Bioprocesses and Sustainability

Revista Brasileira de Ciências Ambientais
Brazilian Journal of Environmental Sciences

Bioprocesses and biotechnologies for reducing the impacts of climate change and socio-environmental disputes

Bioprocessos e biotecnologias para a redução dos impactos das mudanças climáticas e de litígios socioambientais

Talissa Truccolo Reato[1], *Paulo Hartmann*[1]

ABSTRACT

The environment is a constant nucleus of conflicting interests. The environmental conservation, in general, tends to conflict with economic and, often, political interests, generating socio-environmental disputes. Climate change is related to the precariousness of accountability and the insistence on dependence on fossil resources. With the advancement of science and technology, bioprocesses and biotechnologies can act as important mechanisms for ensuring sustainability, avoiding socio-environmental disputes and also helping mitigate climate emergencies. Thus, technologies such as bioenergy, biofuels, bioremediation, and carbon sequestration are important strategies that can help reverse the global scenario of widespread environmental degradation and the potential social collapse. Hence, this study discusses how bioprocesses and biotechnologies can act to avoid socio-environmental disputes and help mitigate climate emergencies. The study is a literature review that carried out using the hypothetical-deductive, bibliographic method, which studies variables and operational concepts regarding climate change, as well as socio-environmental disputes (with examples involving multinationals), bioprocesses, biotechnologies, responsibility, social relations, sustainability, globalization, fossil resources, the Earth's biophysical limits, among other expressions. As result and conclusion, if investments were channeled into bioprocesses and biotechnologies and not into fossil resources, the dynamics between the environmental, social, and economic dimensions of sustainability would be better balanced, avoiding socio-environmental disputes. However, political and economic willingness is needed, as well as alignment between governments, society, and companies.

Keywords: environmental science; climate emergencies; planetary limits; sustainability; technology.

RESUMO

O meio ambiente é um constante núcleo de interesses conflitantes. A sua conservação, em geral, tende a se contrapor aos interesses econômicos e muitas vezes políticos, gerando litígios socioambientais. As mudanças climáticas, por sua vez, relacionam-se com a precarização da responsabilização e com a insistência na dependência de recursos fósseis. Com o avanço da ciência e da tecnologia, os bioprocessos e biotecnologias podem atuar como importantes mecanismos para garantir a sustentabilidade, evitar litígios socioambientais e também auxiliar na mitigação das emergências climáticas. Assim, tecnologias como bioenergia, biocombustíveis, biorremediação e sequestro de carbono são importantes estratégias que podem colaborar para a reversão do cenário global de ampla degradação ambiental e potencial colapso social. Isto posto, este estudo discute como os bioprocessos e biotecnologias podem atuar para evitar litígios socioambientais e auxiliar na mitigação das emergências climáticas. Trata-se de uma revisão de literatura realizada pelo método hipotético-dedutivo, bibliográfico, que estuda variáveis e conceitos operacionais acerca das mudanças climáticas, bem como de litígios socioambientais (com exemplos envolvendo multinacionais), de bioprocessos, biotecnologias, responsabilidade, relações sociais, sustentabilidade, globalização, recursos fósseis, dos limites biofísicos da Terra, entre outras expressões. Como resultado e conclusão, se investimentos fossem canalizados para bioprocessos e biotecnologias, e não para recursos fósseis, a dinâmica entre as dimensões ambiental, social e econômica da sustentabilidade seria mais bem balanceada, evitando litígios socioambientais. Todavia, é preciso disposição política e econômica, além de alinhamento entre governos, sociedade e empresas.

Palavras-chave: ciência ambiental; emergências climáticas; limites planetários; sustentabilidade; tecnologia.

[1]Federal University of Fronteira Sul – Erechim (RS), Brazil.

Correspondence author: Talissa Truccolo Reato – Pedro Pinto de Souza Avenue, 683 – CEP: 99700-097 – Erechim (RS), Brazil. E-mail: talissareato@gmail.com

Conflicts of interest: the authors declare no conflicts of interest.

Funding: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Process nº 88887.820013/2023-00.

