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Opinion

Economic Gain vs. Ecological Pain—Environmental Sustainability in Economies Based on Renewable Biological Resources

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Abstract: There are two main international strategies concerning how to ensure a sustainable environment: one is to develop a globally bio-based economy, or bioeconomy, to meet the increased demand of goods and products to maintain our well-being and to reduce climate change. On the other hand, there is an aim to decrease the negative impacts on nature and natural habitats to conserve and maintain ecosystems and control the loss of biodiversity. There is a trade-off between these two strategies; as we increase the commitment to the bioeconomy by intensifying biomass production, we will simultaneously challenge biodiversity through the increased pressure on, and the utilization of, biological raw materials. Here, we first review and discuss the challenges and opportunities in terrestrial and marine ecosystems for the production of biomass for the bioeconomy. We focus on the trade-offs between economic sustainability on one hand, and environmental sustainability and resilience on the other hand. We conclude with a discussion of the various bioeconomy strategies. Finally, we present a conceptual model on how to sustainably develop the bioeconomies (by introducing the concept of optimizing the economic gain/ecological pain ratio) to be able to manage the biodiversity in a sustainable way.

Keywords: bioeconomy; ecosystem services; environmental sustainability; biodiversity

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1. Introduction

The increasing awareness of the adverse effects of climate change is shifting policymakers' focus from fossil fuels to renewable biological resources, thereby developing bioeconomies [1–3]. A bioeconomy includes primary production and industries processing biological resources, such as food industry, fiber, pulp, and paper industries, and parts of the chemical, biotechnological, and energy industries converting biomass to bio-based products and bio-energy. The bioeconomy has been valued at €2 trillion in annual turnover in Europe alone, accounting for more than 22 million jobs [1]. The minimum estimate for the entire biosphere is estimated to be in the range of €15–€50 trillion (10^{12}) per year, with an average of €30 trillion per year [4].

Bioeconomy is based on provisioning the ecosystem services comprising nutrition, materials, and energy [1]. Bioeconomy also exploits cultural ecosystem services economically; for instance, the recreational, health, and tourism industries [5]. The tourism industry (e.g. eco-tourism, skiing, visiting national parks) represents a value of €6.5 trillion worldwide and 266 million jobs [6], in which, eco-tourism is the fastest growing.

In 2012, the European Commission Directorate developed a bioeconomy strategy, which was renewed and updated in 2018 [7,8]. The European Commission expects that a sustainable bioeconomy would strengthen the circular economy by turning bio-waste and residual products into valuable reusable products. The bioeconomy strategy aims to contribute to the fulfillment of the Paris Agreement of a carbon neutral future, building healthy ecosystems that are no longer polluted by plastic or artificial products, and the restoration of already degraded ecosystems [8]. The European bioeconomy strategy also aims at creating 1 million new jobs in 2030 and supporting the European industry to become more cost efficient and produce new and more sustainable bio-based products.

In the upgraded bioeconomy strategy, the EU has included five main objectives to fulfill, and the second objective is managing natural resources sustainably, which includes avoiding ecosystem degradations, and restoring and keeping ecosystem services. Still, the overall aim of the strategy is to: 1) strengthen and scale-up the bio-based sectors, 2) deploy local bioeconomies rapidly across Europe, and 3) understand the ecological boundaries of the bioeconomy [8].

The strong focus on scaling up bioeconomy and growth may require an intensified production of renewable resources. In its most extreme, intensification implies the extensive production of fast-growing biomass in monocultures that are intensively managed with artificial feed or fertilization and the use of alien or genetically modified organisms.

We claim that despite increased monitoring and the increased focus on restoring ecosystem services and biodiversity, a growing bioeconomy may pose a threat to biodiversity.

A further loss of biodiversity to the bioeconomy will be a challenge for regulating and supporting services, comprising the regulation of the local and global climate, CO^2 sequestration, the moderation of extreme weather events, the prevention of erosion, pollination, and the biological control of pests and diseases. Piotrowski et al. [9] has made an estimation that the bioeconomy will increase the demand of natural materials with 1–4% annually to 2050, which means that the use of materials in the bioeconomy will increase from 5–10% today to 20–30% in 2050.

The term "biodiversity," or biological diversity, has been widely used since the Convention on Biological Diversity in Rio (1992), when it was defined as: *The variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems as well as the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems* [10]. This means that biodiversity can be measured on highly divergent levels, such as diversity of genes, species, habitats, or ecosystem services. While biodiversity may have its own eigenvalue, it is still common to use a monetary value of ecosystem services to quantify the value of biodiversity; i.e. the economic value, the socio-cultural value, and the ecological value [11].

Our concern is that biodiversity conservation is driven by the economic and/or socio-cultural valuation, as they are most connected to ecosystem services, while the ecological value, often defined as an indicator that defines the threshold values required to maintain a healthy environment, is not included in the bioeconomy valuation.

