2010).

Esse cálculo de energia acumulada é denominado de emergia (ODUM, 1986, 1988) ou de memória energética (SCIENCEMAN, 1987). Para se medir a qualidade da energia e a sua posição na hierarquia de energia universal é necessário, então, conhecer a sua intensidade emergética, que é definida como a quantidade de emergia requerida, direta ou indiretamente, para gerar uma unidade de energia de outro tipo (ODUM, 1988).

Li et al. (2010) e Le Corre et al. (2015) afirmam que a intensidade emergética é um dos conceitos fundamentais da Teoria dos Sistemas e Energia, e que é fundamental para cálculo da emergia. A intensidade emergética é composta pela razão entre a emergia mínima necessária para um ecossistema produzir um recurso e a energia final contida nos recursos produzidos, ou seu valor em moeda ou peso em kg (ULGIATI; BROWN, 2002). A unidade da intensidade emergética é o emjoule solar/joule ou emjoule solar/kg ou, ainda, emjoule solar/US$. Quando a intensidade emergética é constituída pela razão entre a emergia para produzir o recurso e a energia final deste mesmo recurso, tem-se a transformidade do produto (ALLEGRETTE, 2017).

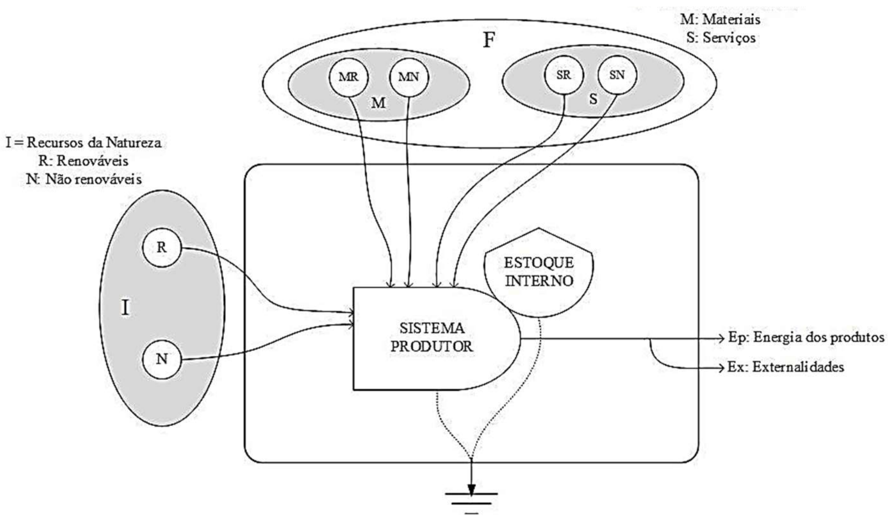
Assim, a transformidade de um produto tem sido calculada somando-se todas as entradas de emergia do processo e dividindo-se pela energia proveniente do produto. Importante destacar que, para se realizar a análise de fluxos de emergia dos sistemas, é indispensável contar com a informação sobre a equivalência em joules de energia solar (seJ). Quanto maior for a intensidade emergética obtida de um recurso, mais longe de sua origem ele estará, uma vez que há muito valor agregado nele (YANG et al., 2010; WU et al., 2014; WANG et al. 2016).

Muitos cálculos e valores de transformidade estão reunidos e disponibilizados no site do International Society for the Advancement of Emergy Research (ISAER) e em artigos científicos. A identificação da fonte utilizada como base para a transformidade de cada insumo é sempre apresentada no memorial de cálculo de cada pesquisa (ALLEGRETTI, 2017).

Outra característica capital da análise emergética é o Princípio da Máxima Empotência, denominada de potência ecossistêmica (emergia/tempo). Os sistemas tendem a maximizar o fluxo de energia, porém, a energia potencial disponível varia com o tempo. Isso implica que os arranjos para maximizar o fluxo de energia em toda a cadeia alimentar mudam com o tempo. Dessa forma, os sistemas se auto organizam (expandem-se e contraem-se) em hierarquias de transformação de energia que pulsam (crescem e decrescem), cobrem diversas áreas, acumulam energia e evoluem (TILLEY, 2004).

Odum (1996) afirma que este princípio determina que os sistemas ecológicos, e econômicos, irão sobreviver ao longo do tempo e, portanto, contribuir para sistemas futuros. O processo da contabilidade emergética segue algumas etapas lineares: (i) levantamento da história do local de estudo; (ii) elaboração de um diagrama (Figura 1); (iii) montagem da tabela de avaliação emergética (Figura 2); (iv) cálculo dos índices emergéticos e (v) interpretação dos resultados.

Figura 1 Exemplo genérico de um diagrama da contabilidade ambiental em emergia



Fonte: Alegretti (2017).

Figura 2 - Exemplo de tabela de avaliação emergética.

1	2	3		4		5	6	7	8
Nota	**Descrição do fluxo**	**Quantidade**		**Transformidade**		**Renovabilidade**	**Fluxo Renovável**	**Fluxo não renovável**	**Emergia**
		Valor	Unidade	Valor	Unidade	%	SeJ	SeJ	SeJ
1	Recurso Renov da Natureza **(R)**								
2	Recurso N Renov da Natureza **(N)**								
3	Materiais da Economia **(M)**								
4	Serviços da Economia **(S)**								
5	Emergia Total **(Y)**								
6	Produtos		Quantidade	Energia					

Fonte: autora da pesquisa.

A análise se inicia por meio da identificação dos componentes principais do sistema, suas entradas e saídas. O passo seguinte consiste na confecção de um diagrama sistêmico do objeto em estudo. Este diagrama é composto por símbolos específicos da contabilidade emergética que representam o processo produtivo. Por meio desta é possível elaborar o diagrama sistêmico, que ilustra com todos os recursos envolvidos no sistema estudado, bem como as suas interações e outputs (DALLEY, 2013).

Diante destas estruturas de avaliação e por permitir uma visão sistêmica do sistema a ser estudado, acredita-se que a contabilidade ambiental em emergia é um dos métodos mais inovadores e completos referente à quantificação e à valoração da sustentabilidade, sendo muito utilizada em pesquisas acadêmicas e de agências públicas como o U.S. Environmental Protection Agency (U.S. EPA) e U.S. Forest Service para políticas públicas e tomadas de decisão (BROWN; CAMPBELL, 2007).

3. HIPÓTESES E OBJETIVOS

3.1. Hipóteses

Hipótese 1: A produção de juvenis de espécies nativas é considerada sustentável;

Hipótese 2: O uso da metodologia de análise emergética permite avaliar a sustentabilidade da produção de juvenis.

3.2. Objetivos

3.3. Geral

Mensurar, através da análise emergética, a sustentabilidade da produção de juvenis de espécies nativas como o tambaqui e seus híbridos.

3.3.1. Específicos

- Identificar as contribuições advindas da natureza e da economia no sistema de produção de juvenis;

- Construção de um diagrama de fluxos de energia para avaliar as interações do processo;
- Calcular os índices emergéticos de produção de juvenis de tambaqui e seus híbridos;
- Verificar se os usos de boas práticas melhoram os indicadores emergéticos na produção de juvenis;
- Disponibilizar dados que sirvam como base para trabalhos futuros e material de estudo sobre questões ligadas a sistemas de produção de juvenis utilizando a metodologia de analise emergética.

CAPITULO II*

Uso da Emergia para avaliar a sustentabilidade na aquicultura: Revisão sistemática.

Use of emergy to assess sustainability in aquaculture: Systematic review

*Artigo elaborado seguindo modelo de estrutura e formatação do periódico Reviews in Fisheries Science & Aquaculture

Use of emergy to assess sustainability in aquaculture: Systematic review

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Use of emergy to assess sustainability in aquaculture: Systematic review

Aquaculture is one of the protein production activities with the most significant potential for development globally. It is one of the fastest-growing in recent years, mainly because of its efficiency in transforming feed into flesh. However, the activity raise can be accompanied baccompany many economic, social and environmental problems. Numerous production systems, models and techniques have been developed and used to manage resources and reduce the negative impacts of the activity. However, it is not known which production systems and management practices are more sustainable, although the development and application of these technologies are crucial and profoundly influence this production aspect. The emergy is a method that considers nature's contribution in creating the product and service, excluding the strictly monetary character present in conventional economic evaluations, being a model used to measure sustainability in productive systems. In this sense, the systematic review's objective was to identify contributions of emergy analysis in aquaculture. The systematic review methodology identified 17 articles using emergy analysis to assess sustainability within the environmental, economic, and social aspects. According to these studies, the production systems evaluated vary among monocultures and polycultures in different production levels (intensive, semi-intensive, extensive). When all these particularities are transformed into the same unit (emjoule or solar joule), it is possible to compare different scenarios. In aquaculture, emergy assessment provides information that allows identifying management to be applied to make production systems more sustainable and resilient. Thus, using emergy to evaluate aquaculture systems can offer helpful information to identify the most sustainable management or production system.

Keywords: Sustainable production, Emergy synthesis, sustainability, fish farming.

Introduction

According to FAO (2018), aquatic food consumption has increased in recent years, driven by population growth and an increased preference for healthy animal protein sources. Furthermore, with the technological advancements, aquaculture stood out in producing aquatic organisms based on introducing new production techniques, accessible costs, and significant gains in productivity and quality in animal protein production (Tacon, 2019). In contrast, the increase in aquaculture production results in numerous concerns about the future of the activity, especially concerning the negative environmental impact it can cause (Nhu et al., 2016).

According to the production system adopted to cultivate aquatic organisms, natural resources can be used irresponsibly, which interferes with the maintenance of biodiversity either through the eutrophication of rivers or the impacts of inadequate production practices (Granada et al., 2018). On the other hand, aquaculture can positively affect the environment, such as ecosystem services and effluent production for agriculture irrigation (Medeiros et al., 2013).

With the market potential and the increase in the number of producers, it is necessary to adopt management so that the activity remains stable, and one of the alternatives is the adoption of sustainability precepts (Havice and Iles, 2015). From this perspective, issues related to environmental impacts, economic viability, social equity, and arrangements constitute the sector's governance (Lazard et al., 2011). However, researchers worldwide are challenged to evaluate and compare the various systems in the aquatic production of organisms within the context of sustainability.

The numerous methods, models, and techniques for measuring sustainability in production have been developed and used to manage resources, reduce the negative impacts of productive activity, and make aquaculture more sustainable (Guan et al., 2016). However, it is unknown which of these methods is really appropriate, revealing an accurate picture of the activity.

Sustainability assessment methodologies can be applied to show each production system's weaknesses and strengths and indicate strategies for improving them (Willot et al., 2019). Among these methodologies, the emergetic synthesis can provide factual information for decision-making and guide sustainability (Odum, 1996; Ulgiati et al., 2011), making it stands out for being a flexible and scientifically robust method (Odum, 1996).

Moreover, this method can provide factual information for decision-making and guide sustainability (Ulgiati et al., 2011). In this way, a holistic view of the applicability of emergy assessment in aquaculture systems is necessary to guide future studies and propose alternatives for the activity's sustainable development. Thus, the foundation question in this review was: "What are the contributions of using the methodology of emergy analysis for aquaculture?" intending to characterise the use of emergy analysis on aquaculture systems and discuss the main applications and potential use.

Material and methods

About data

Initially, a search for data was carried out in different electronic databases to support the systematic review and was based on a structured search developed through digital databases (Figure 1). Several search keys were tested based on adaptations of the PICo strategy (Population ',' Interest ', and' Context) using a series of alternative terms in the characterisation of each term. However, as it is a limited area of research, it was decided to use a simple key to reduce the chance of exclusion from any studies.

Thus, the search words "aquaculture" (population) and "emergy" (interest) were used to find a significant number of studies, even if this represented a large number of initial results that would need to be critically evaluated in the selection steps. The search was conducted in the main electronic databases available for research (Web of Science, Scopus and Science Direct) from August to October 2020. However, as it is a methodology of increasing use in aquaculture, the research period was limited to 2010-2020.

The search results in each database were exported to reference management software Zotero (version 5.0.96). Duplicate references were identified and deleted. The studies were then critically evaluated for their adherence to the research question. Initially, the titles and abstracts of each publication were evaluated, followed by a complete review of the published work. Finally, works that applied the methodology of emergy assessment in aquaculture systems (selection criteria) were selected.

The selection and evaluation of the eligibility of each study were carried out by two reviewers independently. A record was only removed from the database when there was a mutual agreement, and a third reviewer was consulted in case of disagreement. No limitations of geographical origin were applied in the research or selection stages.

