

Review

Bioeconomy and Circular Economy Approaches Need to Enhance the Focus on Biodiversity to Achieve Sustainability

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Abstract: Bioeconomy and circular economy approaches are being adopted by an increasing number of international organizations, governments and companies to enhance sustainability. Concerns have been raised about the implications for biodiversity. Here, we present a review of current research on the two approaches to determine their relationship to each other and to other economic models, their impact on sustainability and their relationship with biodiversity. Bioeconomy and circular economy are both poorly defined, inconsistently implemented and inadequately measured, and neither provides a clear pathway to sustainability. Many actors promote goals around economic growth above environmental issues. Biodiversity is often addressed indirectly or inadequately. Furthermore, many traditionally disadvantaged groups, including women and indigenous people, may be neglected and rarely engage or benefit. These challenges are compounded by capacity gaps and legal and governance complexities around implementation, influenced by traditional mindsets and approaches. Countries and companies need to plan their sustainability strategies more explicitly around the biodiversity they impact. Opportunities include the relevance and timeliness of sustainable economics for delivering Sustainable Development Goals in a post-COVID world, the existence of work to be built on, and the diversity of stakeholders already engaged. We propose five main steps to ensure the sustainability of economic approaches. Ultimately, we can ensure sustainability only by starting to shift mindsets and establishing a more focused agenda for bioeconomy and circular economy that puts species, ecosystems and the wellbeing of local people at the center.

Keywords: biodiversity; bioeconomy; blue economy; circular economy; green economy; monitoring sustainability; valuing nature



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1. Introduction

Biodiversity is in decline [1,2]. Pressures and root causes of environmental degradation are often linked to industrial production and consumption of food, products and services exploiting natural resources. Widespread land conversion for infrastructure, agriculture and other development, and overexploitation of natural resources are being driven by political leaders' prioritization of short-term economic gains and the inability of our economic systems and financial markets to appropriately value and protect our natural capital [3]. There is an urgent need to redress the imbalance between human demand for natural resources and nature's supply, while acknowledging that "markets alone are inadequate for protecting ecosystems" [4]. Governments and businesses need to shift towards approaches that ensure conservation and sustainable use of remaining natural resources as part of the broader delivery of the Sustainable Development Goals or SDGs [5–7].

Sustainability is “a characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs” [8]. With ongoing efforts to value biodiversity and ecosystem services directly [9,10], several economic models have been developed to encourage sustainability. In recent years, bioeconomy and circular economy have become predominant approaches to encourage sustainability, gaining traction and uptake by an ever-increasing community of governments, non-governmental organizations (NGOs), civil society organizations (CSOs) and businesses. Both are based on improved resource access with higher eco-efficiency and a low greenhouse gas footprint. However, there has been inadequate scientific research into the concepts [11–14] and queries raised about their efficacy in reducing impacts on biodiversity [15,16]. The need to find solutions is becoming more urgent as the European Union develops its taxonomy of sustainable business activities [17].

This paper provides a review of the concepts and goals of bioeconomy and circular economy. While it is generally recognized that there are four pillars to sustainability [18], here we focus primarily on the environment (rather than the economic, social and policy pillars) in order to assess to what extent biodiversity decline is being addressed by the two approaches. Our aim was to answer the question: To what extent are bioeconomy and circular economy models enhancing sustainability and ensuring the state of biodiversity improves?

Firstly, we present a review of bioeconomy and circular economy, the definitions and approaches used, the stakeholders involved, and how biodiversity fits within the stated visions for the sustainability of both approaches, in theory and in practice. We also review the linkages and synergies between the two approaches. Secondly, we provide a brief overview of other economic approaches that also strive to enhance sustainability, to see if there are any additional lessons to learn or linkages to be made that might influence the evolution of bioeconomy and circular economy. Thirdly, we summarize the issues identified in monitoring the impacts of economic models on biodiversity. Finally, we draw conclusions on how bioeconomy and circular economy could evolve to better tackle biodiversity, proposing five concrete next steps.

2. Bioeconomy

2.1. Definitions and Approaches

Bioeconomy can be described as “the part of the economy based in biology and the biosciences” [19] but the term is used in different ways around the world [20–24] and there is no single, universally agreed definition. Many definitions [21,25–28] refer to the sustainable or renewable use of terrestrial and marine biological resources to provide products (including food and energy) and services in all economic sectors. Some definitions emphasize this is applicable both upstream and downstream in the value chain [29].

The bioeconomy is seen as an opportunity to mitigate climate change while trying to maintain economic growth and human wellbeing [30] and many governments and international organizations use the approach to encourage sustainability. The notion “has gained importance in both research and policy debates over the last decade, and is frequently argued to be a key part of the solution to multiple grand challenges” [20]. Many see bioeconomy as central to delivering several of the SDGs [19,31,32]; some even see the bioeconomy as the fourth industrial revolution [33]. Expectations are therefore high and it is suggested a transition to a bioeconomy can address, among other things, carbon emissions and climate change, food security, human health and livelihoods, industrial restructuring, energy security, food wastage, and unsustainable consumption patterns [20,34]. Biodiversity is rarely mentioned explicitly [15,35].

Much of the analysis of bioeconomy has been conducted in Europe. Because it covers all sectors that rely on biological resources in land and marine ecosystems, the bioeconomy is seen as a central element to the functioning and success of the European economy, with turnover estimated at Euro 2.3 trillion [36]. By 2015, bioeconomy was accounting for nearly 18 million jobs in industries ranging from agriculture to forest-based industries [37]. As

the concept of bioeconomy has evolved, sustainability has been mentioned more explicitly, and the European Commission [36] stated that the bioeconomy can contribute to restoring ecosystems as well as reducing land degradation and achieving plastic-free oceans. In general, there is acknowledgement that, because biodiversity is impacted by land-use change and greenhouse gas emissions, resource supply “has to be sustainable, and therefore the use of bio-based resources should only be implemented where these perform more sustainably than the fossil alternative” [38].