Here, we first discuss the challenges and opportunities in terrestrial and marine ecosystems for the production of biomass, or other ecosystem services for the bioeconomy. Finally, we conclude with a conceptual model on how to sustainably manage the bioeconomies (optimize the economic gain/ecological pain ratio) to be able to also manage the biodiversity, defined as an ecological biodiversity value.

2. Biomass Production in Different Ecosystems

2.1. Global Biomass

Bioeconomies are based on biomass of different kinds, originating mainly from cultivated areas where we can control or intensify production, but also from areas that are not yet cultivated. In total, there are about 550 gigatons [12] of carbon (Gt C) biomass in all kingdoms of life—of which, terrestrial plants are the dominant biomass, with 450 Gt C [13]. Only 5 to 10 billion tons of C are found in the oceans [14]. Animals account for only approximately 2 Gt C and are mainly marine [13]. In ocean systems, the animal biomass is nearly 30 times larger than the plant biomass, and the total world fish biomass in the oceans is only between 0.8 and 2.0 billion tons [15]. However, being only a small part of the total biomass, the fish biomass is a globally important source of protein for animals and humans [15]. Livestock constitutes about 0.1 Gt C and accounts for 60% of terrestrial mammal biomass, and humans themselves comprise about 0.06 Gt C and account for 36% of mammal biomass. Wild mammals comprise only 0.007 Gt C and constitute 4.2% of mammal biomass [13]. In addition, there is live biomass from bacteria that may be as much as that of plants and animals [16].

2.2. Terrestrial Systems

2.2.1. Forest Production

Forests cover only 6% of the Earth (Figure 1), or 31% of the world's total land areas (about 93% natural forest and 7% cultivated), but account for 90% of the world's terrestrial biodiversity [17]. They are important biologically, economically, and climatically [17], and provide provisioning ecosystem services, such as clean water, food, and timber, in addition to regulation services, such as climate regulation, pollination, and the prevention of soil erosion. Globally, more than 1.6 billion people depend on forests for fuel, medicinal plants, and subsistence income [18]. Forests hold as much as 46 percent of the world's terrestrial carbon stores and provide billions of dollars in raw materials for timber, as well as products such as pharmaceuticals, paper, and building supplies. The forestry sector provides formal employment for approximately 14 million people worldwide, and many more are employed in industries related to forest and forest products [18]. The total value of forest ecosystem services is tremendous and not easy to estimate, as the reduction of greenhouse gas emissions alone is estimated to be worth €3.4 trillion [19], and regulating services, such as pollination alone, are estimated to have a value of €153 billion per year [9].

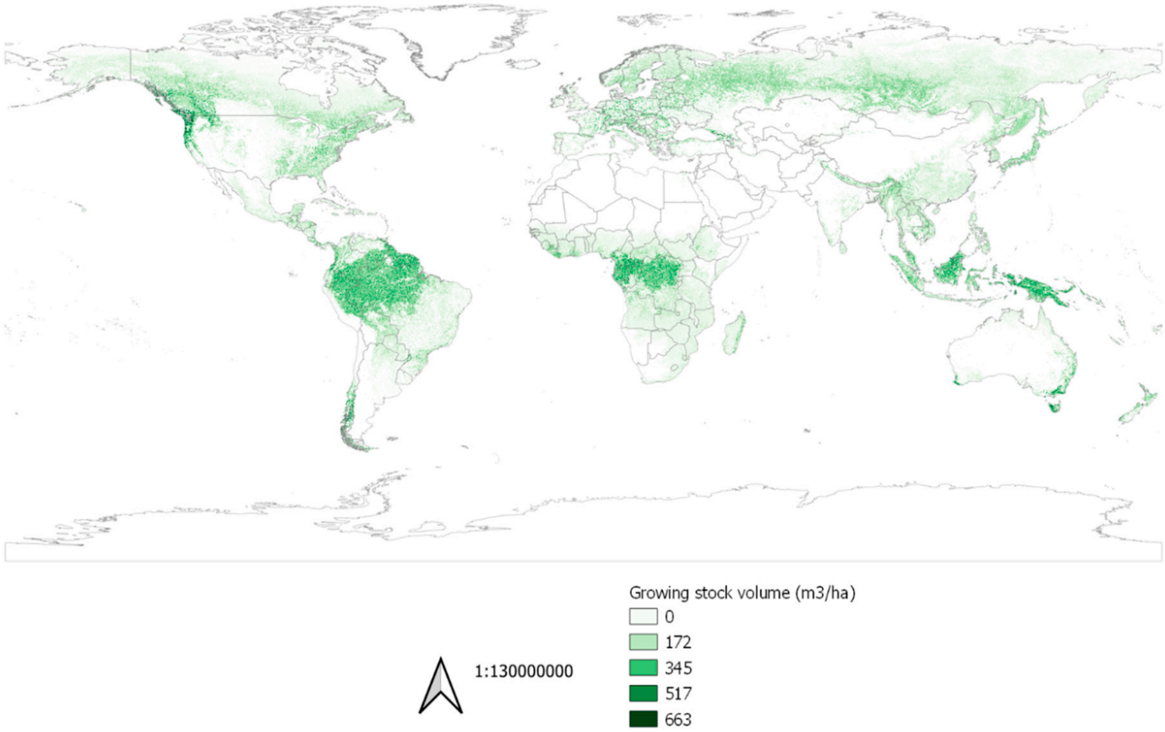

Figure 1. Worldwide biomass of forests reported as growing stock volume (m^3 per ha). Data from Santoro [20].