A backward search strategy was used to ensure that the largest possible number of studies was obtained. In this step, the reference lists for each selected article were checked using the same selection criteria as previously described. Finally, the selected articles were evaluated for their quality and the relevancy and information for the description of the theoretical model proposed by each study and then were transferred to electronic spreadsheets. After descriptive evaluations, comparisons between studies were made.

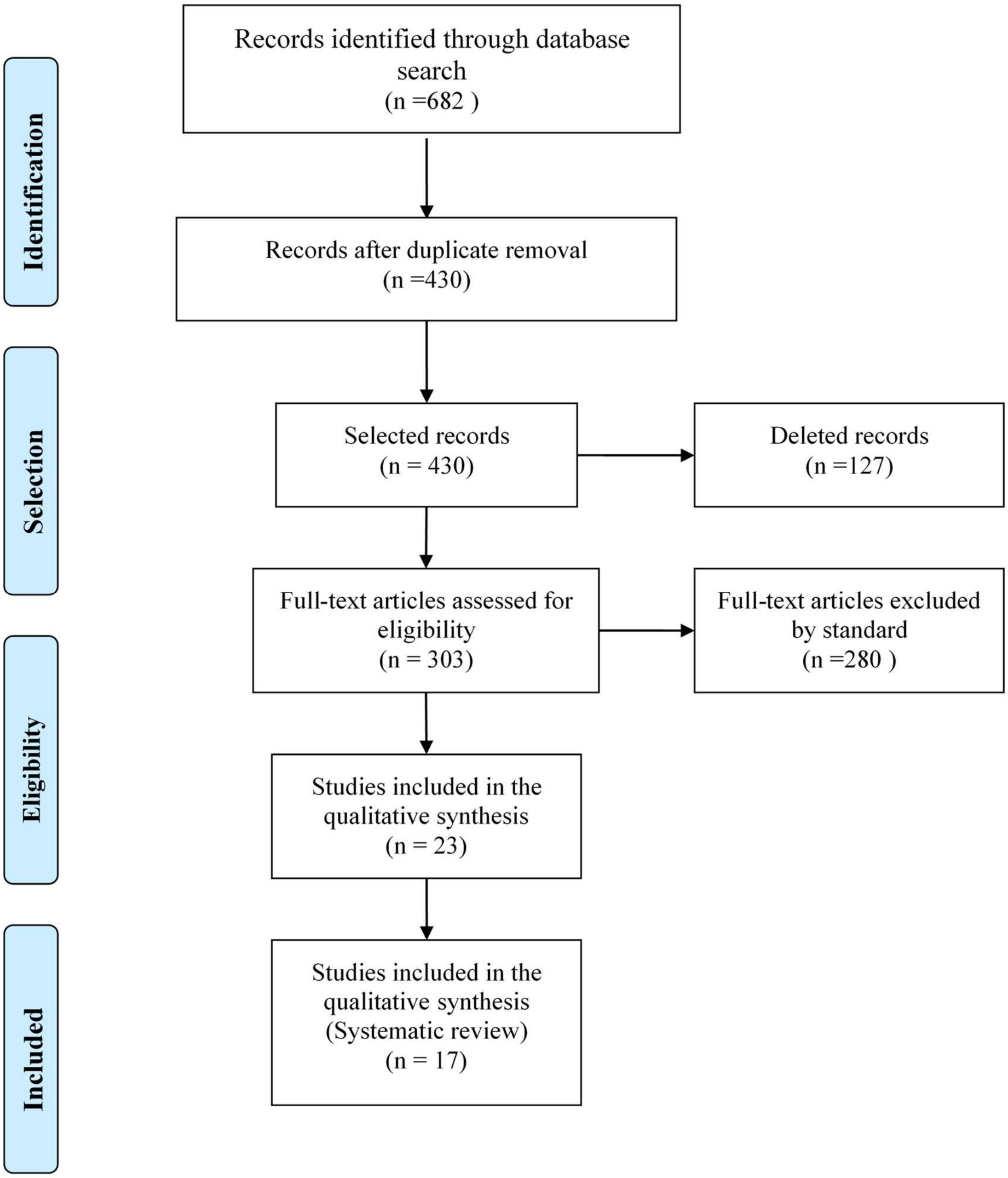


Figure 1. Analysis flowchart used in the development of the systematic review

To illustrate the systematic review were used two qualitative analysis software. Infogrann, which makes it possible to create the word cloud with the frequency of use, and Ucinet – version 6.747, which makes it possible to build a network of authors and co-authors and boost the interaction of published articles.

Emergy accounting

Emergy accounting can be defined as the availability of energy used in direct or indirect transformations to produce a product or service (Odum, 1996). The emergy, or energetic memory, allows the survey of all factors that contribute to the production of goods and services in the same denominator: the energy of solar radiation equivalent or necessary for the integral production process that has emjoule or seJ as a measure (Brown and Ulgiati, 1997).

Emergy accounting is based on thermodynamics principles, systems theory, and systems ecology (Brown and Ulgiati, 1997). Thus, flows of resources that are not exchanged in the market, including solar radiation, wind and waves, can be internalised in economic production and valued by emergy (Haden, 2003).

These flows also incorporate matter, energy, money, and the necessary work, culture, and information, which can be aggregated in this methodology to account for their respective contributions to production processes (Ulgiati et al., 2011). The emergy analysis unifies nature's resources and the economy in the same measure, revealing the vast and branched energy chain that unites the system's parts (Wang et al., 2016).

For example, the sun, fuel, electricity and human services can be placed on a common basis, expressing them all in solar energy emjoules (Odum, 2001). Therefore, the emergy analysis quantifies and valuations of their contributions to renewable and non-renewable energy sources, which other techniques generally do not count or only partially count (Ulgiati and Brown, 2002).

According to Campbell et al. (2005), renewable resources (R) are extracted from the environment and have the capacity for temporal and spatial renewal faster than their consumption (solar energy, wind energy, rain energy, etc.). Non-renewable resources (N) are stored in nature; however, their consumption is faster than their renewal capacity (coal, oil, freshwater, etc.). The resources from the economy (F) refer to materials and services from other regions outside the studied system's borders.

The systems of nature and humanity are part of a universal energy hierarchy and an energy transformation network that unites all systems (Cavalett and Ortega, 2010). As it is a method that accounts for the energy expended in the production processes, it is crucial to recognise the quality and functionality of each type of energy used for the generation of resources given the generation of the energy hierarchy. Therefore, energy transformations can be arranged in an ordered series to form this energy hierarchy (Brown and Buranakarn, 2003).

Based on this understanding, the transformity of a product has been calculated by adding all emergy inputs of the process and dividing it by the energy from the product (Wu et al., 2014). It is essential to highlight that carrying out the analysis of emergy flows from the systems is necessary to have information about the transformity (addressed as solar energy joules (seJ) per joule of energy).

Emergy analysis proceedings

The emergy accounting process follows some linear steps proposed by Odum (1996): (i) survey of the history of the place of study; (ii) drawing up a diagram; (iii) setting up the emergy assessment table; (iv) calculation of the emergy indices and (v) interpretation of the results. According to Daley (2013), the analysis makes a systemic diagram of the studied object (Figure 2).

This diagram is composed of specific symbols of emergy accounting representing the production process (Tab. 1) and identifies all the resources of the studied system and their interactions and outputs (Tab. 2). The emergy flow evaluation results infer the emergy analysis from the calculated emergy indices. For this study, the results of the indices for aquaculture will be discussed.

Table 1. Main symbols used in constructing diagrams for emergy assessment proposed by Daley (2013).

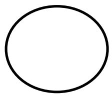
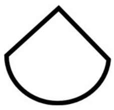
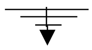
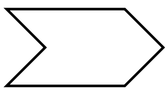
Symbols	Name	Description
	Flow	It determines the flow of energy, information, organisms, materials, etc.
	Source	Represents an energy source that supplies power or flow.
	Stock	It represents an Energy reserve within the system, a compartment of energy, material, information, etc.
	Power sink	Represents the energy degraded during a process, leaving the system as low-intensity energy. According to Thermodynamics' second law, the dispersed energy can no longer perform work (loses its usefulness).
	Interaction	It represents a process that combines different types of energy and materials to produce a different action or resource, a transformation that uses two or more flows of different stocks necessary for a production process, producing a new resource.

Table 2. Emergy indices need to be calculated for the agricultural production system, according to Odum (1996).

Indicators	Description	Equation*
Tr	Transformity	Tr = Emergy/Energy
%R	Renewability	%R = 100 x (R/Y)
EYR	Emergy efficiency rate	EYR = Y / F
EIR	Emergy investment rate	EIR = F / (R + N)
ELR	Environmental loading rate	ELR = (F + N) / R
EER	Emergy exchange rate	EER= Y/ [($) x (sej/$)]
ESI	Environmental sustainability index	ESI = EYR/ELR

(Y): Internal emergy incorporated by the system, (F): Emergy of inputs that come from the economy (N): Emergy of non-renewable natural resources, (R): Emergy of renewable resources

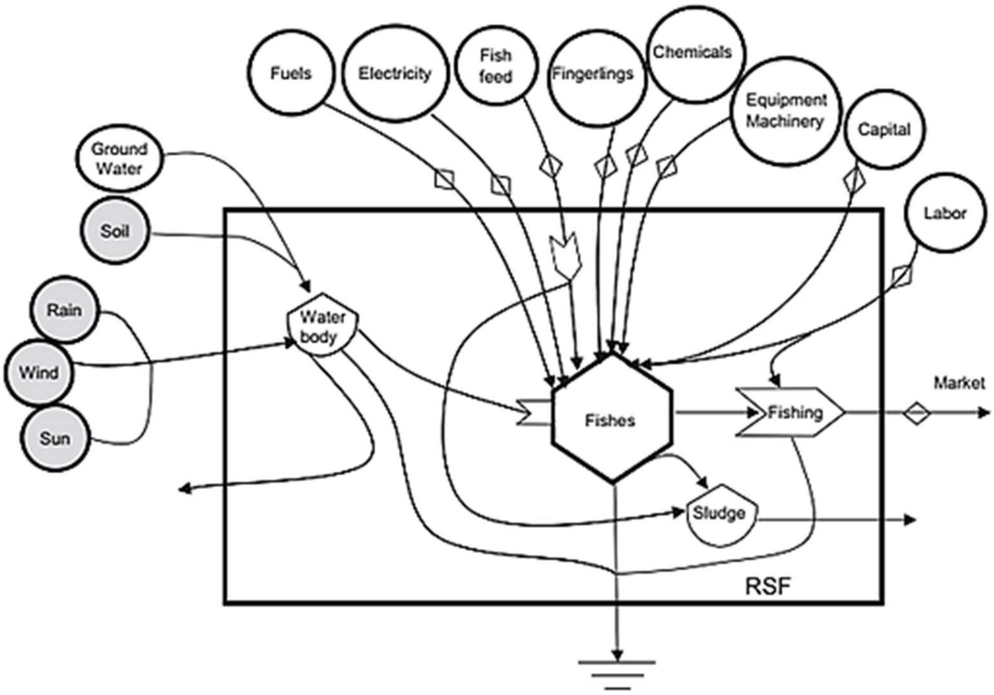


Figure 2. Example of an energy system diagram of fish production in a recirculation system. Source: Wilfart et al. (2013).

Sustainability and Aquaculture

The concern for the environment has become necessary in the fish production process, with water conservation being one of the main aquaculture subjects studied in recent years. To maintain the legality and profitability of any aquaculture enterprise, management strategies must use mostly renewable resources, respect sustainability principles, and reduce the use of non-renewable resources (Willot et al., 2019).

Aquaculture depends fundamentally on the ecosystems in which it operates. Therefore, it is impossible to produce without causing environmental changes (Aubin et al., 2017). However, the environment's impact can be reduced to a minimum and avoid reducing biodiversity, depletion or negative compromise of any natural resource, and significant changes in ecosystems' structure and functioning (Valenti, 2008).

Even though aquaculture changes the natural environment, generating impacts, this concept does not refer only to the biological environment (Rabassó and Hernández, 2015). In this sense, environmental impacts are human-made activities that generate changes in the physical, biological and socio-economic environment (Granada et al., 2018).

Different aquaculture systems can generate other environmental impacts (Barbieri and Cajazeira, 2009), and such impacts depend mainly on: the type of system (closed, semi-open and open); the aquaculture modality (fresh or marine water); species used, and especially the density and size of production. Even so, in any production, the environmental impact occurs through three processes: the consumption of natural resources, the transformation process (processing) and the generation of final products (waste).