In spite of these lofty ambitions and signs of progress, the bioeconomy has been called “the challenge of the century for policy makers” [30]. A major problem with the concept is that multiple terms and definitions have been used and different approaches taken in its implementation. For example, authors have identified different bioeconomy types [39], visions [20], perspectives [40], implementation pathways [41], transformation pathways [32], scenarios [42] and principles [31]. Unsurprisingly, national strategies vary widely in their focus, ranging across topics such as renewable energy, food production, rural development, employment, research, and the economy as a whole [43].

Compared to its original meaning, the currently prevailing understanding of bioeconomy has undergone major changes [41]. Nicholas Georgescu-Roegen, considered by many to be a pioneer of bioeconomy (c.f. Peterson and Kaaret [43]), called for a new economic model that would be compatible with the biophysical limits of the planet [44,45]. However, this early understanding of an “ecologization of the economy” has been reversed by present bioeconomists and, instead of adapting industrial material flows to natural metabolic cycles, there is now a push for nature to be “manipulated and optimized to fit economic purposes” [41]. Some see this as “economization of ecology”, “neo-liberalization of nature”, or “biocapitalism” [41,46,47] and the change in meaning has been termed a “semantic hijacking” [39].

As with other economic models, consensus on a definition for bioeconomy is needed to form the basis for taking forward, promoting and synchronizing a shared policy agenda, which can then be compared and contrasted across countries and stakeholders [29,48].

2.2. Stakeholders

The main international organizations that have pioneered and promoted the bioeconomy are the Organization for Economic Co-operation and Development (OECD) and the European Commission. The OECD started with a narrow focus on biotechnology [27] before expanding the model [23,49,50]. In recent years, the European Commission has also become a major actor in the bioeconomy [26,34,36,42,51–54] and is now seen by some as the global leader [43]. As with the OECD, interest in the issue originally stemmed from biotechnology, for which a strategy was first developed in 2002 [55]. However, as summarized by Vivien et al. [39], the Commission’s use of the concept expanded and since 2010 it has used the term bioeconomy to encompass the agriculture, forestry, fishing, chemistry, biotechnology and energy sectors.

The UN Food and Agriculture Organization (FAO) has started engaging in the bioeconomy; it assessed how sustainability has been addressed in national strategies [56,57] and produced guidance on monitoring bioeconomy [31]. The Global Bioeconomy Summit was established by the Bioeconomy Council of the Federal German Government as a forum for governments, scientists, business and civil society to advance the bioeconomy agenda, with high-level, biennial international conferences to review and discuss emerging opportunities and challenges [21,58].

More than 50 countries from Africa, the Americas, Asia, Australasia and Europe, have developed bioeconomy strategies [32,59]. In most cases, countries have produced more than one strategy relating to the bioeconomy, usually with different ministries leading on different strategies. For example: South Africa has a National Biodiversity Economy Strategy and a separate national bio-technology strategy; China has 11 plans that can be linked to the bioeconomy [32]. Within Europe, there were regionally differing priorities, approaches and objectives [55]. The lack of clear and consistent use of a bioeconomy

definition and approach means several countries invest in multiple strategies that fit under the umbrella of the bioeconomy. It can be assumed that such competing or conflicting goals leads to a dilution of effort and less efficiency and impact than one consolidated cross-sectoral strategy working towards one agreed definition of success.

Numerous research bodies have been involved in different aspects of the bioeconomy. A review by Bugge et al. [20] suggested that the most prominent organizations in terms of papers produced were mostly in Europe and the USA. Bioeconomy is also being advanced by numerous companies, especially those in the sectors of biotechnology, forestry, food, agriculture and fisheries (Table 1). However, as noted by D’Amato et al. [60], since it is a relatively recent concept, bioeconomy is not commonly reported outside of the forest sector.

Table 1. Examples of the types of stakeholders ¹ engaged in work that relates to bioeconomy and circular economy.

Type of Stakeholder	Bioeconomy	Circular Economy
International organizations	European Commission; Global Green Growth Institute; OECD; UN Food and Agriculture Organisation; World Business Council for Sustainable Development.	European Commission; OECD; UN Environment; World Business Council for Sustainable Development; World Economic Forum.
National governments	More than 50 governments, including: <ul style="list-style-type: none"> • Europe (e.g., France, Germany, Italy, Russia, Spain, UK and all the Scandinavian countries) • Africa (e.g., Kenya, Nigeria, South Africa) • the Americas (e.g., Brazil, Canada, Colombia, USA) • Asia and Australasia (e.g., Australia, China, India, Japan). 	Several governments, including Canada, Chile, China, Finland, France, Ghana, Japan, Rwanda, Slovenia, Sweden, The Netherlands, UK.
Business and industry	Companies, especially those in the sectors of biotechnology, food, agriculture and fisheries, including ADM—Archer Daniels Midland Company, ARD (industrial biotechnologies), Cristal Union cooperative, Coq Vert partners, Novamont.	Multinational businesses including Accenture, Apple, Coca-Cola Company, Dell Technologies, Huawei Technologies, Inter-American Development Bank Mitsubishi Motors, Nissan, Proctor and Gamble, Royal Philips, Shell.
Scientists, researchers and their institutions	European Forest Institute; L’Institut Valencià d’Investigacions Agràries (IVIA), Spain; ScienceCampus Halle, Germany; Stockholm Environment Institute; Universities, including Cardiff, Florida, Ghent, Iowa State, Lodz (Technology), Lund, Michigan State, Reims Champagne-Ardenne, Utrecht, Wageningen and York; US Department of Agriculture; Wood Technology Institute, Poland; E-zavod (Institute for Comprehensive Development Solutions), Slovenia; European Center for Biotechnology and Bioeconomics (CEBB); UFZ-Helmholtz Centre for Environmental Research, Germany.	Chatham House; Stockholm Environment Institute; Swedish Environmental Research Institute; World Resources Institute
CSOs, NGOs and the communities they represent	BirdLife Europe; Fern; Oxfam; Transport and Environment; Wetlands International; Zero Waste Europe.	Circle Economy; Danish Association for Nature Conservation; Ellen MacArthur Foundation; Ocean Conservancy; Rediscovery Centre; WWF; Zero Waste Europe.
Platforms, communities and partnerships	Global Bioeconomy Summit; European Commission Bioeconomy Stakeholders Panel; Forest-based Sector Technology Platform. Numerous regional platforms exist in Europe, such as: <ul style="list-style-type: none"> • Plataforma Tecnológica Española—Food for Life Spain • Forest-based Sector Technology Platform, Belgium • EuropaBio—The European Association for Bioindustries. • Cluster of Bioenergy and Environment of Western Macedonia (public sector, research and entrepreneurship cooperation) • BioFuel Region, Sweden. 	Platform for Accelerating the Circular Economy; European Circular Economy Stakeholder Platform; Circular Economy Platform of the Americas.