Received on: 01/24/2024. Accepted on: 04/14/2024.

https://doi.org/10.5327/Z2176-94781935

Introduction

The increase of the socio-environmental disputes, especially involving fossil fuels, reflects the destabilization of the dynamics of natural systems on a planetary level, which manifests itself in an increasingly intense way in climate change. Added to this, the complexity of social relationships (among society, companies, and governments) requires catalytic approaches to sustainability. Therefore, bioprocesses and biotechnologies, such as bioenergy from renewable raw materials, bioremediation of pollutants, and carbon sequestration, come as conditions for the possibility of mitigating environmental problems based on the range of investments in science and appropriate technologies.

In this sense, bioprocesses are the backbone of biotechnology, as it is a field that studies microorganisms, enzymes, and nutrients, largely linked to products of renewable origin (LNBR, 2023). Bioprocesses and biotechnology are closely associated, in such a way that the second article of the Biodiversity Convention (Brasil, 1998b) indicates that biotechnology means "any technological application that uses biological systems, living organisms, or their derivatives, to manufacture or modify products or processes for specific use".

This study aimed to discuss how bioprocesses and biotechnologies can act to avoid socio-environmental disputes and help mitigate climate emergencies. To this end, issues involving socio-environmental responsibility were addressed, as well as political and economic disposition, breadth of knowledge and scientific culture, respect for national and supranational legislation, duty of care, among other related topics.

The study is based on a review of current knowledge, of a theoretical and interdisciplinary nature, with a focus on the discussion on how bioprocesses and biotechnologies can be tools for reducing climate change and socio-environmental disputes. To prepare the article, a bibliographical search was carried out using online search tools, notably "Google Scholar", "Web of Science", and "Scopus". The keywords bioprocesses, biotechnology, environmental law, climate emergencies, planetary limits, socio-environmental disputes, and sustainability were used, individually or in different compositions, in Portuguese and English, with national and international articles, books, and book chapters being found. The search for dissertations and theses was carried out using the Brazilian Digital Library of Theses and Dissertations (BDTD-IBICT). In the case of articles originating from theses and dissertations, only the articles were considered so that there would be no duplication of work.

The time frame for the search for texts was established between the years 2000 and 2023. In addition to the texts found, some classic references were used, even if they came from periods before that established for searching for texts, especially for the purpose of extracting traditional concepts, which are perpetuated and established as usual in environmental sciences and environmental law. The works found were analyzed and selected using the criteria of thematic relevance, timeliness, and epistemological relevance. Afterward, the listed material was recorded in files shared between the authors. Finally, once the works consulted were organized and analyzed, the writing phase began, aiming to bring together the authors' investigations and discussions, building ideas to form research with relevant themes that dialogue with each other.

In terms of textual structure, based on the objective, the text contains the following reasoning: it begins by discussing the context of socio-environmental conflicts and disputes arising from the inappropriate use of natural resources, most notably those that generate climate change. Next, the limits of the impacts of human actions for the maintenance of ecological systems and human societies are addressed. Finally, it analyzes how bioprocesses and biotechnologies can provide mechanisms capable of eliminating dependence on fossil resources.

Social and environmental conflicts and disputes: the dispute over the use of natural resources

Socio-environmental conflicts are related to different discourses about values and meanings that social actors attribute to natural resources in a given context (Moro et al., 2023). Therefore, they emerge as expressions of tensions in the process of reproducing development models and consider aspects of history, time, as well as the context, identification, and interests of the social actors involved. Historicity is related to the development process, industry, capitalism, and the search for profit. Temporality relates to the context and moment in which adversity emerges: the political, economic, cultural, and ecological scenario in which the dispute takes place (Gonçalves et al., 2019).

Socio-environmental conflict is a reality that is related to the breadth of the scope of environmental exploitation (Assis and Kato, 2022) and is close to socio-environmental litigation in that it represents the legal term for adversities involving issues that affect both the environment and the human communities. Thus, Little (2001) conceptualizes socio-environmental conflict as a dispute among social groups (human dimension) that derives from the relationship they maintain with the environment (natural dimension). It should be noted, in this sense, that anthropogenic impacts on the environment derive from countless decision-making, as well as the absence of ecological ethics in various political and economic relationships (Morais and de Freitas, 2023).