For aquaculture, the discussion from the 90's on developing and adopting codes of conduct, Best Management Practices (BPM), and operating standards (among others) was fostered to mitigate its impacts (Boyd et al., 2008). For Clay (2008), the objective of BPM in aquaculture is: to provide a system that reduces the negative impact on social and environmental aspects, reduces the cost of production, increases profitability, reduces waste and pollution, gains or maintains access to new markets, and in addition to promoting the regularisation of aquaculture enterprises.

Adopting best practices in aquaculture management will indeed generate benefits for the producer. According to Valenti et al. (2018), best management practices in aquaculture can ensure the sustainability of the environment within production systems and maintain a healthy ecosystem.

In this case, the authors recommend: prioritising the creation of native species, balanced use of rations and adequate food management to avoid the waste that may pollute the environment, maintenance of water quality, control of fertilisation to prevent excessive use of fertilisers, restriction of the use of chemical products, carrying out compatible sanitary management, use of the polyculture or consortium within the farms, training and qualification of employees, and others.

Every ecosystem has a limit that guarantees its use so that it does not have negative impacts, which can be recognised as carrying capacity. For example, the carrying capacity in aquaculture would produce a certain amount of organisms, such as fish, molluscs, shrimp, or others, without significantly altering the crop's surrounding ecosystem.

According to Kuhlman and Farrington (2010), one of the problems in aquaculture is eutrophication, with the accumulation of nutrients such as Phosphorus (P) and Nitrogen (N) in the water. Acting as fertilisers, P and N facilitate the proliferation of unicellular alga, changing the colour of the water, usually making it a 'green soup'. Subsequently, these algae's mortality is common, generating low oxygen dissolved concentrations in the water that promotes massive fish mortality.

For Granada et al. (2018), respecting the ability to support the aquaculture industry's environment enables the ecosystem's sustainability where the activity is inserted and may avoid negative economic impacts for the aquaculture farmer.

From this context, it is possible to perceive the importance of creating economic conditions to make viable technologies that could reconcile animal production and environmental preservation. In this debate, energy is a central point. Through the discussions presented and based on sustainability principles, economic activities such as aquaculture, in particular, can reach sustainable levels of production by providing and incorporating processes and methods that aim at more sustainable production.

Results of the emergy assessment contributions in world aquaculture

The emergy assessment method has been used to analyse different production systems in aquaculture scales. According to the topics studied, the subjects most covered among recent publications with the application of emergy are integrated assessments of ecosystems dominated by man (Li et al., 2011), sustainability assessment (David et al., 2018), environmental impact (Song et al., 2013), and assessment and the combination of emergy assessment with other methods (Wilfart et al., 2013).

The number of articles found in the search was mainly distributed in the Journal of Cleaner Production (80), Ecological Indicators (46), Ecological Engineering (31), Sustainability Switzerland (31) and Ecological Modelling (21), and Sustainability Switzerland (31).

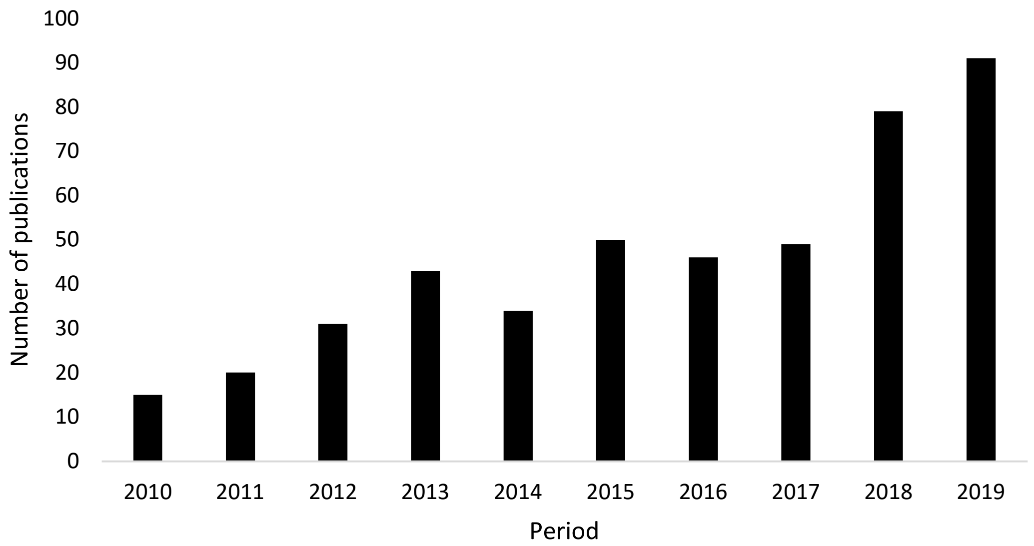


Figure 3. The number of publications on the research platforms (2010-2019) addressing the search terms "emergy" and "aquaculture".

The articles collected revealed the adhesion of authors and co-authors and the concern in favour of themes related to sustainability in global aquaculture. The studies also address the analysis of various production systems and sustainable development of the aquaculture sector. Of the articles collected in the selected research bases, 17 were related to the use of emergy in aquaculture (figure 4). After reading all the articles in total, it was possible to classify the countries of publication and prepare a timeline evaluating the evolution of the number of articles published on emergy in the last ten years.

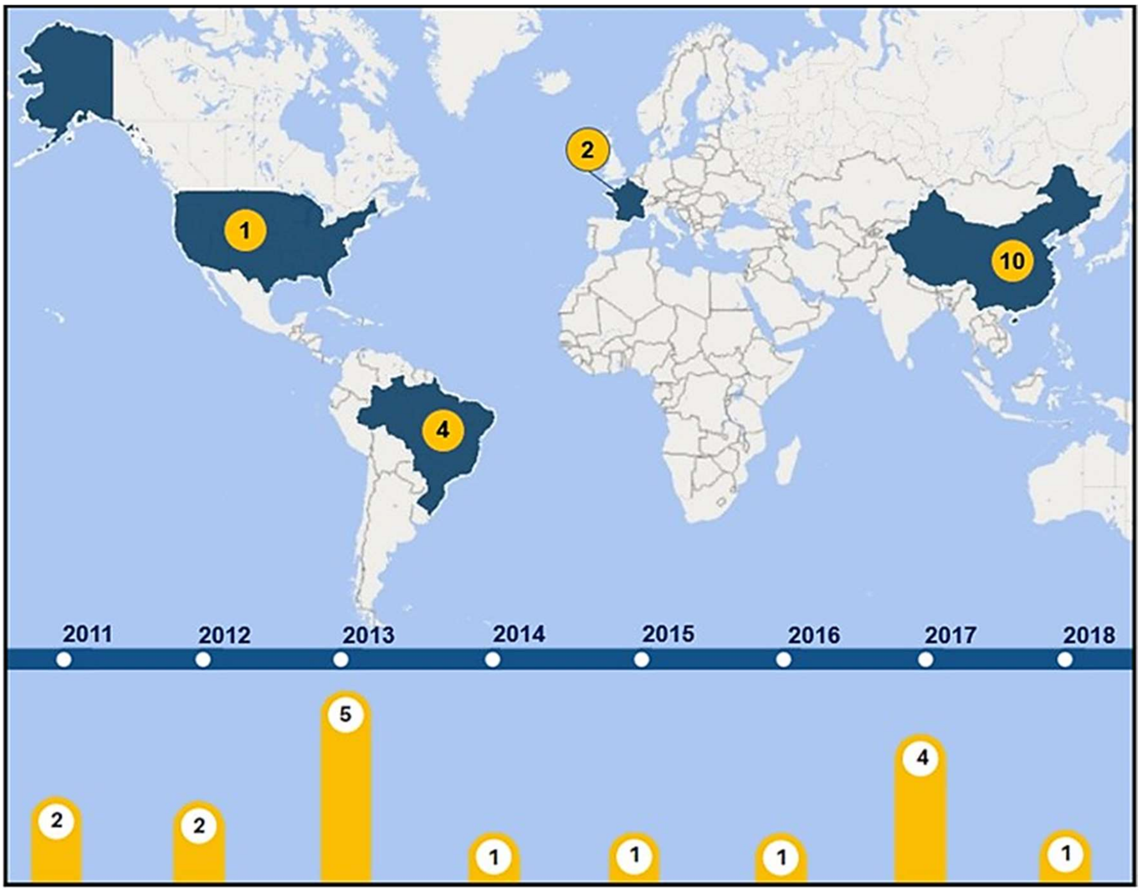


Figure 4. Timeline of collected articles and their countries of publication.

China stood out with ten articles dealing with issues involving emergy assessment methodology in aquaculture. Among the scientific journals with articles related to this theme were Journal of Cleaner Production (4), Ecological Indicators (3), Ecological Engineering (2), Journal of Environmental Management (2), 3rd International Conference on Water Resource and Environment (1), Acta Ecologica Sinica (1), Aquaculture (1), Ifip

International Federation for Information Processing (1), Journal of Fisheries of China (1), Reviews in Aquaculture (1).

After compiling the data, the network of authors and their co-authors was built (Figure 5), where we sought to discover the interfaces and relationship of elaboration of works together.

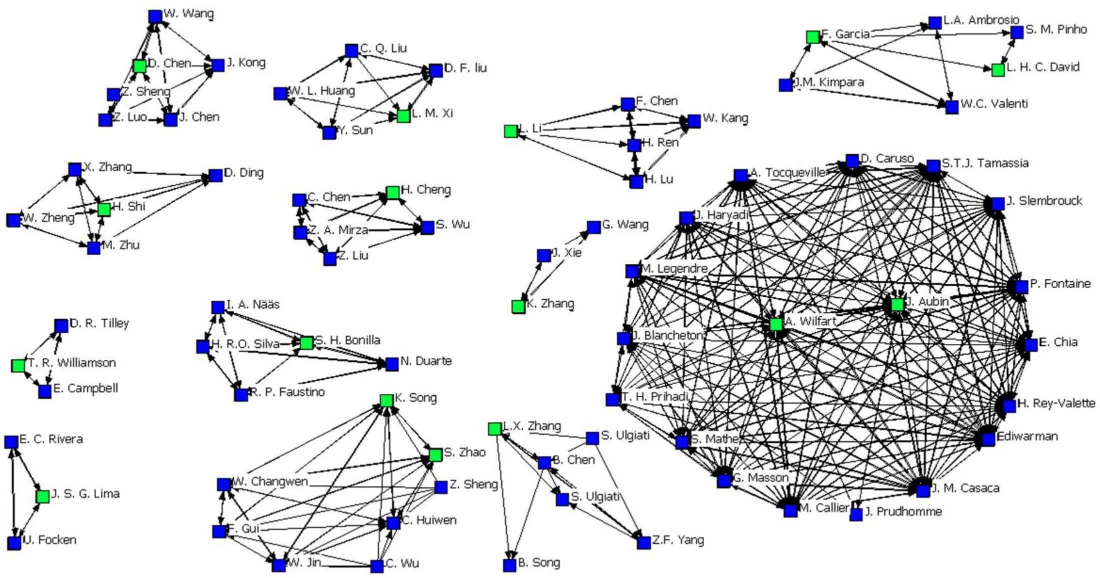


Figure 5. Network of authors and co-authors of articles included in the research. Source: Prepared by the author at Ucinet.

Of the 17 articles analyzed, 16 articles were written by different researchers in terms of authorship (green squares) and co-authorship (blue squares). 13 different groups were formed, evidencing the lack of a relationship of publications between them. However, some authors carried out works in co-authorship linked to the same research networks.

Authors A. Wilfart and J. Aubin worked on two articles together, in 2013 and 2017, in France; and two other articles with different authors (K. Song and S. Zhao in 2013), both in China. In the articles by A. Wilfart and J. Aubin, agroecology concepts were treated to evaluate the performance of different polyculture systems by combining emergy assessment and life cycle analysis (LCA).

The works involving the authors K. Song and S. Zhao were separate subjects. The first evaluated the production system of Yellow croaker (Larimichthys crocea), and S. Zhao used the combination of two methodologies, ecological footprint and emergy, to assess the sustainability of a small fish farm in China.

When analyzing the frequency of terms used in the titles and keywords of the publications (figure 6), words linked to emergy and aquaculture methodology stand out again.

Figure 6. Keyword cloud used in selected articles. Source: elaborated by the author on the Infogrann platform.

It can be seen in the figure above that the keywords of the analyzed articles focus on points addressed by institutional agents to aquaculture. The size of each word indicates its frequency and relevance to a given topic.