¹ Derived from references cited in the text. Note that different stakeholders may use different definitions or have a different understanding of the two economic approaches.

A common theme in bioeconomy is the socio-economic benefits to people, yet there is evidence that, in at least some cases, there is inadequate participation of societal stakeholders and end-users [41,61,62]. Existing networks of stakeholders are sometimes “rather closed”, raising “concerns about equal benefit sharing and the inclusiveness of concerned actors” [14]. The bioeconomy provides a potentially important boost to socio-economic development in many developing countries yet, in countries such as South Africa, “access and participation by previously disadvantaged individuals has been limited” [63]. Adoption of bioeconomy approaches in wealthy countries can also impact negatively those less wealthy countries that supply some of their resources. For example, certification schemes and certain bioeconomy-related regulations can disadvantage producers in poorer countries [19]. It is therefore noteworthy that this review found only a handful of NGOs engaging with the approach (Table 1).

2.3. Sustainability

While there is a general consensus that the bioeconomy is supposed to result in increased sustainability, there is little evidence to support that assumption [16,20,42,64]. Indeed, the increased natural resource use associated with some aspects of bioeconomy compete directly with conservation goals [64] and some bioeconomy visions (such as the bio-technology vision) prioritize economic growth above sustainability [20].

One of the problems is that different bioeconomy models can compete with each other, and the biomass-based economy or bio-resources vision espoused by the European Commission seems to dominate [39,43]. Biomass availability and the competition between alternative uses of biomass (for food, feed, fiber, bio-based materials and bioenergy) are major concerns for the viability of a bioeconomy [43,52,65]. This is compounded by differing national strategies, with biofuel production having negative impacts on land and water resources and food security [32,56,57]. Some national strategies, such as those in Thailand and South Africa, focus on exploiting biodiversity directly [66,67]. Causal factors for this challenge of competing uses for biodiversity and natural resources are complex and diverse and include the lack of coherent, science-based policy decisions embracing bioeconomy [68], poverty, limited land ownership [63], and large fossil fuel subsidies in some countries [30].

As a result, it is clear that the bioeconomy is not necessarily sustainable and the economic aspects are usually given more attention than sustainability-related issues and biodiversity [55,69,70]. The Building Regional Bioeconomies project provided a toolkit for strategy development [71] but it is noticeable that this toolkit’s indicators do not include any metrics on biodiversity. In the ten national bioeconomy strategies reviewed by Peterson and Kaaret [43], none was led by an environment ministry.

3. Circular Economy

3.1. Definitions and Approaches

Although he did not use the term directly, Boulding [72] is often acknowledged as devising the original concept of the circular economy. The Platform for Accelerating the Circular Economy [73] defines the circular economy as “a system that is designed to prevent waste and pollution, keep products and materials in use, and regenerate natural systems”. However, Kirchherr et al. [74] noted that there are at least 114 definitions of circular economy and many interpretations of what it includes. Common themes across definitions include the focus on reducing waste and pollution through reuse and recycling [75–77] so as to reduce the demand for natural resources [14]. This often depends on technological innovation and changes in production and consumption patterns [78]. Other concepts identified as associated with circular economy include sustainable development, ecological transition, life cycle or cradle-to-grave thinking, green economy, ecodesign and extended produced responsibility [79].

The ten common circular economy strategies according to Morsetto [75] are recover, recycle, repurpose, remanufacture, refurbish, repair, re-use, reduce, rethink and refuse. In contrast, Buchmann-Duck and Beazley [15] suggested there are eight different popular

circular economy strategies: biomimicry, ecosystem service valuation, cultural services, regulating services, supporting services, provisioning services, bioeconomy, and renewable energy. Lüdeke-Freund et al. [80] propose six major business model patterns with the potential to support the closing of resource flows: repair and maintenance; reuse and redistribution; refurbishment and remanufacturing; recycling; cascading and repurposing; and organic feedstock business model patterns. However, Stahel [77] suggested that there are only two business models for the circular economy: “those that foster reuse and extend service life through repair, remanufacture, upgrades and retrofits, and those that turn old goods into as-new resources by recycling the materials”.