Wood biomass, such as timber and pulp, is the main industrial output from forests, and is renewable if managed sustainably [19]. An increased focus on the bioeconomy may increase the demand for wood biomass. Intensified forest management means planting monocultural stands of native or introduced trees, and the use of multiple silvicultural treatments, such as cleaning, thinning, and fertilization, with potential negative consequences for the ecosystem and biodiversity [21]. Wood production in the boreal forests of Europe is inversely related to forest biodiversity in a gradient of long (Sweden and Finland) to short (northwest Russia) forestry intensification histories [22]. Tropical countries especially have challenges with conserving forest sustainability, with a net forest loss of about 7.6 million hectares yearly in the period 2010 to 2015 [23].

2.2.2. Non-timber Forest Products

Non-timber forest products (NTFPs) are tangible animal and plant products—other than commercial timber and fiber production—that can be collected from the forest [24,25]. They comprise meat, leather, fur, nuts, spices, latex, fruits, vegetables, medicinal plants, honey, wood for handcrafting and tools, ornamental plants, and construction materials [26–28]. NTFPs are initially considered as minor or secondary forest products compared to wood production [28,29]. Their use is primarily seen as a local interest with little or no commercial value [30]. NTFPs are, however, the main source of the livelihoods of forest dwelling rural communities, who rely on these products for their food, wellbeing, income, and medicine [28]. About 80% of the developing world depends on the NTFPs for food, medicine, and health promoting needs [26]. In industrialized countries, NTFPs provide significant economic benefits to rural households [29]. In Europe and North America, the demand for medicinal plants has increased due to an increased consumer interest in natural products. Hence, although most of NTFPs are used locally as food and medicine, some of them go to international commercial markets [28].

In 1996, the value of the global market for all medicinal plants was €13 billion, with Europe contributing to half of the trade and Asia contributing to 36% of the market [29]. Other internationally traded NTFPs are natural rubber with a value of €3.9 billion per year, essential oils with a value of €294 million per year, cork with a value of €295 million per year, as well as honey, walnuts, mushrooms, rattan, and Brazil nuts [31]. In general, the larger the market for NTFPs, the higher their value and the more prone to overexploitation [30].

The continuous evaluation and monitoring of the ecological impact of NTFP harvesting may increase sustainable utilization [32]. Increased food production can be effective in reducing the dependence on forest foods from rural households. For example, the introduction of sweet potatoes and manioc in Vanuatu Island reduced the utilization of wild taro, arrowroot, wild yams, and sago [33]. The cultivation of wild plant species of NTFPs with high commercial demand and social value is suggested as a way to reduce the pressure on natural forests [34].

Many wild large herbivore populations have increased dramatically across Europe and North America over the last decennia [35,36]. Wild meat is also a major source of protein and income in the tropics [37], in addition to being a potential substitute for the conventional livestock meat production [38]. Furthermore, the illegal harvesting, trade, overhunting, and poaching of wildlife is potentially causing the local extinction of species worldwide, and the trade of NTFPs is an increasing threat towards biodiversity [39,40].

2.2.3. Crops Production

Today, we use 11% of the globe's land surface (13.4 billion ha) for crop production (Figure 2). This is typical arable land and land under permanent crops. Still, this is only 1/3 of the available land estimated suitable for crop production [41]. Hence, there seems to be scope for the expansion of agricultural land, and crop production is projected to increase until 2030 at 1.4 percent per year. Most of this potential cropland is found in sub-Saharan Africa and Latin America, with some in East Asia, but it may not be used due to a lack of infrastructure or because it is located in conservation areas under forest cover or in wetlands [41]. Areas such as grasslands or other natural areas have traditionally been converted into agricultural areas to meet the increased demand of crop or food production. This change in land use from grasslands to croplands has a negative impact on biodiversity and soil composition, and is not an optimal option for sustainable food production [42].