The words focused on emergy topics and with the association of other sustainability analysis methods (such as Life Cycle Analysis and Ecological Footprint) were the most cited. China was the country that concentrated the major number of publications, dealing with evaluating sustainability in cage farming and semi-intensive systems in lake environments, flooded areas and important rivers in the region.

Among the aquatic animals studied in the articles (figure 7), most are fish of the species *Hypoftalmichthys molitrix* (8.2%) and *Oreochromis niloticus* (8.2%). On the other hand, most species are freshwater (62.63%) and carnivorous food habits (43.83%).

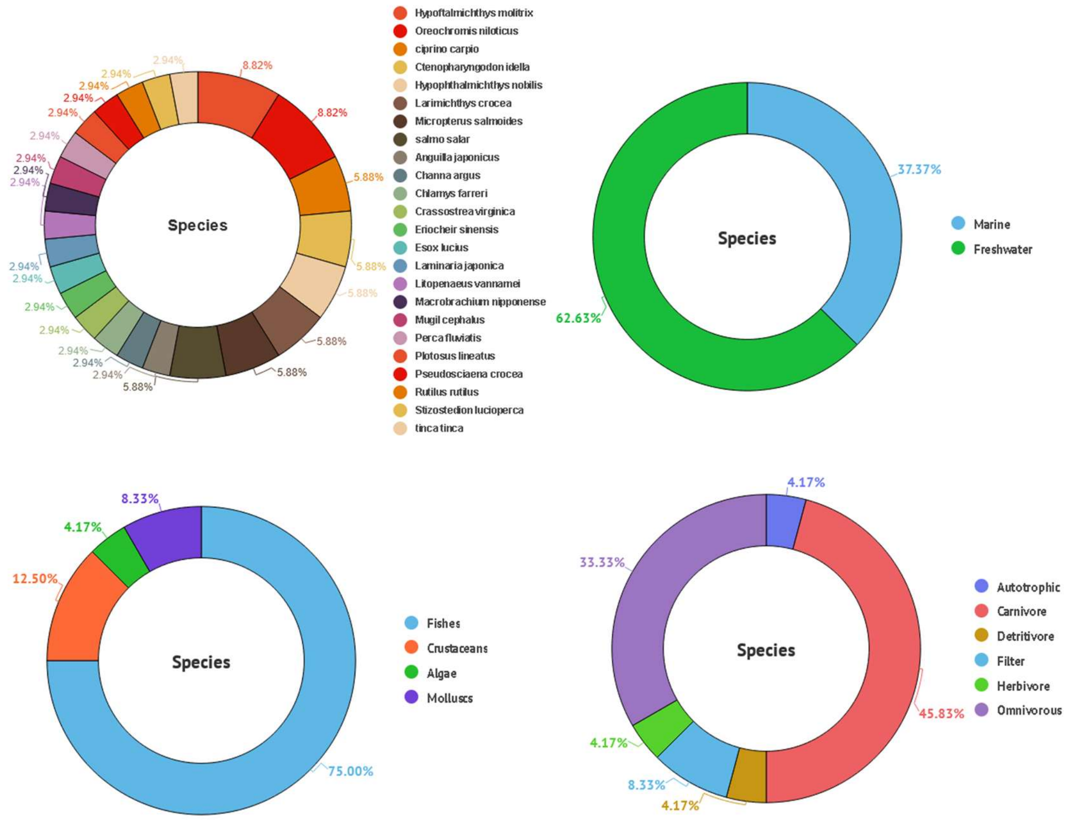


Figure 7 Description of aquatic organisms in articles evaluated with emergy.

Generally, marine fish production that is directed to carnivorous species was observed. For example, the *Larimichthys crocea* and *Salmo salar* were evaluated in the studies by Song et al. (2013) and Aubin et al. (2017), respectively. Quite different from that in freshwater fish farming, where omnivorous species dominate and expand production (FAO, 2020).

Although marine fish have a high production cost due to their intensive farming system (obtention of fingerlings or even in the production of live food), the production of carnivorous species (usually marine species) is more economically attractive and valuable than omnivorous species (TACON, 1994).

According to FAO (2020), aquaculture produces mainly aquatic organisms in freshwater, and, in some countries, inland aquaculture also uses saline and alkaline waters to cultivate species naturally adapted to environments. Introduced species, including marine species, that tolerate water conditions adequately meet fish farmers' expectations.

Carp species are the most produced in the world with 29%, followed by Tilapia with 8% of the total produced in 2016 (FAO, 2018). Of the works presented, Zhang et al. (2011), Zhang et al. (2012), Wilfart et al. (2013), and Xi et al. (2017) evaluated the sustainability of production in polyculture systems for silver carp, common carp and grass carp.

The use of emergy assessment in aquaculture has recently become popular. The collected articles support authors and co-authors on the concern favouring themes related to sustainability in aquaculture. It was found seventeen articles in the search, and the main results and conclusions of these studies are shown in Table 3.

Table 3. Review studies that applied emergy assessment to measure aquaculture production systems' sustainability between 2010-2019.

Fish species	Production system	Objective	Main results and conclusions	Reference
Anguilla (*Anguilla japonicus*), Weever (*Micropterus salmoides*), Ophicephalus (*Channa argus*) and Striped mullet (*Mugil cephallus*)	Monoculture and polyculture	assessed the sustainability of three production systems through emergy and economic assessment in China	The three systems studied showed similar emergy characteristics but different economic features. Eel farming proved the best option to improve the local economy and did not increase the environmental impact. The production of juveniles on the farm was the strategy found in all cultures to reduce production costs and the high input of resources from the economy. The study also showed that nature reserves could increase regional sustainability, although these reserves were not economically viable. According to the authors, emergy assessment has proven to complement economic assessment, production efficiency, environmental impacts, economic benefits, and ecological and sustainability of aquaculture systems.	Li et al. (2011)

Grass carp (*Ctenofaringodonte idelo*) and Siver carp (*Hypoftalmichthys molitrix*), Carp (*Aristichthys mobilis)*	Production systems: in cages with natural feed; in cages with artificial feeding; extensive feeding system with artificial feeding by grass joined around.	Compared to the different fish farming systems regarding resource use and environmental impacts, China	According to the results, the main difference between the three production systems was the emergy cost associated with feeding the fish. The emergy indicators induced that intensive production added to commercial food was not sustainable. The ESI (emergy sustainability index) is less than 0.4, while the other source systems have higher sustainable values. However, the use of plankton and grass was not economically viable.	Zhang et al. (2011)
Grass Carp (*Ctenofaringodonte idelo*) and Silver Carp (*Hypoftalmichthys molitrix*)	Extensive polyculture	They evaluated and compared four local production systems' environmental performance: planting maise, mushrooms, carp and duck farming in China.	The results showed that ducks and mushrooms as diversifying production were not sustainable. On the contrary, an extensive carp polyculture system showed the best emergy performance, mainly with the indicators of renewability and sustainability.	Zhang et al. (2012)

Shrimp (*Litopenaeus vannamei*).	Semi-extensive and extensive system	The sustainable performance of Brazil's conventional and organic shrimp production was evaluated and compared.	Both systems had a high emergy flow of non-renewable resources. However, the results showed that the indicators of renewability, emergy production rate, and emergy investment ratio (EER) were favourable to shrimp's organic cultivation. New improvements in the organic system were indicated to increase efficiency and guarantee economic sustainability, given the low price practised for organic shrimp sales. The authors suggested that multitrophic systems would be beneficial because they would increase and diversify production without increasing commercial feed consumption, the main non-renewable source used in aquaculture.	Lima et al. (2012)
Fishes	Intensive offshore cage system	The authors sought to answer questions about using the emergy assessment methodology and ecological footprint to evaluate the aquaculture	According to the authors, there is a need to improve the evaluated methods (emergy synthesis and ecological footprint). In addition, the input flows (data collection) must be carefully processed due to their significant impact on the results. Also, data that aim to carry out comparative analyses are necessary to improve these methodologies' interpretation and quality.	Chen et al. (2013)

		production system considering the nature of the method, data quality and results proposed by both methods.		
Yellow croaker (*Larimichthys crocea*)	Intensive system in cages	The article sought to analyse, utilising an emergy assessment, the production system of yellow croaker, characterising the use of resources, environmental impact and the general sustainability of the studied system.	The authors understood that the system depended more on inputs from external resources. The ESI (emergy sustainability index) and EISD (sustainable development emergy index) indices indicate that the yellow croaker production system is less sustainable. Based on sensitivity analysis, the ESI and EISD indices were high due to half the number of fry entries and doubled the number of entries in the system of chemical compounds in water. In this way, the authors suggested reducing feed inputs for better efficiency, implementing aquaculture facilities in areas with more precipitation, improving the proportion of local renewable resource inputs and the efficiency of work or farming.	Song et al. (2013)

Kombu (*Laminaria japonica*) and scallops (*Chlamys farreri*)	Monoculture and polyculture	They assessed monoculture's ecological benefits of kelps and scallops and the polyculture of kelps and scallops in China.	Polyculture had the highest sustainability indicator compared to two other isolated monocultures. The study showed that integration is an alternative to a sustainable aquaculture model.	Shi et al. (2013)
Salmon (*Salmo salar*), Carp (*Ciprino carpio*), tench (*Tinca tinca*), roach (*Rutilus rutilus*), perch (*Perca fluviatis*), sander (*Stizostedion lucioperca*) e pike (*Esox lucius*)	Intensive recirculation; Extensive polyculture; Semi-intensive polyculture.	Evaluated the environment, and systems performance by combining emergy assessment and life cycle analysis in France	The recirculation system produced less environmental impact than the two polyculture farms with a low feed conversion rate. The recirculation system has been identified as highly dependent on economic resources. Polycultures incorporated renewable resources but produced more significant environmental impacts due to the inefficient use of economic inputs. The study emphasised that the factors necessary for the successful ecological intensification of fish farming should minimise economic inputs, reduce feed conversion rate and increase local renewable resources. Combining these two methods was a practical strategy to study the optimisation of the efficiency of aquaculture systems.	Wilfart et al. (2013)

Yellow croaker (*Pseudosciaena crocea*)	Intensive offshore cage system	Sustainability assessment using ecological footprint and emergy assessment methods on a small fish farm in China.	The "emergy footprint" was 1,953.9 hectares, an area 14 times greater than the carrying capacity and 293 times greater than the physical area occupied by fish farming. About 2,000 hectares of ecologically productive land were needed to support fish farming. The most usual entrances of the emergy footprint were food, fry and fuel. The authors concluded that combining these two assessment methods could be a practical and efficient means of comparing and monitoring fish farming's environmental impact. Besides, the high dependence on external contributions has affected the sustainability of fish farming.	Zhao et al. (2013)
Tilapia (*Oreochromis niloticus*)	Cage farming	The sustainability of tilapia cage farming in a hydroelectric reservoir was evaluated, and management techniques and public policies contributing	The emergy evaluation showed that the production system is inefficient and pointed out the causes. To solve the problem was suggested to adopt measures that proportionally reduce the supply of commercial feed and increase the inflow of renewable resources. Also, management changes include reducing stocking density and increasing the organic load's dilution area.	Garcia et al. (2014)

		to this production system's sustainability were also evaluated.		
Oyster (*Crassostrea virginica*)	Floating and bottom cage system	An assessment and comparison of the different production systems' sustainability were conducted on an aquaculture farm in the United States.	The emergy results from both systems had acceptable rates referring to the economy's resources, such as human labour, purchase of juveniles, fuels, goods, and services. In addition, oyster production farms were supported by a larger percentage of local renewable resource sources than other aquaculture products, mainly by particulate organic matter and estuarine water circulation. Overall, the study showed that oyster production farms have less impact on the environment, greater sustainability and benefit to society than other aquaculture forms. The authors suggested reducing fuel and electricity as two efficient ways to increase the sustainability of the oyster aquaculture farm.	Williamson et al. (2015)