D’Amato et al. [60] identified three main circular economy themes: monitoring/assessing; reducing/optimizing; recycling/reusing energy and material flows. UNEP [81] talks of circularity: “Circular processes contributing to circularity include: reduce by design (reducing the amount of material used, particularly raw material, should be applied as an overall guiding principle from the earliest stages of design of products and services); from a user-to-user perspective, refuse, reduce and re-use; from a user-to-business intermediary perspective, repair, refurbish and remanufacture; and from business-to-business: repurpose and recycle”. Bocken et al. [82] advocate for a sufficiency-based circular economy, with more effort to change individual behavior and reduce resource consumption (sensu Gossen & Heinrick [83]).

Like bioeconomy, therefore, there are several different interpretations and approaches to this economic model and, like bioeconomy, biodiversity is rarely mentioned explicitly. Overall, the concept is confusing and means different things to different people [14,15,74,84–86]. Similar to the bioeconomy, for the circular economy different actors sometimes have a different focus and emphasis, ranging from recycling to plastic pollution to climate change.

Progress in implementing a circular economy has so far been limited and poor [85,87]. Morsetto [75] suggested that, while recovery and recycling are the most common strategies applied, they do not necessarily promote a circular economy. Challenges to implementing a circular economy appear to be numerous and include financial, structural, operational, attitudinal and technological barriers [88].

3.2. Stakeholders

Although a strong proponent of bioeconomy, the European Commission is also commonly promoting a circular economy. “The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized, is an essential contribution to the EU’s efforts to develop a sustainable, low carbon, resource efficient and competitive economy” [89]. Efforts are underway to develop an EU Taxonomy [17] to allow companies to report on the proportion of their activities that are sustainable. While there is no mention of bioeconomy, one of the environmental objectives for the taxonomy is “the transition to a circular economy” [17], further underlining the importance of this approach to the Commission. The Ellen MacArthur Foundation [90] is a civil society proponent of the approach and estimates that, in the EU alone, it could result in material cost savings of up to USD 630 billion.

Like the EU, the OECD is also a proponent of both bioeconomy and circular economy [22,47], as is the UN Environment Program [81,91]. Several governments and many multinational businesses are also actively promoting a circular economy [14,73] (Table 1). The Platform for Accelerating the Circular Economy (PACE) was established by the World Economic Forum in 2018 and is now hosted by the World Resources Institute. PACE [73] strives to bring together leaders from the different sectors involved across business, government and civil society “to develop a collective agenda and drive ambitious action”.

3.3. Sustainability

Circular economy is often presented as equating sustainability and assisting sustainable development. There is a large volume of work in recent years exploring the concept

(see 14, 77 and 78 for reviews). Like bioeconomy, circular economy is expected to deliver a large and diverse suite of advantages, including improvements in human health, nutrition and wellbeing, increased food security, better jobs, reduced emissions and climate change, and improvements in biodiversity [92,93]. Results in Europe have been quantified to some degree. For example, “seven European nations found that a shift to a circular economy would reduce each nation’s greenhouse-gas emissions by up to 70% and grow its workforce by about 4%” [77].

It is notable that even the original proponent of the concept felt that a circular economy could only be achieved if demand and global consumption were stabilized [72]. Since increasing human populations will cause demand for natural resources to continue to increase, it is not surprising that numerous studies [14,15,74,84–86,94] flag the fact that circular economy does not necessarily enhance sustainability and benefit biodiversity. Indeed, circular economy often puts too much importance and emphasis on economic prosperity and business-led economic growth [74,95,96] and “biodiversity protection is rarely mentioned in theory and policy” [15]. For example, a recent World Economic Forum report [97] on plastics and circular economy mentioned biodiversity only once, in a footnote. Social dimensions are also rarely demonstrated. However, D’Amato et al. [60] found some food companies that changed consumer behavior were able to lead to the redistribution of excess food to local communities. However, clearly circular economy links to biodiversity goals and social goals need to be strengthened [98] as well as methods to monitor progress in their delivery [99]. Others [100,101] have suggested the use of nature-based solutions [102] could facilitate a more sustainable circular economy.

Rebound effects are a significant concern with the circular economy. There are two main rebound mechanisms: (1) imperfect substitution between “re-circulated” (recycled, reused, etc.) and new products and (2) re-spending due to economic savings [103]. This can mean that circular economy activities increase overall production, an impact that for-profit companies may find hard to mitigate [104]. Overall, therefore, growth and production in a particular economy are likely to involve increased competition for land and biomass for agriculture and biofuels and ultimately a decrease in biodiversity [64,105–107]. IPBES [1] also noted that the bioeconomy competes with protected area goals.

4. Linking Bioeconomy and Circular Economy

Several key stakeholders, including the European Commission, the Organization for Economic Co-operation and Development, and the Global Bioeconomy Summit, consider the circular economy closely linked to, and necessarily aligned with, the bioeconomy [21,36,49]. Other authors have suggested that, in reducing pressure on biological resources, a bioeconomy could help realize a circular economy [34]; indeed, Buchmann-Duck and Beazley [15] explicitly propose bioeconomy as a strategy to achieve a circular economy. Notably, the European Commission’s argument for linking the two approaches includes a direct reference to biodiversity: “To be successful, the European bioeconomy needs to have sustainability and circularity at its heart. This will drive the renewal of our industries, the modernization of our primary production systems, the protection of the environment and will enhance biodiversity” [36]. Several countries have both bioeconomy and circular economy plans or explicitly link the bioeconomy to a circular economy and sustainability [49,108]. The OECD [49] makes explicit reference to potential synergies and conflicts between the two approaches. Tensons identified include the qualification of a material as a ‘waste’ rather than a ‘secondary raw material’ disqualifies it from being used as a biorefinery feedstock in some countries.