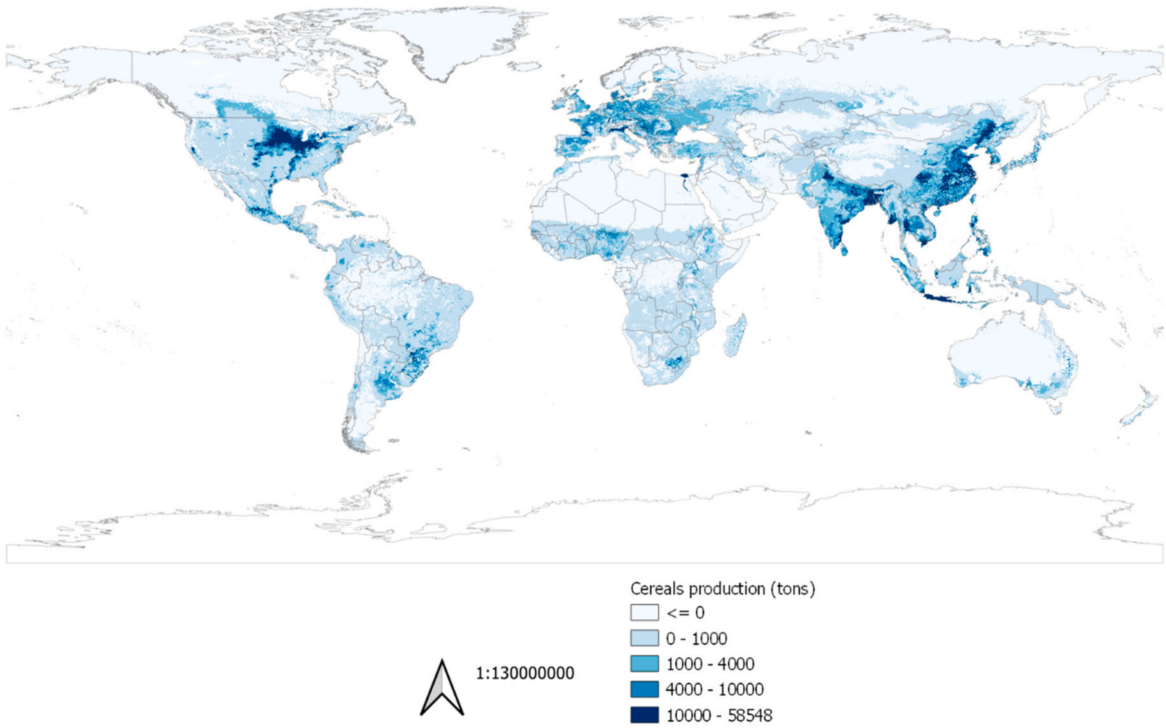

Figure 2. Worldwide biomass of cereal crops (barley, buckwheat, canaryseed, fonio, maize, millet, oats, quinoa, rice, rye, sorghum, triticale, and wheat) (tons per 100 km^2). Data from Monfreda et al. [43].

The potential increase in crop production is also challenged by climate change [44]. Global warming will be more adverse in tropical areas than in temperate areas. The Northern hemisphere is expected to increase crop production due to global warming, while a number of countries in the Southern hemisphere are likely to be negatively affected [45], particularly in sub-Saharan Africa and Southern Europe [46,47]. In the Southern hemisphere, extreme climatic events started in the 1990s and they will increase in frequency and severity [48–50] with the loss of crops, livestock, homes, food stores, and livelihoods.

Food production also has a large environmental impact, being the main source of nitrate pollution, ammonia pollution, and a major contributor to the phosphate pollution of waterways [51]. Food production also affects climate change by releasing methane and nitrous oxide into the atmosphere [52].

2.2.4. Livestock Production

Livestock production represents the largest of all anthropogenic land uses, covering 30% of the world's total land area, accounting for 70 percent of all agricultural land [53] (Figure 3). It provides livelihood for 1 billion people in rural areas [54]. Conventional meat production has increased between 40% and 60% over the last 40 years [55] and it is expected to continue to rise slowly in developed countries (0.2 percent per year) and fast in developing countries (1.6 percent per year) [56], yielding a 70% increase in livestock products by 2050 due to the increase in human population and increased consumption [53].