Tilapia (*Oreochromis niloticus*), chicken of the Hubbard genetics	Greenhouse tunnel system; cage system	Using the emergy of the role of natural services in an area of land, it evaluated the role of a sink for ammonia emissions from a poultry production shed in the region of Mato Grosso and phosphorus from an aquaculture farm in São Paulo, Brazil	The results suggest that poultry farming seems to be a thousand times more "eco-efficient" than aquaculture, in addition to having a smaller support area. Accounting for environmental services to dilute emissions was necessary to assess the sustainability of processes and quantify externalities properly. The challenge is to adjust human production patterns to the biosphere's ability to absorb by-products without overload. To this end, the services provided by natural capital have to be appropriately assessed and finally quantified in terms comparable to the economy.	Bonilla et al. (2016)
Pigs and fish	Polyculture and recirculation system	This article aimed to adapt this concept of sustainability for fish farming using agroecological principles and the	The method was developed from published literature and applications in four study sites chosen for their differences in production intensity: polyculture ponds in France, integrated pig and pond polyculture in Brazil, and striped catfish in Indonesia, an aquaculture system for salmon recirculation in France. Based on the construction of a scenario, aquaculture's ecological intensification was defined as the use of ecological	Aubin et al. (2017)

		structure of ecosystem services.	processes and functions to increase productivity, strengthen ecosystem services, and decrease disservices. The expected consequences for agricultural systems include greater autonomy, efficiency and better integration in the surrounding territories. Ecological intensification requires territorial governance and helps improve from a sustainable development perspective.	
Poultry and fish	Poultry and fish polyculture	The study evaluated and compared the environmental performance of three monocultures in China.	Polyculture produced the most significant inflow of renewable resources, showing less dependence on the economy than other crops. In addition, emergy indicators showed that the fish farming system was more sustainable when compared to others. The authors recommended public policies that encourage sustainable agricultural production by local producers and the use of clean energy.	Cheng et al. (2017)
Water chestnut (*Trapa bispinosa*), Silver carp (*Hypophthalmichthy*	Polyculture system	In this study, the eco-economic systems were compared under different polyculture	Based on the results, the authors could observe that the Xiaoxidian ecological system has higher emergy production and economic income per unit area than the Dujiadian area. In comparison, the Dujiadiana area has a higher emergy	Xi et al. (2017)

s molitrix), Bighead carp (*Aristichthys nobilis*), snail (*Cipangopaludina cahayensis*), Chinese mitten crab (*Eriocheir sinensis*), shrimp (*Macrobrachium nipponense*), snail (*Radix auricularia*), *common carp* (*Cyprinus carpio*)		models between China's Xiaoxidian and Dujiadiana areas.	production rate and a lower environmental load rate. Therefore, the Dujiadian area is less sustainable due to humans' constant overload of non-renewable energy. Therefore, adjusting and optimising the aquaculture system's management in the Xiaoxidian area was recommended to find a stable balance between environmental sustainability and economic benefits.	

Largemouth bass (*Micropterus salmoides*)	Semi-intensive system.	In this study, the objective was to evaluate the benefits and driving forces of the M. salmoides aquaculture system using an emergy analysis method from the ecological and economic points of view (country)	The lower ESI (Emergy Sustainability Index) with EISD (Emergy Sustainable Development Index) and the higher ELR (Environmental Loading Rate) showed that emerging inputs from acquired external resources achieved a more significant effect than emergy from renewable environmental resources in the aquaculture system of M. salmoides. The system was more dependent on emergy inputs from external acquired resources, which indicated that the production of M. salmoides is less sustainable. The result showed that measures that reduced feed inputs improved their use as the use of feed and additives with a low feed coefficient could reduce the inputs of acquired external resources and then raise the ESI and EISD of the feed system. Aquaculture of M. salmoides. Integrated aquaculture was another method that could achieve the same result.	Zhang et al. (2017)

Tilapia (*Oreochromis niloticus*)	cage system	The study's objectives were to identify the contributions of nature and the economy to raising Tilapia in cages using emergy to assess whether using the periphyton as a complementary food and whether reducing storage density could improve the system's sustainability of production. (parents)	Three different production systems were evaluated and compared: using traditional stocking density adopted by farmers (80 kg / m3) with 100% of the recommended daily ratio and without substrates for the periphyton (TRAD); traditional stocking density (80 kg / m3) with 50% of the recommended daily ration and with substrates for periphyton (TDS); lower density (40 kg / m3) with 50% of the recommended daily food and with substrates for the periphyton (LDS). Based on the results' interpretation, the authors concluded that tilapia production in cages is highly dependent on economic resources, and animal feed is responsible for this. Therefore, from the emergy study, it was possible to identify that using periphyton to feed fish in cultivation combined with a reduction in artificial feeding and the use and reduction of stocking density should be encouraged to promote tilapia sustainability.	David et al. (2018)

Emergy assessment has been used to assess and compare sustainability in various aquaculture systems such as monocultures and polycultures production systems (intensive, semi-intensive, extensive), and more traditional alternatives according to the region studied. These analyses (Table 3) were made in production at different scales, species, locations, levels of intensification and structures.

However, when transformed into the same unit (emjoule), all these particularities can be compared even in different scenarios. As the model permits, each productive system had its sustainability evaluated within the environmental, economic and social context inserted, representing a detailed view of all processes and can indicate where are the solutions or problems in each system.

In the study by Zhang et al. (2011), the authors demonstrated that the application of emergy assessment allowed identifying the emergy of each item or input needed for production, making it possible to modify different production flows. Furthermore, the analysis showed that more sustainable management and actions could benefit the environment and the local economy.

One of the main input items in the evaluated aquaculture systems is commercial feed (31.99%) as the primary source of emergy expenditure in intensive or semi-intensive systems, followed by the purchase of juveniles and other inputs such as pesticides, machinery, oil, and services contributed with 88.17% in the production of cage fish and 73.30% in the extensive semi-natural fish farming system of the different species cultivated.

Studies such as those by Wilfart et al. (2013), Garcia et al. (2014), and David et al. (2018) pointed to artificial food as the primary input for the instability of the production system, representing an average of 65.00; 76.43 and 67.08% respectively, suggesting the reduction of artificial foods and the increase of natural foods or alternating both as an alternative for more sustainable production.

Besides, changes in the production systems schedules aim to carry out the rearing and fattening phases on the same farm are also encouraged. As these measures mentioned have low emergy, they could increase the renewability of the systems since it would reduce the external inputs that increase the cost of production.

From the interpretation of the synthesized results (Table 3), it is clear that the aquaculture systems cannot be highly productive and sustainable at the same time. According to FAO (2018), this occurs in intensive monocultures in small spaces that seek to serve the avid world market in short periods. These fish production systems with high dependence on economic resources have a high impact and are not sustainable.

For example, the intensive cage farming of yellow Corvina is not sustainable, according to Song et al. (2013), with registered values of transformity (Tr) of 1.46E+06 se/J, sustainability index (ESI) of 0.011 and a high environmental loading rate (ELR) 91.10, well above those found in systems in integrated "pig-biogas-fish" production systems evaluated by de Wu et al. (2014), with sustainability index (ESI) values of .1.17 and high environmental loading rate (ELR) 0.90.

However, several alternatives, such as natural food, in other cultivation systems were evaluated by Zhang et al. (2011), comparing production in different systems. They showed that sustainability was higher in extensive systems ESI (4.61) and lower ELR (0.38) indexes when compared to an intensive system ESI (0.38) and ELR (2.73), respectively.

In the study by David et al. (2018), the authors evaluated tilapia production in cage farming they verified that the use of periphyton as food combined with a reduction in commercial feed is an effective alternative for the production of the species in a more sustainable way, with better ESI (0.35) and ELR (3.63) values compared to the system with a high density of fish and without the use of periphyton as food ESI (0.17) and ELR (6.81).

Suppose current aquaculture demands are considered, such as the scarcity of natural resources (marine fish meal and fish oil) and the growing demand for more sustainable food. In that case, the trend is to search for systems and managements that meet market demand and respect the laws and environmental conditions.

According to the studies by Zhao et al. (2013), Aubin et al. (2017) and Xi et al. (2017), the reduced use of renewable resources and high consumption of resources in the economy contribute to less system stability, since when used sustainably, renewable resources make the system economically less dependent and more balanced.

Concerning the alternatives to optimise the use of resources, reducing the dependence on economic inputs, mainly commercial feed, the use of polyculture or integrated aquaculture systems were the most indicated by Lima et al. (2012); Wilfart et al. (2013); Shi et al. (2013); Cheng et al. (2017), since the efficient use of different trophic levels reduces the production costs and the emission of pollutants to the environment. Furthermore, the literature proposes creating or adapting public policies that encourage farmers to adopt sustainable practices on their properties (Zhang et al., 2012).

The elaboration of regulations that consider the carrying capacity of the systems and the use of natural resources must be taken into account. Analyzing Zhang et al. 2011, Zhang et al. 2012, Song et al. 2013, and David et al. 2018 (table 3), it was possible to observe that the evaluated products concerning emergy exchange (EER) cost less than they should if the environmental value were considered. It shows that in less intensive a system, more resources are used and, therefore, more free resources he delivered to the buyer.

In turn, if the same system buys goods and commodities for its operation, the environmental resources incorporated in these purchases are generally much smaller, depending on the level of development of the surrounding economy (ZHANG et al., 2011).

Conclusions

The set of information provided by the emergy assessment offers technical and scientific data that can contribute to the planning and adoption of more sustainable production systems and help ensure long-term activity success.

Most studies evaluate productive systems in the aquaculture chain's final stages, such as the growth-out systems, and the evaluation of different fish farming types. From this observation, it is possible to suggest utilising the methodology in the initial stages of fish production as a way of aggregating information about emergy expenditure, especially in inputs such as commercial feed and juveniles, which have shown to be factors that significantly contribute to the emergy calculation in aquaculture systems.

Such information can also help develop more sustainable techniques from the initial links in the production chain and the emergetic information to reduce energy use rates. Furthermore, utilising emergy to assess the sustainability of aquaculture can promote the necessity to increase the use of renewable resources, using an integrated production system and other food alternatives as multitrophic systems.

Besides, this method's results allow discussions on public policies for aquaculture and natural resources enhancement. These strategies can be part of the sustainability guidelines in fish production, promoting well-being in the community, environment and local economy.

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References

Aubin, J., Callier, M., Rey-Valette, H., Mathé, S., Wilfart, A., Legendre, M., Fontaine, P. Implementing ecological intensification in fish farming: definition and principles from contrasting experiences. Reviews in Aquaculture. **0**: 1-19 (2017). doi:10.1111/raq.12231

Barbieri, J. C., Cajazeira, J. E. R. Responsabilidade social empresarial e empresa sustentável: da teoria à prática. São Paulo: Saraiva. (2009).

Boyd, C. E., Zajicek, P. W., Hargreaves, J. A., Jensen, G. L. Development, Implementation and Verification of Better Management Practices for Aquaculture. Environmental Best Management Practices for Aquaculture. 129–149 (2008). doi:10.1002/9780813818672.ch5

Brown, M. T., Buranakarn, V. Emergy indices and ratios for sustainable material cycles and recycle options. Resources, Conservation and Recycling. **38** (1): 1-22 (2003).

Brown, M. T., Ulgiati, S. Emergy-based indices and ratios to evaluate sustainability: monitoring economies and technology toward environmentally sound innovation. Ecological Engineering, Oxford. **9** (1): 51-69 (1997).

Campbell, E., Brandt-Williams, S. L., Meisch, M. E. Environmental accounting using emergy: Evaluation of the state of West Virginia. US Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division (2005).

Cavalett, O., Ortega, E. Integrated environmental assessment of biodiesel production from soybean in Brazil. Journal of Cleaner Production, Amsterdam. **18** (1): 55-70 (2010). doi:10.1016/j.jclepro.2009.09.008

Chen, D., Luo, Z., Wang, W., Chen, J., & Kong, J. Communicating about the emergy ecological footprint for a small fish farm in China. Ecological Indicators. **34**: 623–626 (2013). doi:10.1016

Cheng, H., Chen, C., Wu, S., Mirza, Z.A., Liu, Z. Emergy evaluation of cropping poultry rearing and fish raising systems in the drawdown zone of Three Gorges Reservoir of China. J. Clean. Production. **144**: 559–571 (2017) doi:10.1016/j.jclepro.2016.12.053

Clark, W.C. Sustainable development and sustainability science. In: LEVIN, SA; CLARK, WC (Ed.). Toward a Science of Sustainability: Report from Toward a Science of Sustainability Conference. Princeton: Princeton University Press (2010).

Clay, J. W. The role of Better Management Practices in Environmental Management. In: TUCKER, C. S.; HARGREAVES, J. A. (Ed.). Environmental Best Management Practices for aquaculture (2008).

Cleveland, C. J., Kaufmann, R. K., Stern, D. I. Aggregation and the role of energy in the economy. Ecological Economics, Amsterdam. **32** (2): 301-317 (2000).

Daley, D. Emergy accounting for assessing the sustainability of wastewater management systems. Clear Waters **43** (2): 39–46 (2013).