Some agencies explicitly adopt both approaches together as an integrated model. For example, the World Business Council for Sustainable Development [109] recently called for “a shift to a sustainable, low-carbon, circular bioeconomy”; the Global Green Growth institute aims to achieve “a sustainable and circular bioeconomy while securing healthy natural systems” [110]. As proposed by several authors and agencies [36,49,111,112], it may therefore be best to consider bioeconomy and circular economy as complementary,

with one model a subset of activities under the other. Several stakeholders have made some effort to adopt both approaches (see Table 1) further suggesting efficiencies could be made if the models were better aligned and harmonized.

5. Other Economic Approaches Attempting to Address Sustainability

Bioeconomy and circular economy are not the only economic approaches aimed at enhancing sustainability. Here, we provide a snapshot of the broader landscape of economic options to put bioeconomy and circular economy in perspective.

Green and blue economies focus primarily on carbon issues and resource-use issues in terrestrial and marine biomes respectively. According to UNEP [113], a green economy is “one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive.” This can involve sustainably use of biodiversity for economic growth [114]. Blue economy has been called “the sustainable industrialization of the oceans to the benefit of all” [115] and covers sectors such as fisheries, aquaculture, tourism, bio-prospecting, seabed mining, oil and gas, renewable energy, and shipping [116]. As with bioeconomy and circular economy, there is a lack of consensus over global definitions and approaches for blue and green economies [117–120] and sustainability is sometimes less of a focus than economic development [116].

A low-carbon economy is an economy that causes low levels of greenhouse gas emissions compared with carbon-intensive economies [121]. Low carbon economics—driven strongly by the UN Framework Convention on Climate Change (UNFCCC)—revolve around the promotion of approaches such as renewable energy, carbon pricing, and modern, smart and clean infrastructure. The agriculture and forestry sectors, so prevalent in the green economy and bioeconomy, are also key. Although there are numerous different climate economy models [122], the carbon economy, in general, seems to be more clearly understood and widely implemented than other models, largely as it is associated with government commitments to the UNFCCC.

Work on green, blue and carbon economies has highlighted the need to better integrate resource users such as local communities and indigenous people into environmental management decisions and agenda-setting [116,118,123], with gender issues also being neglected or weakly addressed [119]. The educated elite often dominates civil society voices [118]. Some authors have suggested it is the initiatives that involve local communities that are more successful [124].

Given that the green economy approach is often seen as a means of uniting all economic policies relating to sustainable development [125], it may provide a suitable umbrella term under which bioeconomy and circular economy fit, with blue economy being the equivalent for the oceans and covering sectors such as fisheries, aquaculture, tourism, bio-prospecting, seabed mining, oil and gas, renewable energy, and shipping [116].

Loiseau et al. [126] noted that the green economy incorporates many other concepts and approaches, such as environmental economics, ecological economics, cleaner production, waste hierarchy, bioeconomy, industrial ecology, circular economy, nature-based solutions, and dematerialization through product-servicing, as well as tools like life cycle assessment, and cost-benefit analysis. However, as noted by D’Amato et al. [111], “the concepts of circular economy, green economy and bioeconomy are joined by the common ideal to reconcile economic, environmental and social goals” and green economy could potentially act as an umbrella concept, including elements from circular economy and bioeconomy as well as additional ideas such as nature-based solutions. At the very least their relationship needs to be made more explicit.

Other models exist but are less well developed or less extensively implemented. De-growth (and the related sharing economy) focuses on sustainable production and consumption. Although widely discussed and offering the possibility of supporting biodiversity,

it also suffers from problems of unharmonized definitions and approaches and limited application, compounded by a name that has negative associations [118,127–130].

It may have potential links to the circular economy but also needs to address potential rebound effects [131]. Post-consumerism (also known as post-capitalism or post-growth) remains a poorly studied concept or a movement rather than a credible model [132,133]. Doughnut economics link social wellbeing to planetary boundaries [134–136], but the approach has not been subject to much critical review and it remains unclear how countries can turn the theory into practice. However, there is a Doughnut Economics Action Lab actively working to prototype new practices at local scales [137] and some recent reflections [138,139] suggest that the concept of doughnut economics may be more appealing after the COVID-19 pandemic. The concept of consumption corridors [140–142] pursues the aim of well-being in a world of limits. Consumption corridors take a needs-based approach, address intergenerational justice and acknowledge that planetary boundaries imply imposing limits on consumption. Universal basic services (and the more specific idea of a universal basic income) has a long history [143] but is now gaining traction, especially for a post-COVID world [144–146]. Although it is generally more focused on social cohesion and equality than sustainability, a version called conservation basic income has been proposed to pay people directly for conserving ecosystem services [147]. The Efficiency Economy Philosophy developed in Thailand is based around living within community means and has strong underlying links to sustainability [148,149], but it has not been adopted by other countries, biodiversity is in the background, and it is probably too nationally focused to be of use in changing global economies.

Companies, as well as some governments, are using an increasing number of tools and approaches to enhance sustainability and biodiversity gains, such as nature-based solutions [102,150,151] and a focus on nature-positive goals [6,152,153]. In turn, many are being encouraged to plan this work through science-based targets [154] and to monitor and disclose their biodiversity results [155,156]. If a bioeconomy or circular economy is to deliver meaningful conservation results, the communities implementing them need to integrate the latest thinking into their strategies.

6. Measuring the Sustainability of Economic Models and Their Impact on Biodiversity

Policies need to “acknowledge the conflict between economic growth and biodiversity conservation” [157]. The current measurement of economic progress around the world is focused on Gross Domestic Product or GDP. However, GDP is limited to marketed goods and services produced by the economy and fails to capture fully the contributions of nature to economic activity and human well-being [158,159]. Therefore, “we badly need new measures of the impact of economic growth” [160]. An OECD high-level panel concluded that “no single metric will ever provide a good measure of the health of a country” and instead encouraged the use of a suite of indicators measuring variables such as quality of life and sustainability [161]. However, the current lack of obvious alternatives means that many countries continue to use GDP; some, such as Argentina and South Africa, even measure the contribution of the bioeconomy to the national economy in terms of GDP [31,66].