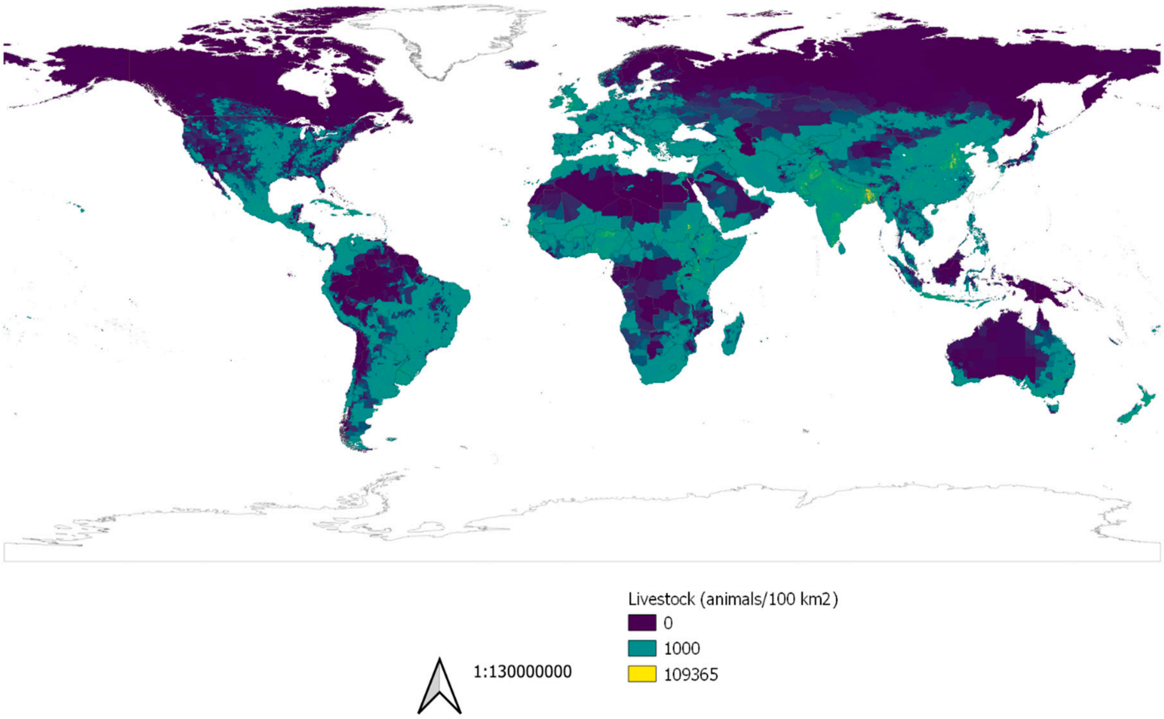

Figure 3. Worldwide biomass of livestock (cattle, sheep, horse, goats) (individuals per 100 km^2). Data from Gilbert et al. [57–60].

However, livestock farming is considered among the least efficient ways to produce edible proteins [61], possibly with the exception of areas of low primary productivity, where grazing may be the only way of producing proteins. The subsequent creation of monocultures can facilitate the spread of pathogens, pests, and disease, in addition to increased greenhouse gas emissions, water usage, and land use [62].

Thus, overgrazing, deforestation, water pollution, and soil erosion challenge biodiversity, especially in the arid parts of the world [63]. The environmental impacts of livestock production and consumption has not been fully addressed [64]. There is a need for an increased focus on nutrient recycling from large-scale meat production facilities, animal welfare, and preventive measures against animal diseases and the use of medication [65].

There are also positive impacts of livestock; for instance, as a protection for biodiversity, especially by maintaining valuable habitats [66], as free ranging livestock contributes to the maintenance of grasslands and landscaping [67].

2.3. Marine and Freshwater Systems

2.3.1. Marine Production

Water covers 70% of the world's surface, and marine ecosystems provide a wide range of invaluable ecosystem services, including global climate regulation, nutrient cycling, and the provision of food [68,69]. Coastal waters sustain approximately 90% of the annual marine fishing efforts. Globally, 86.6 million tons of fish are captured, either for direct human consumption or indirectly by the production of fishmeal for aquaculture, with a total value of €91 billion [70] (Figure 4).