David, L. H. C., Pinho, S. M., Garcia, F. Improving the sustainability of tilapia cage farming in Brazil: An emergy approach. Journal of Cleaner Production. **201**: 1012–1018 (2018).

Fao. El Estado mundial de la pesca y la aquicultura: cumprir los objetivos de desarrollo sostenible. Rome. 230 p (2018).

Farmaki, E. G., Thomaidis, N. S., Pasias, I. N., Baulard, C., Papaharisis, L., Efstathiou, C. E. Environmental impact of intensive aquaculture: Investigation on the accumulation of metals and nutrients in marine sediments of Greece. Science of The Total Environment. **485**: 554-562 (2014). DOI: 10.1016/j.scitotenv.2014.03.125

Garcia, F., Kimpara, J.M., Valenti, W.C., Ambrosio, L.A. Emergy assessment of tilapia cage farming in a hydroelectric reservoir. Ecological Engineering. **68**: 72–79 (2014). doi:10.1016/j.ecoleng.2014.03.076

Granada, L., Lopes, S., Novais, S. C., Lemos, M. F. L. Modelling integrated multitrophic aquaculture: Optimising a three trophic level system. Aquaculture, **495**: 90-97 (2018). doi:10.1016/j.aquaculture.2018.05.029

GIL, A. C. Como elaborar projetos de pesquisa. 4. Ed.São Paulo: Atlas, (2007).

Guan, F., Sha., Z., Zhang, Y., Wang, J., Wang, C. Guan. Emergy assessment of three home courtyard agriculture production systems in Tibet Autonomous Region, China. Journal of Zhejiang University-SCIENCE B. **17** (8): 628-639. (2016). DOI:10.1631/jzus.b1500154

Haden, A. C. Emergy evaluations of Denmark and Danish agriculture assessing the limits of agricultural systems to power society. Ekologiskt Lantbruk, **37.** (2003).

Havice, E., Iles, A. Shaping the aquaculture sustainability assemblage: Revealing the rule-making behind the rules. Geoforum. **58**: 27-37 (2015). doi:10.1016/j.geoforum.2014.10.008

Kuhlman, T.; Farrington, J. What is Sustainability? Sustainability. **2** (11): 3436-3448 (2010).

Lazard, J., Rey-Valette, H., Aubin, J., Mathé, S., Chia, E., Caruso, D., Mikolasek, O.,Blancheton, J.P., Legendre, M., Baruthio, A., René, F., Levang, P., Slembrouck, J.,Morissens, P., Clément, O. Evaluation of aquaculture system sustainability: amethodology and comparative approaches. In: ARAL, F., DOGU, Z. (Eds), recentadvances in fish farms. France. p.p. 1–24 (2011).

Le Corre, O., Truffet, L., Lahlou, C. Odum–Tennenbaum–Brown calculus vs emergy and co-emergy analysis. Ecological Modelling. **302**: 9-12 (2015). doi:10.1016/j.ecolmodel.2015.01.021

Li, L., Lu, H., Ren, H., Kang, W., Chen, F. Emergy evaluations of three aquaculture systems on wetlands surrounding the Pearl River Estuary, China. Ecological Indicators. **11**: 526–534 (2011). doi:10.1016/j.ecolind.2010.07.008

Lima, J.S.G., Rivera, E.C., Focken, U. Emergy evaluation of organic and conventional marine shrimp farms in Guaraira Lagoon, Brazil. J. Clean. Production. **35** (12): 194–202. (2012) doi:10.1016/j.jclepro.2012.05.009

Medeiros, D. C., Azevedo, C. M. S. B., Marques, L. F., Sousa, R. A., Oliveira, C. J. Qualidade de mudas de tomate em função do substrato e irrigação com efluente de piscicultura. Revista Brasileira de Agroecologia. **8** (2): 170-175 (2013).

Nhu, T.T., Schaubroeck, T., Henriksson, P.J.G., Bosma, R., Sorgeloos, P., Dewulf, J. Environmental impact of non-certified versus certified (ASC) intensive Pangasius aquaculture in Vietnam, a comparison based on a statistically supported LCA. Environmental Pollution. **219**: 156–165 (2016). doi:10.1016/j.envpol.2016.10.006.

Odum, E. P. Fundamentos de ecologia. 6. ed. Lisboa: Fundação Calouste Gulbenkian. (2001).

Odum, H. T. Environmental accounting, emergy and decision making. New York: J. Wiley, p 370. (1996)

Rabassó, M., Hernández, J. M. Bioeconomic analysis of the environmental impact of a marine fish farm. Journal of environmental management. **158**: 24-35 (2015). DOI:10.1016/j.jenvman.2015.04.034

Ortega, E. R., Guerra, J. G. M., Assis, R. L., Ribeiro, L. D. Análise emergética de sistemas de produção de olerícolas sob manejo orgânico. Revista Brasileira de Tecnologia Aplicada nas Ciências Agrárias. **3** (3) (2011).

Sampaio, R. F., Mancini, M. C. Estudos de revisão sistemática: um guia para síntese criteriosa da evidência científica Rev.bras. fisioter., São Carlos. **11** (1): 83-89 (2007)

Shi, H., Zheng, W., Zhang, X., Zhu, M., Ding, D. Ecological-economic assessment of monoculture and integrated multitrophic aquaculture in Sanggou Bay of China. Aquaculture **410**: 172–178 (2013) doi:10.1016/j.aquaculture.2013.06.033

Tacon, A. G. J. Dependence of intensive aquaculture systems on fishmeal and other fishery resources" trends and prospects"." FAO Aquaculture Newsletter (FAO) (1994).

Tacon, A. G. J. Trends in Global Aquaculture and Aquafeed Production: 2000–2017. Reviews in Fisheries Science & Aquaculture. **28** (1): 43-56 (2019) DOI: https://doi.org/10.1080/23308249.2019.1649634

Tilley, D. R., Brown, M. T. Dynamic emergy accounting for assessing the environmental benefits of subtropical wetland stormwater management systems. Ecological Modelling. **192 (**4): 327-361 (2006).

Ulgiati, S., Ascione, M., Zucaro. A., Campanella., L. Emergy-based complexity measures in natural and social systems. Ecological Indicators. **11 (**5): 1185-1190 (2011). DOI:10.1016/j.ecolind.2010.12.021

Ulgiati, S., Brown., M. T. Quantifying the environmental support for dilution and abatement of process emissions: the case of electricity production. Journal of Cleaner Production, Amsterdam. **10** (4): 335-348 (2002). DOI:10.1016/s0959-6526(01)00044-0

Valenti, W. C. A aquicultura brasileira é sustentável. Palestra apresentada durante o IV Seminário Internacional de Aquicultura, Maricultura e Pesca. Aquafair, p. 13-15, (2008).

Valenti, W. C., Kimpara, J. M., Preto, B. L., Moraes-Valenti. P. Indicators of Sustainability to assess aquaculture systems. Ecological indicators. **88**: 402-413 (2018).

Wang, C.; Gengyuan, L.; Ren, S.; Liu, X.; Hao, Y. Provincial sustainability evaluation based on the standardised national emergy database. Energy Procedia, v. 88, p. 153-159, 2016.

Wilfart, A., Prudhomme, J., Blancheton, J. P., Aubin, J. LCA and emergy accounting of aquaculture systems: Towards ecological intensification. Journal of environmental management. **121**: 96-109 (2013). doi:10.1016/j.jenvman.2013.01.031

Williamson, T. R., Tilley., D. R., Campbell, E. Emergy analysis to evaluate the sustainability of two oyster aquaculture systems in the Chesapeake Bay. Ecological Engineering. **85**: 103–120 (2015). doi:10.1016/j.ecoleng.2015.09.052

Willot, P. A., Aubin. J., Salles., J.M., Wilfart, A. Ecosystem service framework and typology for an ecosystem approach to aquaculture. Aquaculture p. 734-260 (2019). doi:10.1016/j.aquaculture.2019.734260

Wu, X. F., Wu, X. D., Li, J. S., Xia, X. H., Mi, T., Yang, Q., Chen, G. Q., Chen, B., Hayat, T., Alsaedi, A. Ecological accounting for an integrated "pig–biogas–fish" system based on emergetic indicators. Ecological indicators. **47**: 189-197 (2014). DOI:10.1016/j.ecolind.2014.04.033.

Xi, L. M., Liu, C. Q., Liu, D. F., Huang, W. L., & Sun, Y. Water quality and emergy evaluation of two freshwater aquacultural systems for eutrophic water in the Controlling by Biological Chains. IOP Conference Series: Earth and Environmental Science **82**: 012-070 (2017). DOI:10.1088/1755-1315/82/1/012070

Yang, Z. F., Jiang, M. M., Chen, B., Zhou, J. B., Chen, G. Q., Li, S. C. Solar emergy evaluation for Chinese economy. Energy policy. **38** (2): 875-886 (2010). DOI:10.1016/j.enpol.2009.10.038.

Zhang, L.X., Ulgiati, S., Yang, Z.F., Chen, B. Emergy evaluation and economic analysis of three wetland fish farming systems in Nansi Lake area, China. J. Environ. Manage. **92**: 683–694 (2011). doi:10.1016/j.jenvman.2010.10.005

Zhang, L.X., Song, B., Chen, B. Emergy-based analysis of four farming systems: insight into agricultural diversification in rural China. J. Clean. Prod. 28: 33–44 (2012). DOI:10.1016/j.jclepro.2011.10.042

Zhang, Kai & Yu, D. & Xie, J. & Wang, Guangjun & Yu, E. & Gong, W. & Li, Z. & Wei, Ningrui & Xia, Y. & Wang, C. & Liu, B. Emergy evaluation of largemouth bass (Micropterus salmoides) aquaculture system in the Pearl River Delta, China. Journal of Fisheries of China. **41**: 1424-1433 (2017). DOI: 10.11964/jfc.20160310324.

Zhao, S., Song, K., Gui, F., Cai, H., Jin, W., Wu, C. The emergy ecological footprint for small fish farm in China. Ecological Indicators. **29**: 62-67 (2013). DOI: 10.1016/j.ecolind.2012.12.009.

CONSIDERAÇÕES FINAIS

A busca por meios de produção mais eficientes que visem a redução dos recursos advindos da natureza tem sido o grande desafio da humanidade. O conceito de sustentabilidade, por mais polêmico e divergente em interesses e proposições, nos permite refletir e nortear o conhecimento em direção a questões ambientais, sociais e econômicas.

O aumento do volume populacional e da renda mundial, principalmente nos países em desenvolvimento, também tem alertado para a crescente demanda por proteínas de origem animal, assim como, a busca por melhores parâmetros zootécnicos nos sistemas de produção, sem levar em consideração a melhor escolha quanto a eficiência no uso de energia. Este fato, traz consequências diretas, especialmente para os principais países produtores e exportadores mundiais, referente a disponibilidade de recursos naturais para produção e impactos da geração de resíduos desses sistemas produtivos.

Este trabalho procurou trazer dados inéditos no processo de avaliação ambiental na produção de juvenis de espécies nativas no Brasil, visando contribuir na geração de novos conhecimentos para a sustentabilidade de sistemas aquícolas. A utilização da emergia, permitiu a análise de diferentes áreas do conhecimento (ciências agrárias, ciências contábeis e administração), buscando desenvolver um processo de análise que envolvesse, além dos fundamentos da avaliação emergética, alguns fundamentos acerca da racionalidade ambiental em suas diferentes vertentes, ou seja, abordar a relação entre as atividades humanas e o meio ambiente.

Os resultados deste estudo indicam que a adoção de práticas e manejos que reduzam a dependência de recursos da economia e aumentem o uso de recursos renováveis ajudam a tornar a aquicultura uma atividade resiliente e economicamente mais justa com menores impactos ambientais negativos. Além disso, novos estudos abordando a avaliação emergética devem ser promovidos, especialmente para a cadeia produtiva de espécies nativas que representa expressiva importância econômica na piscicultura brasileira. Assim, estas informações poderão nortear outras pesquisas para fins comparativos derivadas da avaliação emergética, frente as demonstrações contábeis tradicionais, tendo em vista uma contabilidade mais holística das organizações.

REFERÊNCIAS

ALLEGRETTI, G. **Insect as feed**: uma análise bioeconômica do uso de insetos como fonte proteica alternativa à avicultura de corte brasileira. 2017. 177 f. Tese (Doutorado) – Programa de Pós-Graduação em Agronegócios, Centro de Estudos e Pesquisas em Agronegócios, Universidade Federal do Rio Grande do Sul, Porto Alegre, 2017.