Generally, in the context of bioeconomy and circular economy, indicators, systems and data are inadequate to monitor sustainability and the impact on biodiversity [30,52,162,163]. Where indicators have been developed [71,164], biodiversity is notably absent. The FAO reviewed indicators being used to monitor the bioeconomy but found sustainability indicators lacking in most countries [31]. This challenge is compounded by the lack of a common definition of what constitutes a contribution to a bioeconomy or circular economy, making it impossible to compare progress in different countries [57]. OECD [165] produced a list of green growth indicators but, while these include some measures of biodiversity, they are not comprehensive and should be better harmonized with those for the SDGs [166].

More broadly, there have been suggestions that policymakers need to use indicators such as value-per-weight and labor-input-per-weight ratios rather than GDP [167]. Sta-

hel [167] further suggests that “societal wealth and well-being should be measured in stock instead of flow, in capital instead of sales. Growth then corresponds to a rise in the quality and quantity of all stocks—natural, cultural, human and manufactured”. Stiglitz et al. [161] noted that better measures of sustainability are needed, and data on human well-being should be disaggregated by age, gender, disability status, sexual orientation, education and other markers of social status in order to describe group differences in well-being outcomes. Diaz-Chavez et al. [18] suggested looking at economic indicators through an SDG lens, and Bracco et al. [31] proposed bioeconomy monitoring frameworks closely tied to those used for SDGs. Links could also be made to indicator sets used for green or blue economies [168,169]. However, it is clear that, unless the bioeconomy and circular economy can be monitored with indicators that include measures of biodiversity, ecosystem services and human well-being, as well as sustainability and equity, it will be hard to measure their impact.

Some useful data exist. For example, data of potential use in tracking biodiversity finance include the OECD database on Policy Instruments for the Environment (PINE), which tracks progress on the implementation of biodiversity-relevant taxes, fees and charges, environmentally motivated subsidies and tradable permit systems (i.e., the positive incentives in Aichi Target 3), and the revenue they generate [170]. Currently, more than 110 countries report to the PINE database. The OECD is currently expanding this work to collect data on biodiversity offsets and payments for ecosystem services. Databases for multi-regional input-output analyses are also available on the impacts of global value chains that can help assess progress against some elements of the green economy [171].

More companies are starting to monitor biodiversity performance, and recent guidelines [154–156] suggest that setting measurable goals and indicators could facilitate improved company reporting on biodiversity. Furthermore, many global data sources exist for monitoring biodiversity [172] that could support corporate reporting. A key pre-requisite for corporate biodiversity reporting is that companies need to understand their pressures on the environment upstream and downstream in their value chains [156], a principle that is also essential in the sustainability of any bioeconomy or circular economy model.

7. Summary of Challenges and Opportunities

7.1. Challenges

Factors hampering the development and acceleration of viable and credible sustainable economic models are numerous. The main challenges identified for bioeconomy and circular economy include the following (Table 2).

Table 2. Summary of the main challenges and opportunities in implementing bioeconomy and circular economy approaches.

Challenges	Opportunities
Definitions are confused and unharmonized.	Work, thinking and experience exist that can be built on
Biodiversity is neglected in both models and proof of concept is lacking on how biodiversity will benefit.	Sustainability is a topical, relevant and timely issue
Many elements of society are excluded.	Diverse and influential stakeholders are involved and engaged
Monitoring is weak with no use of biodiversity indicators	Some indicators have been identified
Inflated expectations of what each approach can achieve. Implementation is unharmonized and causes competition. Legal and organizational complexity across multiple sectors	The COVID-19 pandemic may create the stimulus for improving economic models
Limited organizational and operational capacity for implementation.	

Definitions are confused and unharmonized. A common problem across economic approaches is a lack of agreement on definitions. “A proliferation in terms adds more complexity to an already challenging management space” [119] and significantly varying

definitions and approaches of key models may even lead to the eventual collapse of the concepts [74].

Implementation is unharmonized and causes competition. Multiple goals, strategies and approaches exist at global, regional and national levels for implementing the models and many of these compete with each other and for land or biomass [20,32,39,43,52,65].

Biodiversity is often neglected. Many economic actions and approaches, even if outwardly promoted as nature-friendly, may conflict with biodiversity protection and ecosystem services and may not be sustainable, or prioritize economic growth above sustainability [15,16,20,74]. There is therefore an urgent need to identify “different viable schemes to combine both sustainability and profitability” [48]. Without such a biodiversity focus, neither model is adequately changing or challenging dominant economic approaches such as capitalism.

Proof of concept is lacking. Little research exists on how biodiversity will be protected if bioeconomy and circular economy approaches are implemented [14,15,86,173].

Many elements of society are excluded. Sustainable economic models offer opportunities for socio-economic development, yet access, engagement and participation by women, local communities, indigenous people, people from small-island developing states and tropical low-income high-biodiversity countries, as well as other traditionally disadvantaged groups, has been limited [19,41,61–63,116,118,119,123,174]. Furthermore, most of the literature framing the definitions and driving the development of the models arises in the global north, risking the perpetuation of the economic status quo with all its inherent inequalities [175].

Expectations of what each approach can achieve are inflated. Ambitions are probably too high, with many actors relying on different economic models to solve all of the world’s environmental problems across multiple sectors [20,34]; yet existing definitions, policies, approaches do not support that and do not appear to challenge significantly the dominant economic paradigms.

Capacity gaps exist. At least some governments have limited organizational and operational capacity to develop or implement economic policies and strategies [67] and the research community is fragmented and distributed across different fields of science [20].