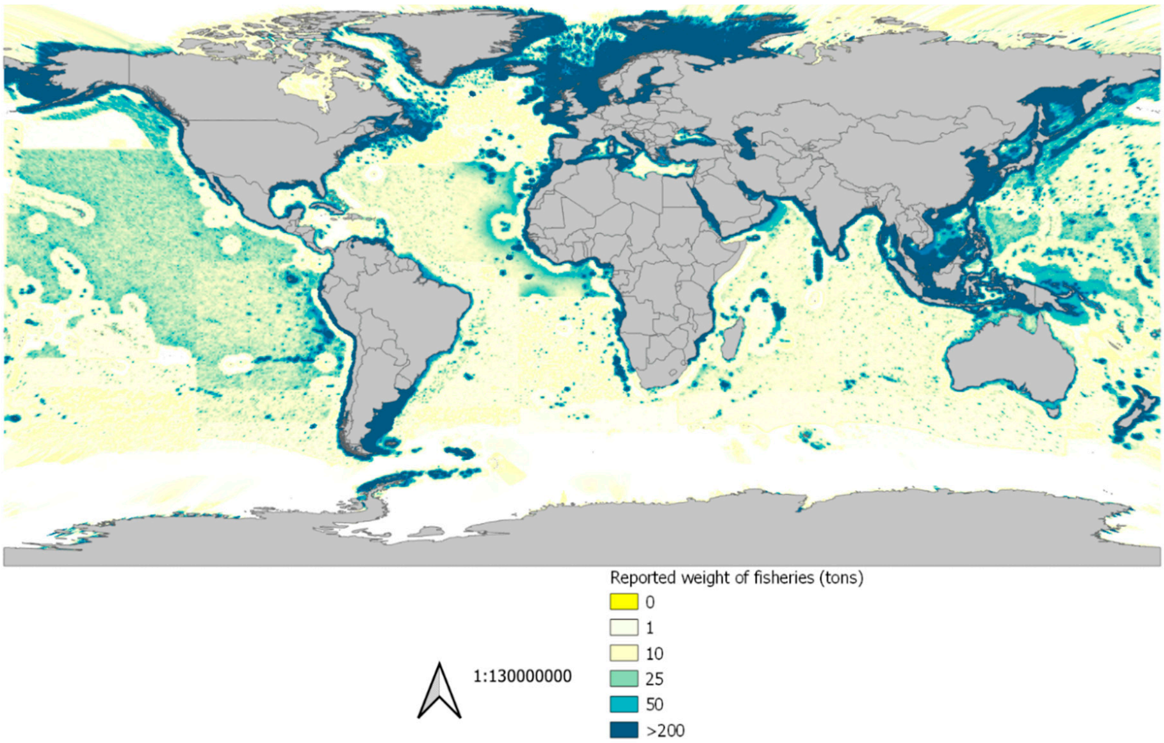

Figure 4. Worldwide reported catches of marine fisheries (tons per 100 km^2). Data from Watson [71].

Currently, over 80% of the available fish stocks are exploited maximally or are already subject to over-exploitation, and the proportion is increasing [70,72]. An increase in the amount of marine catches is, therefore, not in concurrence with the preservation of biodiversity unless there is a shift in the management of the marine fisheries [73]. These marine systems are under severe pressure from anthropogenic influencers, which has resulted in a severe decrease and degradation of marine habitats [69,74]. Coupled with climate change and the persistent over-exploitation of fish stocks, the situation with the marine system and biota is dire [75,76].

2.3.2. Freshwater Production

Only about 3% of the water in the world is freshwater and 0.02% of the freshwater is found in streams and lakes [77]. Freshwater generates essential ecosystem services, such as drinking water, water for domestic, agricultural, and industrial use, hydroelectricity, food, medicines, recreational activities (e.g. sport fishing), tourism, and public health measures [78]. Freshwater fish constitutes over 2% of animal protein consumed by humans. In addition, it provides jobs and income (i.e. export) for several million people, particularly in developing countries [79].

The reservoirs of fresh water (e.g. ground water and surface water) are dependent on replenishment from the water cycle. However, here, we experience a long array of challenges.

The human use of freshwater today exceeds the rate of replenishment. The world's clean water is decreasing at an accelerating pace due to a combination of increased evaporation and lower precipitation [80], coupled with an accelerated degree of pollution [81]. Climate change is increasingly affecting weather patterns around the world, causing droughts in some regions and floods in others [71,82]. Clean freshwater is a necessity for humans; however, an increasing percentage of humans are lacking a steady supply of clean water, and it is expected that two-thirds of the world's population will experience water shortages within 2025 [83].

The use of hydropower (15% of today's world electricity) is renewable and climate friendly [84]. However, it can largely affect the local environment through the alteration of the water quality and temperature and changes in aquatic and terrestrial habitats, and contributes to habitat fragmentation (physical barrier; hindering the upstream and/or downstream migration of aquatic organisms) [84].

2.3.3. Aquaculture Production

Aquaculture production (both marine and freshwater) produced over 59 million tons of food products in 2010, with a total value of €110 billion, and the production is continuing to increase [71]. Current aquaculture may have an adverse effect on the natural fish populations due to the high demand for fish from natural populations as aquaculture feed [85,86]. Approximately 40% of the current aquaculture production is dependent on fish feed from marine ecosystems [71]. If aquaculture production is to be increased, this will give an added pressure on the already fully exploited natural fish stocks through the increased catching of fish to feed farmed fish [85]. In addition, aquaculture poses several ecological risks; e.g. pollution from the farms, the spread of parasites, diseases, and invasive species, escaped farmed fish that negatively affect the genetic composition of native stocks and cascading effects through the decimation of small prey fish stocks for fish feed, and reducing prey availability for predatory marine animals and sea birds [71,86]. However, there are several promising adaptations towards making aquaculture more economically and ecologically sustainable, including land-based farming [87], utilizing fish manure as field fertilizer [88], aquaponics [89], producing fish feed from wood by-products, and lice-free net pens [90].

3. Bioeconomy Strategies and the Economic Gain and Ecological Pain Model

Through evolutionary time, there have been five mass extinctions, with a loss of 75% of the Earth's species within 2 million years. With the current trend of species losses over the past few centuries and millennia, biologists now assume that a sixth mass extinction may be underway [91]. The current extinction rate is 100–5000 times higher than the natural extinction rate. There is strong evidence that the approaching mass extinction is directly driven by human activity, such as habitat destruction and fragmentation, due to land use change, direct exploitation, the introduction of alien species, the spreading of pathogens, and the discharge of environmental poisons or climatic gasses [92,93].

3.1. Bioeconomy Strategies

A refined bioeconomy is one of the solutions to halt climate change and CO^2 emissions, and the development of bioeconomy strategies are important in the process of establishing a more sustainable society. However, there is a paradox that high bioeconomical growth may feedback on the exploitation of biodiversity. This will happen as long as a sustainable bioeconomy is not based on a sustainable harvest of bio-based raw materials [9]. Today, ecosystem diversity and species diversity is challenged because there is virtually no systematic monitoring of the biomass access and market demand in the high growing bioeconomy. The UN's Nature Panel stresses how markets and socioeconomical factors, such as values, income, technology, and power, are drivers of the exploitation of nature [94]. This challenge is by no means solved in the various bioeconomy strategies.