ANDERSON, J. L. Private aquaculture and commercial fisheries: bioeconomics of salmon ranching. **Journal of Environmental Economics and Management**, New York, v. 12, n. 4, p. 353-370, 1985.

ASSAD, L. T.; BURSZTYN, M. Aquicultura sustentável. *In*: VALENTI, W. C. *et al.* (ed.). **Aquicultura no Brasil:** bases para um desenvolvimento sustentável. Brasília, DF: CNPq, Ministério da Ciência e Tecnologia, 2000. p. 33-72.

BIRCH, K.; TYFIELD, D. Theorizing the bioeconomy: biovalue, biocapital, bioeconomics or... what? **Science, Technology, & Human Values**, Cambridge, v. 38, n. 3, p. 299-327, 2013.

BONAIUTI, M. Bioeconomics. *In*: D'ALISA, G.; DEMARIA, F.; KALLIS, G. (ed.). **Degrowth:** a vocabulary for a new era. Routledge: Taylor & Francis, 2014. p. 53-56.

BROWN, M. T.; BURANAKARN, V. Emergy indices and ratios for sustainable material cycles and recycle options. **Resources, Conservation and Recycling**, New York, v. 38, n. 1, p. 1-22, 2003.

BROWN, M. T.; ULGIATI, S. Emergy-based indices and ratios to evaluate sustainability: monitoring economies and technology toward environmentally sound innovation. **Ecological Engineering**, Oxford, v. 9, n. 1/2, p. 51-69, Sept. 1997.

BROWN, M. T.; CAMPBELL, E. **Evaluation of natural capital and environmental services of U.S. national forests using emergy synthesis**. Gainesville: Center for Environmental Policy. University of Florida, 2007.

BUGGE, M. M.; HANSEN, T.; KLITKOU, A. What is the bioeconomy? A review of the literature. **Sustainability**, Basel, v. 8, n. 7, [art.] 691, [p. 1-22], 2016.

CAMPBELL, D. E.; BRANDT-WILLIAMS, S. L.; MEISCH, M. E. A. **Environmental accounting using emergy:** evaluation of the state of West Virginia. Narragansett: US Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, 2005.

CAVALETT, O.; ORTEGA, E. Integrated environmental assessment of biodiesel production from soybean in Brazil. **Journal of Cleaner Production**, Amsterdam, v. 18, n. 1, p. 55-70, Jan. 2010.

CLEVELAND, C. J.; KAUFMANN, R. K.; STERN, D. I. Aggregation and the role of energy in the economy. **Ecological Economics**, Amsterdam, v. 32, n. 2, p. 301-317, Feb. 2000.

CNI - CONFEDERAÇÃO NACIONAL DA INDÚSTRIA. **Proposta da indústria para o aprimoramento do licenciamento ambiental Brasília**. Brasília, DF: CNI, 2013. Disponível em: www.fiems.com.br_arte_proposta_licenciamento_cni. Acesso em: 4 jun. 2022

DALEY, D. Emergy accounting for assessing the sustainability of wastewater management systems. **Clear Waters**, [*S. l.*], v. 43, n. 2, p. 39–46, 2013.

FAO - FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. **The state of world fisheries and aquaculture:** towards blue transformation. Rome: FAO, 2022. Disponível em: https://doi.org/10.4060/cc0461en. Acesso em: 1º ago. 2022

FAO - FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. **El Estado mundial de la pesca y la aquicultura**: cumprir los objetivos de desarrollo sostenible. Rome: FAO, 2018. 230 p.

FARMAKI, E. G. *et al*. Environmental impact of intensive aquaculture: investigation on the accumulation of metals and nutrients in marine sediments of Greece. **Science of the Total Environment**, Amsterdam, v. 485, p. 554-562, 2014.

FUNTOWICZ, S. O.; O'CONNOR, M.; MAYUMI, K. The passage from entropy to thermodynamic indeterminacy: a social and science epistemology for sustainability. *In*: GEORGESCU-ROEGEN, N.; MAYUMI, K.; GOWDY, J. M. (ed.). **Bioeconomics and sustainability:** essays in honour of Nicholas Georgescu-Roegen. Cheltenham: Edward Elga, 1999. p. 257-286.

GOWDY, J.; MESNER, S. The evolution of Georgescu-Roegen's bioeconomics. **Review of Social Economy**, Chicago, v. 56, n. 2, p. 136-156, 1998.

GRANADA, L. *et al*. Modelling integrated multi-trophic aquaculture: optimizing a three trophic level system. **Aquaculture**, Amsterdam, v. 495, p. 90-97, 2018.

GUAN, Fa-chun *et al.* Emergy assessment of three home courtyard agriculture production systems in Tibet Autonomous Region, China. **Journal of Zhejiang University-Science B**, Hangzhaou, v. 17, n. 8, p. 628-639, 2016.

HADEN, A. C. **Emergy evaluations of Denmark and Danish agriculture:** assessing the limits of agricultural systems to power society. Uppsala: Centrum för Uthålligt Lantbruk, 2003. (Ekologiskt lantbruk, 37).

HAVICE, Elizabeth; ILES, Alastair. Shaping the aquaculture sustainability assemblage: Revealing the rule-making behind the rules. **Geoforum**, Oxford, v. 58, p. 27-37, 2015.

IBGE - INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Produção da Pecuária Municipal**, Rio de Janeiro, v. 43, p. 1-49, 2015.

IBGE - INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Produção da Pecuária Municipal**, Rio de Janeiro, v. 49, p. 1-12, 2022.

KAMIYA, D. S. *et al*. **Análise emergética on-line para diagnóstico de sistemas agrícolas**. 2005. 164 f. Dissertação (Mestrado) - Faculdade de Engenharia de Alimentos, Universidade Estadual de Campinas, Campinas, 2005.

KIMPARA, J. M.; ZADJBAND, A. D.; VALENTI, W. C. **Métodos para medir a sustentabilidade na aquicultura**. Teresina: Embrapa Meio-Norte, 2012. (Documentos, 218).

KUHLMAN, T.; FARRINGTON, J. What is sustainability? **Sustainability,** Basel, v. 2, n. 11, p. 3436-3448, 2010.

LAZARD, Jérôme *et al*. Evaluation of aquaculture system sustainability: a methodology and comparative approaches. *In*: ARAL, F.; DOĞU, Z. (ed.). **Recent advances in fish farms**. London: IntechOpen, 2011. cap. 1, [p. 1-26].

LE CORRE, O.; TRUFFET, L.; LAHLOU, C. Odum–Tennenbaum–Brown calculus vs emergy and co-emergy analysis. **Ecological Modelling**, Amsterdam, v. 302, p. 9-12, 2015.

LI, L. J. *et al*. Emergy algebra: improving matrix methods for calculating transformities. **Ecological Modelling**, Amsterdam, v. 221, n. 3, p. 411-422, Feb. 2010.

MACEDO, C. F. *et al*. Eutrophication and water quality in pisciculture: consequences and recommendations**. Boletim do Instituto de Pesca**, São Paulo, v. 36, n. 2, p. 149-163, 2010.

MAYUMI, K. Nicholas Georgescu-Roegen: His Bioeconomics Approach to Development and Change. **Development and Change**, Oxford, v. 40, n. 6, p. 1235-1254, 2009.

MISSEMER, A. Nicholas Georgescu-Roegen and degrowth. **The European Journal of the History of Economic Thought**, London, v. 24, n. 3, p. 493-506, 2017.

MUNGKUNG, R. *et al*. Life cycle assessment for environmentally sustainable aquaculture management: a case study of combined aquaculture systems for carp and tilapia. **Journal of Cleaner Production**, Amsterdam, v. 57, p. 249-256, 2013.

ODUM, E. P. **Fundamentos de ecologia**. 6. ed. Lisboa: Fundação Calouste Gulbenkian, 2001.

ODUM, H. T. **Environmental accounting, emergy and decision making**. New York: J. Wiley, 1996. 370 p.

OLIVEIRA, R. C. O panorama da aquicultura no Brasil: a prática com foco na sustentabilidade. **Revinter: Revista Intertox de Toxicologia, Risco Ambiental e Sociedade**, São Paulo, v. 2, n. 1, p. 71-89, 2009.

PEIXE BR. **Anuário brasileiro da piscicultura**. São Paulo: Edição Texto Comunicatvio, 2019. 71 p.

PEIXE BR. **Associação Brasileira da Piscicultura**. São Paulo: Edição Texto Comunicação Corporativa, 2022. 79 p.

RABASSÓ, M.; HERNÁNDEZ, J. M. Bioeconomic analysis of the environmental impact of a marine fish farm. **Journal of Environmental Management**, New York, v. 158, p. 24-35, 2015.

ROCHA, C. M. C. *et al*. Avanços na pesquisa e no desenvolvimento da aquicultura brasileira. **Pesquisa Agropecuária Brasileira**, Brasília, DF, v. 48, n. 8, p. iv-vi, ago. 2013.

RODRIGUES, E. O. *et al*. Análise emergética de sistemas de produção de olerícolas sob manejo orgânico. **Pesquisa Aplicada & Agrotecnologia**, Guarapuava, v. 3, n. 3, p. 165-182, 2010.

ROHDE, G. M. **Economia ecológica da emissão antropogênica de CO2:** uma abordagem filosófico-científica sobre a efetuação humana alopoiética da terra em escala planetária. 2003. 102 f. Tese (Doutorado) – Curso de Pós-Graduação em Ecologia, Instituto de Biociências, Universidade Federal do Rio Grande do Sul, Porto Alegre, 2003.

RORIZ, Geórgia Dantas. **Caracterização de aspectos produtivos e sanitários da criação de tilápia em tanque rede no reservatório de Três Marias, Minas Gerais**. 2016. 48 f. Dissertação (Mestrado em Saúde Animal) - Universidade de Brasília, Brasília, DF, 2016.

SILVA, W. L. M. *et al*. Sustentabilidade na aquicultura: dimensões social, econômica e ambiental–uma revisão de literatura. **Educamazônia-Educação, Sociedade e Meio Ambiente**, Humaitá, v. 20, n. 1, p. 87-108, jan./jun. 2018

TILLEY, D. R.; BROWN, M. T. Dynamic emergy accounting for assessing the environmental benefits of subtropical wetland stormwater management systems. **Ecological Modelling**, Amsterdam, v. 192, n. 3/4, p. 327-361, 2006.

ULGIATI, S. *et al*. Emergy-based complexity measures in natural and social systems. **Ecological Indicators**, New York, v. 11, n. 5, p. 1185-1190, 2011

ULGIATI, S.; BROWN, M. T. Quantifying the environmental support for dilution and abatement of process emissions: the case of electricity production. **Journal of Cleaner Production**, Amsterdam, v. 10, n. 4, p. 335-348, Aug. 2002.

VALENTI, W. C. A aquicultura brasileira é sustentável? *In*: SEMINÁRIO INTERNACIONAL DE AQUICULTURA, MARICULTURA E PESCA - AQUAFAIR, 4., 2008, Florianópolis. [**Anais...**]. Medianeira: AveSui América Latina, 2008. p. 13-15. Palestra apresentada no evento.

VALENTI, W. C. *et al*. Aquaculture in Brazil: past, present and future. **Aquaculture Reports**, Amsterdam, v. 19, [art.] 100611, [p. 1-18], Mar. 2021.

VALENTI, W. C. *et al*. Indicators of sustainability to assess aquaculture systems. **Ecological indicators**, New York, v. 88, p. 402-413, 2018.

WANG, C. *et al*. Provincial sustainability evaluation based on the standardized national emergy database. **Energy Procedia**, Oxford, v. 88, p. 153-159, 2016.

WILFART, A. *et al*. LCA and emergy accounting of aquaculture systems: towards ecological intensification. **Journal of Environmental Management**, New York, v. 121, p. 96-109, 2013.

WILLOT, Pierre-Alexandre *et al.* Ecosystem service framework and typology for an ecosystem approach to aquaculture. **Aquaculture**, Amsterdam, v. 512, [art.] 734260, [p. 1-9], 2019.

WITT, U. Bioeconomics as economics from a Darwinian perspective. **Journal of Bioeconomics**, Dordrecht, v. 1, n. 1, p. 19-34, 1999.

WU, X. F. *et al*. Ecological accounting for an integrated “pig–biogas–fish” system based on emergetic indicators. **Ecological indicators**, New York, v. 47, p. 189-197, 2014.

YANG, Z. F. *et al*. Solar emergy evaluation for Chinese economy. **Energy Policy**, Guildford, v. 38, n. 2, p. 875-886, 2010.