Among today's socio-environmental conflicts, some can be highlighted due to the potential for environmental impacts and disrespect for human rights: the Belo Monte Hydroelectric Project, in Brazil, which has already impacted extensive areas of forest; contamination caused by oil in the Niger Delta, Nigeria; toxic mineral leaks in Minas Gerais, Brazil; the coal mines that destroy sacred places in South Africa; deforestation, impact on productive areas, and local water sources for the installation of wind turbines in India, among others (IHU, 2016).

According to the 2023 Climate Litigation Bulletin in Brazil, the main sector contributing to greenhouse gas (GHG) emissions is land

use change and forests, followed by energy, agriculture, industrial processes, and waste. Furthermore, on the defendant side of legal actions, federative entities appear as the most sought-after actors, followed by companies (JUMA, 2023). In the case of companies, the conduct of business and the way in which resources are managed are factors that define their performance as agents that cause degradation or conservation of natural resources. Therefore, due to their management models, large companies in the energy sector frequently become involved in socio-environmental disputes.

It is important to emphasize that this perception is relatively recent. The global milestone for concern about environmental impacts was the publication of the work *Silent Spring*, in 1962, written by Rachel Carson. In the book, the author denounces the contamination of the environment due to the use of pesticides in agriculture. With this manifesto, many companies, due to the socio-environmental impacts generated, began to be held responsible for the use of resources, especially from the second half of the 20th century onwards (Dias, 2022).

Frictions arising from the way resources are used tend to provoke socio-environmental disputes. In this sense, although many companies, especially those that operate at a multinational level, are sources of investment and jobs, they can cause negative impacts by promoting environmental degradation and conflicts with local communities. Unsustainable exploitation and excessive extraction of natural resources, especially by the companies in question, are problems that lead to socio-environmental degradation.

Many companies have adapted to new times, investing in socio-environmental themes, as well as in sustainable practices, promoting dialogue with stakeholders, and improving transparency (Silva et al., 2023). However, it turns out that several of them still wildly and selfishly seek profit at any cost, sacrificing natural resources, devaluing life, including human life (Dias, 2022). The obsession with maximizing profit, in general, is accompanied by a lack of ethical balance and also of socio-environmental responsibility.

One of the examples that can be highlighted is the company ExxonMobil, accused of committing misleading practices against investors and consumers in Massachusetts (USA), by not disclosing the risks of climate change (Mass.gov, 2019). In 2019, the Massachusetts Attorney General sued ExxonMobil Corporation, which is the largest publicly traded oil and gas company in the world, for misleading advertising to consumers and for misleading investors about the business risks posed by fossil fuels to changes in the Earth's climate (Mass.gov, 2019).

In the lawsuit, the allegation is that the company violated state law protecting consumers and related investors, as it systematically and intentionally deceived about the dangers to the climate balance caused by its business, as well as defrauded consumers about the central role their fossil fuel products play in climate change (Mass.gov, 2019).

Another company in the fossil fuel sector that stands out when addressing socio-environmental disputes is Shell. The environmental group Milieudefensie, Friends of the Earth Netherlands, as well as several non-governmental organizations and more than 17,000 citizens promoted climate litigation against Royal Dutch Shell alleging that its contributions to climate change violated the duty of care (provided for in legislation Dutch) and international law regulations that regulate obligations arising from human rights violations (Wedy, 2021).

In this case, the Dutch Court ordered the company's unit in the country to cut its carbon dioxide emissions by 45% by the year 2030, in relation to 2019 levels. This is, therefore, a paradigmatic decision, given that the Judiciary has ordered a large corporation to comply with the Paris Agreement, based on global standards. Shell, in 2022, appealed the decision, which is awaiting judgment (Climate Case Chart, 2021).

When addressing the topic of sustainability, although it is multidimensional, one cannot fail to emphasize the classic "triple bottom line", which is constantly remembered, that is, in order to move toward sustainability, it is necessary to bring together social, environmental, and economic spheres.

Another case involving Shell, specifically the Shell Petroleum Development Company of Nigeria, together with the Italian company Eni, through its subsidiary Nigerian Agip Oil Company, was held responsible for the pollution caused by oil extraction in the state of Bayelsa, Nigeria, in the report of the Bayelsa State Petroleum and Environmental Commission. In short, the chemicals present in a sample of groundwater were found to be more than a million times above the safe limits. These toxic contaminants cause burns, lung problems, and the risk of cancer (Neomundo, 2023).