In 2016, the 2030 Agenda for Sustainable Development uniformly defined 17 sustainability development goals (SDG) to strengthen universal peace and increase human rights, fighting hunger, poverty, and inequalities to build a sustainable future for mankind. The 17 goals deal with sustainability in all three dimensions—economic, social, and environmental—and two of the 17 goals deal directly with biodiversity and ecosystems (SDG 14 and SDG 15). This means that an economy can be defined as sustainable when the economy targets one or several of the UN SDGs, such as poverty, inequalities, or other SDGs. This is certainly a good way of bringing economy and sustainability together as a tool for building a sustainable future, but there is also a challenge when definitions such as sustainable bioeconomy are understood as a bioeconomy that is highly based on SDG 14 and/or SDG 15. Both globally and in Europe, we see that countries show large differences in which sectors they include in the definition of bioeconomy, and, thus, their bioeconomy strategies will differ greatly in how they define their sustainable bioeconomy [95]. For instance, in Argentina, bioeconomy is seen as a tool for sustainable development in the country, focusing on halting climate change (SDG 13) and supporting a continued economic progress to reduce poverty (SDG 1) [96]. In Germany, the national bioeconomy strategy prioritizes a secure supply of high-quality food (SDG 3), the transition from a fossil-based economy to an economy based on renewable resources while conserving biodiversity and soil fertility, and strengthening innovative power and international competitiveness in business and research (SDG 6, 7, and 9) [96]. In Malaysia, bioeconomy is seen as a key contributor to economic growth, which can provide benefits to society via breakthroughs in agricultural productivity, innovations in healthcare, and the adoption of sustainable industrial processes (SDG 3, 9, and 15) [96]. Hence, if bioeconomy is meant to be a contribution to sustainable development in future biodiversity and ecosystems, we need a common definition of the concept to ensure that bioeconomy really contributes to the whole sustainability concept: social sustainability, economic sustainability, and environmental sustainability [95,97,98]. There may be a need to include a new dimension to the concept of environmental sustainability that emphasizes biodiversity or ecological sustainability.

The European bioeconomy strategy has included monitoring and sustainability as an objective in their aims [8], but whenever a monitoring program reveals biodiversity loss, we are already too late for biodiversity conservation. We see this in the blue bioeconomy, which is already an important economic factor in most countries with a coastal line; however, hardly any of them have a monitoring system for the marine ecosystems or marine biodiversity [99].

Secondly, there is no agreement of the level that biodiversity should be defined at in the bioeconomy strategies. Should there be a focus on genes, species, or ecosystems? Bioeconomy strategies often define sustainability in association with ecosystem services, but if we value biodiversity through ecosystem services, these services are already defined as those benefitting human needs, and not services that are purely for the conservation of biodiversity.

We see equal challenges when it comes to marine ecosystems. Bioeconomy based on marine products is crucial for food production, feed, and energy, and we also see an increased effort to increase the innovation and development of the blue bioeconomy. However, marine environments are extremely vulnerable and, in spite of an increased effort to protect marine biodiversity, there is a challenge in fighting overharvest, illegal fishing, and pollution, among other threats [75,76].

3.2. The Economic Gain and Ecological Pain Model

We have to develop a bioeconomy where we produce biomass, the raw material for bioeconomy, with proper long-term sustainable management for safeguarding biodiversity in well-functioning and resilient ecosystems.

The long-term sustainability of utilizing biological resources requires that we plan our bioeconomies in relation to biodiversity targets and biodiversity levels that maintain well-functioning ecosystems.

The utilization of renewable biological resources as the basis for a bioeconomy must be managed in relation to the environmental impact—not only on short-term financial perspectives. We need to build optimization models where land use is defined based on what is economically and ecologically optimal (Figure 5). If we focus on the terrestrial system, it is evident from Figures 3 and 4 and Hansen et al. [100] that crop and livestock production, as well as deforestation through forestry, are impacting biodiversity on an unimaginatively large scale [100,101]. As one increases from a low intensity production of crops, livestock, and forestry, there is a steady gain in economic benefit and a limited impact on biodiversity. Thus, the total economic gain/environmental pain ratio increases (Figure 5). However, as we intensify production or harvest, the environmental pain starts to become unbearable and too high to be counteracted by the economic gain. Thus, the ratio reaches its optimum and starts to decrease. The entire figure can be shifted to the right or left along the x-axis, depending on cultural, social, or emotional factors of decisionmakers or society at large. However, irrespective of having an ecocentric or anthropocentric world view—at some point of extreme utilization of livestock, crops, or forestry—the economic gain would decrease because of large scale challenges due to intensive production. This is exemplified to some degree with the current (April 2020) COVID-19 pandemic, as well as swine flu, antibiotic resistance (for livestock), pesticide resistance (for crops), floods, and erosion (for forestry).