APÊNDICES

Apêndice A - Memorial de cálculo das propriedades avaliadas no estudo

Empresa 1

Sol	
Incidência solar diária (kWh/m2/dia)	4,91
Conversão (dias/ano)	365
Incidência solar diária (kWh/m2/ano)	1792,15
Albedo (%)	15
Área de produção (m²)	54000
Conversão (J/kWh)	3600000
Calculo	8,23E+07
Energia (J)	2,96E+14
Chuva	
Chuva mm/ano	1300
Área de produção (m²)	54000
Densidade da água (kg/l)	1
Energia da chuva/ Energia livre de Gibbs (J/kg)	5000
Energia (J)	3,51E+11
Água dos viveiros	
Densidade da água (kg/l)	1
Energia da chuva/ Energia livre de Gibbs (J/kg)	5000
Energia (J)	4,05E+11
Reprodutores	
Quantidade reprodutores (kg)	2000
Valor calórico da carne do tambaqui (kcal)	1222,2
Fator de Conversão(j/kcal)	4186
calculo	2,44E+06
Energia (J)	5,84E+02
Cal virgem	
Quantidade de cal virgem (kg/ciclo)	1470
Área de produção (ha)	5,4
ciclo de produção (dia)	120
Cálculo	7,94E+03
Quantidade (kg/ha/ciclo)	9,53E+05
Calcário	
Quantidade de calcário (kg/ciclo)	2450
Área de produção (ha)	5,4
ciclo de produção (dia)	120
Cálculo	1,32E+04
Quantidade (kg/ha/ciclo)	1,59E+06
Farelo de arroz	
Quantidade de farelo (kg/ciclo)	735
Área de produção (ha)	5,4
ciclo de produção (dia)	120
Quantidade (kg/ha/ciclo)	8,82E+04
Larvaway	

Quantidade de Larvaway (kg/ciclo)	7,35E+03
Área de produção (ha)	5,4
ciclo de produção (dia)	120
Quantidade (kg/ha/ciclo)	4,76E+06
Sal	
Quantidade de sal (kg/ciclo)	2,70E+03
Área de produção (ha)	5,4
ciclo de produção (dia)	120
Quantidade (kg/ha/ciclo)	
Poço artesiano	
Quantidade	1
Vida útil (anos)	30
Valor	15000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	9,69E+01
Aerador	
Quantidade	4
Vida útil (anos)	8
Valor	1500
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	3,63E+01
Aquecedores	
Quantidade	2
Vida útil (anos)	15
Valor	1500
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	1,94E+01
Incubadora de fluxo ascendente de 200l	
Quantidade	32
Vida útil (anos)	10
Valor	31680
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	6,14E+02
Microscópio	
Quantidade	1
Vida útil (anos)	10
Valor	1500
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	2,91E+01
Caixa de transporte	
Quantidade	2
Vida útil (anos)	10
Valor	3000,00
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	5,81E+01
Lupa de aumento de 10 a 40 vezes	
Quantidade	1
Vida útil (anos)	10
Valor	1200
Valor do câmbio dólar/ US$	5,16

Valor (US$/ha/ano)	2,33E+01
Edificações	
Vida útil (anos)	20
Valor do investimento	631.465,39
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	6,12E+03
Ração reprodutores	
Quantidade de animais	200
Consumo da produção (kg/dia)	60
ciclo de produção (dia)	365
Consumo de ração por ciclo (kg)	118260
ração de tambaqui (kcal)	3300
Fator de Conversão(j)	4186
Energia (J)	1,63E+12
Ração alevinos	
Quantidade de animais	5322240
Consumo da produção (kg/dia)	50
ciclo de produção (dia)	120
Consumo de ração por ciclo (kg)	32400
ração de tambaqui (kcal)	3300
Fator de Conversão(j)	4186
Energia (J)	4,48E+11
Medicamentos	
Valor consumido	3000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	5,81E+02
Manutenção de equipamento	
Valor consumido	4000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	7,75E+02
Telefone	
Valor consumido	3800
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	7,36E+02
Eletricidade	
Consumo de energia (KWh/ano)	84192
Conversão (J/kWh)	3600000
Valor	3,03E+11
Impostos	
Valor do câmbio dólar/ US$	5,16
Valor consumido	5000
Valor (US$/ha/ano)	9,69E+02
Mão de obra nivel superior	
Valor da mão de obra (R$/ano)	36000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	6,98E+03
Mão de obra técnica	
Valor da mão de obra (R$/ano)	18000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	3,49E+03

Mão de obra simples (nivel fundamental/médio	
Valor da mão de obra (R$/ano)	14544
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	2,82E+03

Calculos da Empresa 2

Sol	
Incidência solar diária (kWh/m2/dia)	4,91
Conversão (dias/ano)	365
Incidência solar diária (kWh/m2/ano)	1792,15
Albedo (%)	15
Área de produção (m²)	54000
Conversão (J/kWh)	3600000
Calculo	8,23E+07
Energia (J)	2,96E+14
Chuva	
Chuva mm/ano	1300
Área de produção (m²)	54000
Densidade da água (kg/l)	1
Energia da chuva/ Energia livre de Gibbs (J/kg)	5000
Energia (J)	3,51E+11
Água dos viveiros	
Densidade da água (kg/l)	1
Energia da chuva/ Energia livre de Gibbs (J/kg)	5000
Água dos viveiros (kg/ano)	81.000.000
Energia (J)	4,05E+11
Reprodutores	
Quantidade reprodutores (kg)	3000
Valor calórico da carne do tambaqui (kcal)	1222,2
Fator de Conversão(j/kcal)	4186
calculo	3,67E+06
Energia (J)	8,76E+02
Cal virgem	
Quantidade de cal virgem (kg/ciclo)	1926,6
Área de produção (ha)	5,4
ciclo de produção (dia)	120
Cálculo	1,04E+04
Quantidade (kg/ha/ciclo)	1,25E+06
Calcário	
Quantidade de calcário (kg/ciclo)	7818,92
Área de produção (ha)	5,4
ciclo de produção (dia)	120
Cálculo	4,22E+04
Quantidade (kg/ha/ciclo)	5,07E+06
Larvaway	
Quantidade de Larvaway (kg/ciclo)	7,35E+03
Área de produção (ha)	5,4
ciclo de produção (dia)	120

Quantidade (kg/ha/ciclo)	4,76E+06
Sal	
Quantidade de sal (kg/ciclo)	7954,6
Área de produção (ha)	5,4
ciclo de produção (dia)	120
Quantidade (kg/ha/ciclo)	
Aerador	
Quantidade	10
Vida útil (anos)	8
Valor	15000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	3,63E+02
Incubadora de fluxo ascendente de 200l	
Quantidade	140
Vida útil (anos)	10
Valor	138600
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	2,69E+03
Microscópio	
Quantidade	1
Vida útil (anos)	10
Valor	1500
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	2,91E+01
Caixa de transporte	
Quantidade	6
Vida útil (anos)	10
Valor	18000,00
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	3,49E+02
Lupa de aumento de 10 a 40 vezes	
Quantidade	1
Vida útil (anos)	10
Valor	1200
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	2,33E+01
Edificações	
Vida útil (anos)	20
Valor do investimento	631.465,39
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	6,12E+03
Ração reprodutores	
Quantidade de animais	600
Consumo da produção (kg/dia)	60
ciclo de produção (dia)	365
Consumo de ração por ciclo (kg)	21900
ração de tambaqui (kcal)	3300
Fator de Conversão(j)	4186
Energia (J)	3,03E+11
Ração alevinos	

Quantidade de animais	6000000
Consumo da produção (kg/dia)	50
ciclo de produção (dia)	120
Consumo de ração por ciclo (kg)	169920
ração de tambaqui (kcal)	3300
Fator de Conversão(j)	4186
Energia (J)	2,35E+12
Medicamentos	
Valor consumido	3000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	5,81E+02
Manutenção de equipamento	
Valor consumido	10000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	1,94E+03
Telefone	
Valor consumido	5000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	9,69E+02
Eletricidade	
Consumo de energia (KWh/ano)	84192
Conversão (J/kWh)	3600000
Valor	3,03E+11
Impostos	
Valor do câmbio dólar/ US$	5,16
Valor consumido	5000
Valor (US$/ha/ano)	9,69E+02
Mão de obra nível superior	
Valor da mão de obra (R$/ano)	36000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	6,98E+03
Mão de obra técnica	
Valor da mão de obra (R$/ano)	18000
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	3,49E+03
Mão de obra simples (nível fundamental/médio	
Valor da mão de obra (R$/ano)	14544
Valor do câmbio dólar/ US$	5,16
Valor (US$/ha/ano)	2,82E+03

Apêndice B – Reviews in Fisheries Science & Aquaculture

Preparing Your Paper

Structure

Your paper should be compiled in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list).

Word Limits: Please include a word count for your paper. There are no word limits for papers in this journal.

Style Guidelines: Please refer to these quick style guidelines when preparing your paper, rather than any published articles or a sample copy. Please use American spelling style consistently throughout your manuscript.Please use double quotation marks, except where "a quotation is 'within' a quotation". Please note that long quotations should be indented without quotation marks.

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Papers may be submitted in Word format. Please do not submit your paper as a PDF. Figures should be saved separately from the text. To assist you in preparing your paper, we provide formatting template(s).Word templates are available for this journal. Please save the template to your hard drive, ready for use.If you are not able to use the template via the links (or if you have any other template queries) please contact us here.

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Please supply all details required by your funding and grant-awarding bodies as follows: For single agency grants This work was supported by the [Funding Agency] under Grant [number xxxx].

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Data availability statement. If there is a data set associated with the paper, please provide information about where the data supporting the results or analyses presented in the paper can be found. Where applicable, this should include the hyperlink, DOI or other persistent identifier associated with the data set(s). Templates are also available to support authors.

Data deposition. If you choose to share or make the data underlying the study open, please deposit your data in a recognized data repository prior to or at the time of submission. You will be asked to provide the DOI, pre-reserved DOI, or other persistent identifier for the data set.

Supplemental online material. Supplemental material can be a video, dataset, fileset, sound file or anything which supports (and is pertinent to) your paper. We publish supplemental material online via Figshare. Find out more about supplemental material and how to submit it with your article.

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Tables. Tables should present new information rather than duplicating what is in the text. Readers should be able to interpret the table without reference to the text. Please supply editable files.

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Apêndice C – Normas do periódico Cleaner Production

Submission
Our online submission system guides you stepwise through the process of entering your article details and uploading your files. The system converts your article files to a single PDF file used in the peer-review process. Editable files (e.g., Word, LaTeX) are required to typeset your article for final publication. All correspondence, including notification of the Editor's decision and requests for revision, is sent by e-mail.
Referees
Please submit, with the manuscript a list of three qualified, independent, prospective reviewers who could perform quality peer reviews of your document. (Include their full names, affiliations and their current E-mail addresses.). The Journal of Cleaner Production used 'Single-blind' reviewing, where the names of the reviewers are hidden from the Author, but the reviewer knows who the authors are
PREPARATION
Queries
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Use of word processing software
It is important that the file be saved in the native format of the word processor used. The text should be in single-column format. Keep the layout of the text as simple as possible. Most formatting codes will be removed and replaced on processing the article. In particular, do not use the word processor's options to justify text or to hyphenate words. However, do use bold face, italics, subscripts, superscripts etc. When preparing tables, if you are using a table grid, use only one grid for each individual table and not a grid for each row. If no grid is used, use tabs, not spaces, to align columns. The electronic text should be prepared in a way very similar to that of conventional manuscripts (see also the Guide to Publishing with Elsevier). Note that source files of figures, tables and text graphics will be required whether or not you embed your figures in the text. See also the section on Electronic artwork.
To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check'functions of your word processor.
Article structure
Subdivision - numbered sections: Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-

referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line

Introduction: State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Material and methods: Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

Theory/calculation: A Theory section should extend, not repeat, the background to the article already dealt with in the Introduction and lay the foundation for further work. In contrast, a calculation section represents a practical development from a theoretical basis.

Results: Results should be clear and concise.

Discussion: This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions: The main conclusions of the study may be presented in a short Conclusions section, which may standalone or form a subsection of a Discussion or Results and Discussion section.

Appendices: If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations inappendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

Essential title page information

• Title. Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.

• Author names and affiliations. Please clearly indicate the given name(s) and family name(s)of each author and check that all names are accurately spelled. You can add your name betweenparentheses in your own script behind the English transliteration. Present the authors' affiliationaddresses (where the actual work was done) below the names.

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• Corresponding author. Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. This responsibility includes answering any future queries about Methodology and Materials. Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.

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Keywords:Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

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