In studies on sustainability, it is clear that in the face of various environmental disputes, in the sense of legal actions related to pollution and violation of environmental standards, such as those exemplified, there is a commitment to holding degraders responsible and establishing precedents and jurisprudential theses to curb new adversities. The conflicts in question are related to climate change and the need to decarbonize the global energy matrix, which is increasingly urgent.

In this line of reasoning, according to Araújo et al. (2020), considering that the promotion of sustainability is at the heart of the objectives of the United Nations, so that this perspective can be realized, especially with regard to decarbonization and adoption of sustainable practices, it is essential to increase scientific culture and promote public participation in science and technology, bringing populations into the development of diagnoses in favor of behavioral changes.

Limits and limitations on the use of natural resources

There is, increasingly, a perception that modifications of anthropogenic origin in natural environments can induce abrupt changes in a variety of components of the Earth, considered as an integrated and interdependent system (Brovkin et al., 2021). Ingo Sarlet et al. (2023) add that many scientists use the expression "planetary limits" in order to identify the main biophysical processes on the Earth, in

which the capacity for self-regulation and resilience are compromised (or almost compromised), putting irreversible processes at risk if the aforementioned limits (tipping points) are exceeded. Therefore, it is necessary to quickly correct errors, acting in a systemic way, as we are approaching "breaking points", largely due to climate change and the degradation of ecosystem functions (Lenton, 2020), both on a regional and global scale.

In this sense, global climate change has occurred at an accelerated rate and is largely driven by the anthropogenic burning of fossil fuels and the increase in atmospheric concentrations of GHGs. Therefore, if we exceed this breaking point, the possibility of the system recovering tends to be reduced, that is, the system loses its resilience capacity, with a potential collapse of its functioning (Flores et al., 2024). This transition from the current state to a point of no return can be rapid, such as the loss of a forest's ecosystem functions, or take longer, such as the loss of ice sheets (Ritchie et al., 2021).

The current environmental situation is already triggering one of the deepest and most threatening global crises for ensuring a habitable planet (Graham, 2023). The current global context requires that new metrics be found, especially with the capacity to encourage decarbonization and the energy transition. This requires a profound change in the logic of continuous economic growth, which transcends individual and organizational desires, since a profound change in the social, political, and economic reality in relation to the priorities we have as a society is prudent (Shiva, 2020; March, 2023).

Planetary boundaries are described in categories of environmental adversities, the first of which is climate change, followed by ocean acidification, depletion of the ozone layer, atmospheric aerosol load, interference in the global phosphorus and nitrogen cycles, rate of biodiversity loss, global use of freshwater, change in the soil system, and, finally, chemical pollution (Richardson et al., 2023; Sarlet et al., 2023). These environmental disturbances are not separate issues, although it is common to approach them as isolated issues. There are nonlinear interactions among them and aggregate effects resulting from the general state of the global system. It turns out that several regional climatic points, relevant for the stabilization of the global system, have already been or are close to being transgressed, weakening the global resilience capacity (Richardson et al., 2023).

According to Steffen et al. (2015), although the integrity limits of the biosphere provide a restriction on the amount and pattern of system change in all biomes on the Earth (forests, woodlands, etc.), the frontier of changing it is more directed toward a specific threat: the biogeophysical processes in the systems that directly regulate the climate (exchange of energy, water, and momentum between the Earth's surface and atmosphere).

Thus, analyzing the various interactions between the limits, it is observed that two of them, climate change and the integrity of the biosphere, are emergent and integrated phenomena at the system level that, obviously, are linked to all the others. In this sense, the structure of planetary boundaries arises from the fact that the planet is a single, complex, and integrated system, so that the limits operate as an interdependent set (Steffen et al., 2015).

Furthermore, planetary boundaries go beyond obvious physical, chemical, and biological parameters, as they must consider justice, especially in its socio-environmental aspect. Rockström et al. (2023) recognize, with regard to the limits of the planet, that although the damage to humans themselves is caused, in part, by greater exposure to biophysical changes, such problems are a function of socioeconomic vulnerability and the inability to adapt of people.