Monitoring is weak. Biodiversity indicators are not being used to monitor the delivery of both approaches, meaning environmental impacts are not measured. Furthermore, a focus on GDP as the main economic metric means that biodiversity and other environmental and social factors related to sustainability and human wellbeing are not being monitored.

There is legal and organizational complexity. The fact that bioeconomy and circular economy cut across multiple sectors, government departments and organizations [43] means regulatory and governance frameworks are very complex.

7.2. Opportunities

There are several opportunities that help create an enabling environment for bioeconomy and circular economy.

Sustainability is a topical, relevant and timely issue. There appears to be widescale interest to address issues around sustainable economies to help deliver several SDGs (sensu Dietz et al. [32]), and the public and private sectors are increasingly recognizing the need to address biodiversity [17,152]. Several authors suggest the COVID-19 pandemic may create the enabling conditions for introducing new economic models or making existing ones more sustainable [146,160].

Work and experience exist that can be built on. Numerous stakeholders have developed and tested a range of economic models and several wealthy countries and high-biodiversity countries are already implementing relevant strategies. More than a decade of experience in defining and addressing the bioeconomy in the European Commission and OECD could provide a springboard for more focused biodiversity-focused economic approaches. The FAO has also made a good start at defining indicators to monitor sustainability. Existing work to track sustainability [31] and expenditure on biodiver-

sity [171,176] could be used to inform the better integration of ecosystem conservation into a more biodiversity-focused economic model. Guidelines and tools are also being produced [92,93,177].

Some indicators have been identified. So far, the main effort to develop a coherent system to monitor the sustainability of economics was made by FAO [31] which describes existing national efforts and several biodiversity-focused indicators. OECD [165] is also using green growth indicators. The global effort to monitor SDGs [166] and the increasing interest and options for companies to measure corporate biodiversity performance [152,155,156] also offer momentum and opportunities to build on.

Stakeholder engagement is diverse. A wide range of governments, businesses, research institutions and civil society organizations have committed to sustainable economic approaches (Table 1). More effort to bring these communities together could potentially help create a critical mass of interest to challenge the dominant economic systems and catalyze the relevant evolution of sustainable approaches to meet more people's needs and better address biodiversity.

8. Conclusions and Proposed Steps Forward

The economic benefits of maintaining healthy ecosystems need to be given more emphasis than the simple use, exploitation and manipulation of biodiversity. People continue to adapt definitions of different economic approaches, building on them to meet their own needs, agendas and world views. As a result, there are no common visions or generalized views on what each approach entails, or agreement on their advantages and disadvantages for the environment and for achieving sustainability. This needs to be rectified and the bioeconomy and circular economy in particular need to enhance their focus on biodiversity if they are to facilitate sustainability.

Therefore, building on the opportunities we have identified, we propose five main steps to ensure bioeconomy and circular economy adequately address sustainability issues and improve the state of nature. Our five steps have repercussions for the theoretical and practical evolution of the two economic approaches. Theoretically, definitions and synergies need to be mapped out and harmonized to better define expectations for biodiversity and people and how each approach should operate and interlink. Research and innovation are also required to improve the sustainability of biodiversity-related economic activities. Practically, the implementation of the two approaches needs to engage civil society, define and implement effective governance frameworks, and monitor delivery sufficiently well to ensure proof of concept and palpable impacts on biodiversity. The stakeholders identified (Table 1) could play a key role in implementing the five steps.

8.1. Step 1: Confirm Definitions, Synergies and Approaches

Stakeholders across sectors need to come together and agree on credible, widely-acceptable definitions for both bioeconomy and circular economy. Definitions need to resolve confusion and uncertainty, with explicit mention of biodiversity and how it will benefit, and direct reference to the social and equity ambitions of each approach. There also needs to be a formal statement clarifying linkages between bioeconomy and circular economy, and with the broader green and blue economies.

A hierarchy of approaches should be used, where some concepts are a subset of others that act as umbrellas. For example, it has already been noted that the green economy acts as an umbrella concept for other sustainable economic models and includes elements from the circular economy and bioeconomy (e.g., eco-efficiency, renewables), as well as additional ideas such as nature-based solutions [112]. Some authors have suggested that the bioeconomy be considered an integral component of the green economy [40,178]. D'Amato and Korhonen [179] recently suggested that none of the three narratives of bioeconomy, circular economy and green economy individually "offer a comprehensive package of solutions" but that can be resolved by considering them together as collaborative narratives.

Therefore, it would seem apposite to consider the circular economy as a more focused element of the broader concept of bioeconomy, which in turn should be seen as a subset of the blue and green economies (Figure 1). The carbon economy is relevant to all but, since it primarily relates to reducing greenhouse gas emissions in all contexts, it could be seen as separate or embedded in all three layers.

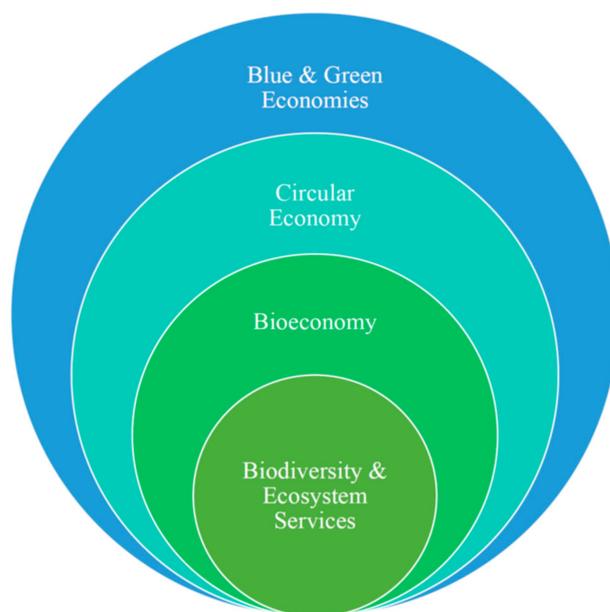


Figure 1. Bioeconomy can be seen as a subset of the broader circular economy and the blue and green economies.