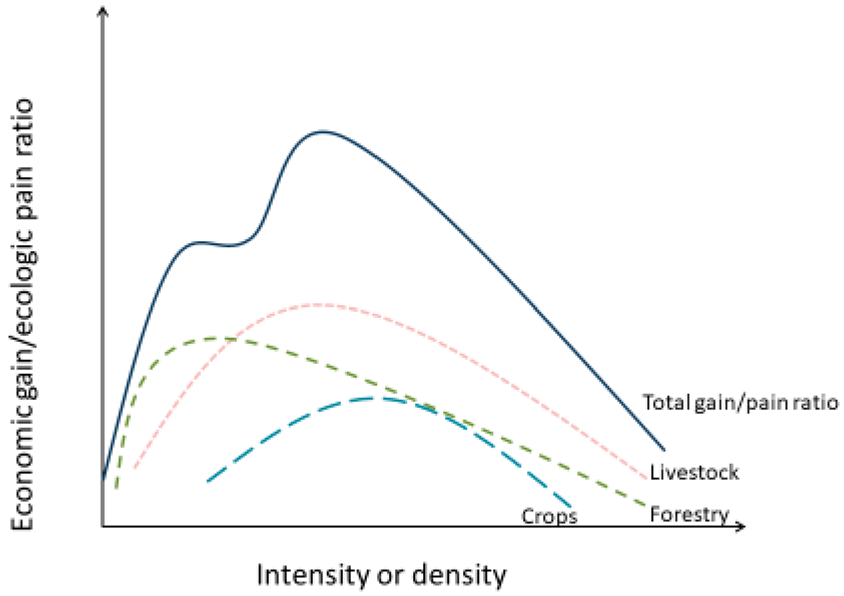

Figure 5. Schematic figure illustrates the optimization of economy and ecology in a multipurpose landscape, exemplified though livestock, forestry, and crop production (dotted lines, note: lines do not represent true values; they are only for illustration purposes). As production intensity increases from zero, the economic gain increases faster compared to the ecological cost or pain. However, as ecosystems are pushed towards more intensive or extensive production, the ecological pain—e.g. loss of biodiversity—increases, the gain/pain ratio reaches its maximum level and starts to decrease as ecological pain continues to increase. Identifying the economic gain/ecological pain optimum is crucial in the developing bioeconomies.

In a large-scale landscape consisting of a mosaic of crops, livestock, and forest, we should aim to identify the optimum intensity of production that maximizes the economic gain/ecological pain ratio. Crops, livestock, and forestry are just example biomasses, but this concept can be applied to all landscapes where one utilizes some resource that could potentially harm biodiversity.

Intensified land use required by bioeconomies will change the landscape with unknown consequences for biodiversity, ecosystem functioning, and the multitude of ecosystem services. Thus, we might have to move from thinking about the intensification of land use to the optimization of land use—i.e. the optimal livestock/wildlife/crop density and distribution in the landscape in order to maximize the economic gain and minimize the ecological pain (i.e. biodiversity loss) (Figure 5).

We can further develop the production in the optimization model by increasing the ability of an ecosystem to produce biomass. We can manage the ecosystem to increase production for human needs by using technology (e.g. fertilization, genetically modified crops, pesticides, aquaponics, companion planting, and forestry scarification). As we intensify the production, we need a continuous development of knowledge and technology to maintain environmental sustainability. This is a risky technology-driven ecosystem where intensification increases the risk of passing a threshold where the technological development surpasses the ecological system so that the ecological system is no longer resilient and collapses.

We expect that the economies based on biological resources will have an optimum at a somewhat intermediate intensification, as technological demands will increase the cost at high intensification (Figure 5). The social acceptance of intensification will probably also be at a somewhat intermediate level, while health issues (except hunger) may be optimal at lower levels of intensification. However, social acceptance may continuously push towards increased production, as long as the system does not collapse (Figure 5). Furthermore, society's perception of "intermediate" will change, and the "high" intensification of today will be the "intermediate" of tomorrow, following the Shifting Baseline Syndrome [102].

The challenge is how individual countries or continents could operationalize the gain/pain concept. There is, unfortunately, a time lag from the current economic gain to the future ecological pain it causes, meaning that elected politicians do not want to make the tough decisions needed for the future. The problem with this time lag is beautifully and dramatically illustrated by the reluctancy of world leaders to make tough decisions to decrease climate gas emissions for our future benefit, while the current (April 2020) COVID-19 pandemic causes the same leaders to take extreme measures to fight a current problem (i.e. closing down universities, schools, shops, regions, and nations).

We fear that sustainability discussions risk being just that—discussions—and that they do not lead to concrete guidelines and tools to determine the optimal intensity production in a landscape. However, the increased focus on the bioeconomy also being ecologically sustainable [8] gives us hope for tools to use on the ground.

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