When approaching the limits of the Earth, it is clear that the stability of the Holocene has been removed. Humanity is in the Anthropocene, with significant social impacts already felt. The most critical thing is that changes can trigger tipping points that irreversibly destabilize the Earth system. The changes under discussion are generally driven by socioeconomic systems that operate based on the unsustainable extraction and consumption of resources (Rockström et al., 2023).

The planet has already exceeded 1.5°C of warming and studies indicate that rates of climate change are expected to continue throughout the 21st century (Montràs-Janer et al., 2024). It is noteworthy that in the 2015 Paris Climate Agreement, nations agreed not to exceed 1.5°C, a protection against climate change (Nogrady, 2024). Ferrajoli (2023, p. 9) is clear when he asserts that "because of the ecological catastrophe, for the first time in history, the human race is at risk of extinction: [...] a senseless mass suicide due to irresponsible activity of humans themselves."

According to Bennett (2020), in the Anthropocene, the appreciation of ruin changed the architectural focus to the deterioration of the planet. The ruin contemplated the reconquest of the environment built by nature, and now the carbon-intensive infrastructures of global capitalism transform nature into ruin. Therefore, it is clear that scientists, civil society, and local communities, in an atmosphere of mutual respect, must combine their knowledge with equitable collaboration (Kothari, 2021; Dryzek, 2022), avoiding the ruin of the Earth.

This scenario provokes the need to thrive efficient mechanisms to move away from dependence on finite fossil resources, which consequently attracts focus to so-called renewable resources, which are becoming increasingly important in the total supply of primary energy (Gernaat, 2021).

Bioprocesses and biotechnologies at the service of society

With regard to concerns about sustainability, especially industrial processes, related to the use and reuse of energy resources, the demand for bioprocesses and biotechnology grows considerably (Viera, 2022). The interest focused on the conservation of natural resources, as well as renewable resources and lower costs associated with energy consump-

tion lead to evolution, including the use of technologies and bioprocess development strategies (Fraga et al., 2020).

Maiorano (2018) explains that microorganisms, enzymes, and their genetically modified forms form the basis of bioprocesses, so the use of renewable resources and environmentally friendly, clean, and safe production processes is crucial to achieving sustainability. Thus, the combination of sustainability and "green chemistry" culminates in processes and products that minimize waste, GHG, etc., favoring industrial biotechnology.

Bioprocesses find driving force in social issues, especially due to the demand for new technologies, new products, and environmental preservation, as well as in the business area, based on biotechnological products with greater profit, less cost, and smaller ecological footprint. Furthermore, they provoke government actions, especially due to regulatory pressures and the need to replace fossil fuels. Finally, they are catalyzed due to available scientific knowledge (Maiorano, 2018). In this context, bioprocesses are seen as important mechanisms to eliminate dependence on fossil resources. Bioprocesses and biotechnologies play a fundamental role in mitigating the environmental impacts associated with the extraction and burning of fossil resources. Therefore, biomass, agricultural residues, and microorganisms can be used in an efficient and ecologically appropriate way, for example, to the detriment of the use of oil.

José Eli da Veiga (2023) warns that issues such as climate change, loss of biodiversity, among other problems, are global emergencies. In turn, the author says that to achieve sustainability, global actions are necessary, that is, new initiatives combined with old development actions are not enough. Precisely for this reason, it is understood that the stimulation of bioprocesses is so relevant today. An example is the production of biofuels, in the sense that bioprocesses transform biomass into fuel, which reduces the emission of GHGs and also reduces dependence on fossil resources.

In this sense, bioprocesses and biotechnologies can be understood as mechanisms that aim to reduce impacts and promote adaptations to climate change. Despite understanding the difficulty, bioprocesses appear as instruments capable of minimizing socio-environmental disputes and climate change, contributing to reducing the tension between the implementation of sustainability (as a guarantee of a healthy environment for present and future generations), pointed out in article 225 of the Federal Constitution of Brazil (Brasil, 1988a), and the global neoliberal reality, which maximizes economic power. At this point, it is important to emphasize biotechnologies aimed at improving living conditions on the Earth, such as bioenergy (production of energy through biomass and renewable biomass derivatives), bioremediation (the use of microorganisms to remove pollutants from the soil and water), among many others.