The agreed definitions and hierarchy of approaches should explain the main sectors covered by each approach, specify the types of activity applied, and how the economic benefits of biodiversity will be realized, including the contribution to ecosystem functions, non-use values, the contribution to ecosystem resilience and the value of biodiversity as information (sensu Pearce [180]). It should also be specified how nature-positive and nature-based solutions can be used to realize the goals of each approach. Stakeholders might find it most appropriate to develop a standard for each economic approach, as has been developed for nature-based solutions [102] and, in doing so, define the main goals for each approach.

8.2. Step 2: Widen the Discussion to Include Civil Society

As with the blue economy [137], bioeconomy and circular economy need to ensure that civil society (including scientists, civil society groups, marginalized groups and media) is represented in decision-making processes on how biodiversity will be managed and by whom, how and to whom benefits will be distributed, how harms will be minimized, and who will bear responsibility for environmental and social outcomes. This will mean broader engagement in the debate and in the implementation of economic approaches by a wider and more diverse selection of stakeholders, and more effort to bring together epistemic communities to form a wider, collaborative consensus on sustainable approaches. Inclusiveness and knowledge transfer within and between countries with different capacities and knowledge bases will be very important.

8.3. Step 3: Define Governance Frameworks

Suitable regulations, policies and investments will need to be put in place that ensure sustainability [42], as well as policies that are “stable and long-term so that the private sector has the confidence to invest in risky projects” [30]. More explicitly linking bioeconomy and circular economy to the delivery of SDGs would be pertinent and the relevant UN

agencies could take more of a lead in guiding stakeholders. Regulatory frameworks for intellectual property, the access to and use of genetic resources, biosafety and the ethics of biosciences and industrial standards may also need to be reviewed. In addition, companies need to institutionalize sustainability, ensuring board oversight and remuneration linked to biodiversity performance.

8.4. Step 4: Act and Innovate

A suite of diverse but harmonized approaches to implementing a green economy and its constituent parts needs to be developed, based on existing ones that are working well and can be replicated, as well as innovative new ideas to be tested. This work needs to include an effort to ensure sustainability challenges that have plagued the bioeconomy are resolved, especially the competing demands for land and biomass, as well as the rebound issues of the circular economy. Technological, organizational and social innovations will likely be needed [19]. Most effort should focus on interdisciplinary research to improve the sustainability, social equity and efficiency of the main biodiversity-related economic activities such as ecotourism, forest landscape restoration, offsetting, fisheries and forestry, including improvements in the biodiversity impacts of certification schemes. However, other innovations in the broader bioeconomy, especially around agriculture, will also have positive ramifications for land use and biodiversity. Examples include new sustainable building materials and more sustainable food systems, the latter requiring advances in plant breeding, food products, and farming and cultivation techniques, as well as steps to optimize shelf-life and food distribution, and social initiatives such as the revival of traditional crops, food-sharing platforms and low-meat diets. The key is to actively test and adapt strategies for implementing economic models that are expected to result in improved biodiversity.

8.5. Step 5: Develop Monitoring Systems and an Evidence Base

Identification and use of appropriate indicators to monitor progress against goals defined in step 1 is essential; this can be used as a leverage point to start to move people away from GDP as the only economic indicator. More emphasis will be needed on biodiversity and sustainability measures. Impact evaluations (sensu Karousakis [181]) should be conducted to complement long-term monitoring schemes to provide a rational, data-based argument for how the bioeconomy and circular economy can improve biodiversity as well as human wellbeing and wealth, and to also flag where they do not. This will ideally include some case studies of where existing work delivers and some lessons from where it does not. Biodiversity indicator sets already identified to measure sustainability or SDGs [7,31,166] need to be adapted and built on, and further exploration made of the potential value of indices or aggregate indicators [182]. The value of existing global biodiversity data sources [173] should be reviewed to see which one may be of use. Data sharing will also be essential to help learning [87].

8.6. Working Together for the Long Term

Sustainability is “the biggest challenge ahead of us” [183] yet existing economic approaches have not succeeded in ensuring the protection of biodiversity and ecosystem services. Most of the current focus is on the bioeconomy and circular economy, yet neither model is well defined, consistently implemented or properly measured, and neither provides a clear pathway to sustainability. The proliferation of approaches has helped create a debate and develop the thinking, but ultimately it has led to confusion. A number of key terms are misused or “semantically hijacked”, suggesting it may be easier for resource users to greenwash their activities under the banner of an ill-defined economic concept.

If the world is to move towards economies that maintain and conserve ecosystems and the services they provide to humanity, then an improved economic vision needs to be created with a greater focus on biodiversity, social equity and justice and sustainability. This will only be achieved if key stakeholders come together and define together a vision

and how best to implement different approaches under a blue and green economy. More interaction between existing platforms, and more engagement of civil society, is essential. While international organizations could continue to play key convening roles, they must revise their governance mechanisms to be more inclusive.

Our five recommended next steps are short-term priorities, but for transformative change, where diverse societies actively work to regenerate nature, long-term engagement is also needed. Opportunities need to be created for a critical mass of innovators and adopters to help evolve proposed economic approaches to make them work for biodiversity and people. This will include formulating and rethinking the way the world thinks about economics and the role of nature across stakeholder groups, and across research and learning institutions. This will require broad and high-level commitments from governments, businesses and civil society.

Ultimately, only if the global community can come together to establish a more focused agenda for bioeconomy and circular economy, that puts species, ecosystems and the wellbeing of local people at the center, will we be able to ensure sustainability.

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