As for bioenergy, Nogueira et al. (2021) state that it represents a strategic option for the desired energy transition to renewable and sustainable systems. The motivations for the increasing use of bioenergy to replace fossil fuels are GHG reduction and energy security. Thus, there are several sources of biomass used in energy production. Resources can be direct (produced specifically for energy purposes, such as sugarcane used to produce ethanol), indirect (biomass as a by-product of agro-industrial and forestry processes), or recovered (biomass produced from materials already used, such as wooden boxes and cardboard, and urban liquid and solid waste).

It is important to highlight, in this sense, that the use of bioenergy from biomass has several advantages, such as benefits for the environment, reducing dependence on non-renewable resources, social improvements (such as the creation of jobs), prevention of forest fires, productivity improvement, and rural development (Ferreira, 2015). In specific terms regarding biofuels, these can be used in the transport sector (in the case of bioethanol, biodiesel, and biomethane, for example) (Nogueira et al., 2021). In legal terms, it is noteworthy that Brazilian legislation corroborates such actions, through RenovaBio, which is the National Biofuels Policy, established by Law No. 13,576/2017, which, among others, aims to promote the expansion of biofuels in the energy matrix (Brasil, 2023).

Biofuels arise from renewable raw materials, especially those of plant origin. Thus, they can have a neutral balance in relation to carbon, that is, the CO_2 emitted during burning can be reabsorbed by plants in the photosynthesis process. However, there are arguments that condemn the expenditure of fossil energy in production, planting, and harvesting; even so in the case of sugarcane, for example, 8–10 times more energy is produced than that is spent in the production process. In addition to sugarcane, corn and other cultivars are used in the production of biofuels (Mota and Monteiro, 2013).

Bioremediation is a process in which living organisms (plants or microorganisms) are used technologically to reduce or remove (remediate) pollutants from the environment. The process is a very interesting and viable alternative for treating contaminated environments, such as surface water, groundwater, and soil, waste, and industrial effluents in landfills or containment areas (Gaylarde et al., 2005). Interest in bioremediation has been aroused to rehabilitate many contaminated areas, including by petroleum hydrocarbons. It is noteworthy that Brazil has suitable soil to use this technique, considering its physical–chemical characteristics for the degradation of contaminants, such as environmental factors, nutrients in the soil, and climate conditions (Andrade et al., 2010).

Furthermore, another interesting example stands out, in the sense that biotechnology can generate plants that are more resilient to climate change. Climatic events (drought, heat, excessive rain, etc.) lead to food risk. Thus, the expectation is that biotechnology will benefit humanity in terms of health and nutrition, guaranteeing quality and variety of food, reducing pesticides, and providing greater food security (FAPESP, 2003).

Another example of biotechnology concerns biomaterials, with an emphasis on the search for and use of plant fibers. Many adverse environmental effects, such as GHG emissions, are being reduced by reinforcing plant fiber with polymeric material, as they are alternative materials to conventional ones that are petroleum-based, using renewable carbon as raw material (Ramesh et al., 2022).

We can also highlight what concerns carbon sequestration, which is a technology for absorbing and storing carbon dioxide with the intention of reducing its impacts on the environment. The purpose of the process is to contain and reverse the accumulation of atmospheric CO_2. Carbon sequestration can occur through forestry (which is the most common way) or through chemical removal of exhaust gases from thermoelectric plants, among others (Barreto et al., 2009).

Therefore, we highlight, as an example, the possibility of photobioreactors, which are used to produce microorganisms outside their natural environment. The microalgae can be used in civil construction and in architecture and urban planning, contributing to the sequestration of carbon dioxide and other GHGs (Frandoloso et al., 2023).

Hence, it is important to highlight that the bioprocesses and biotechnologies mentioned, among others, are related to the Sustainable Development Goals (SDGs) of the 2030 Agenda, in particular, SDG 2 in achieving food security through the promotion of agriculture sustainable, SDG 3 on health and well-being, SDG 7 on affordable and clean energy, SDG 9 in fostering innovation, SDG 12 in ensuring sustainable production and consumption patterns, SDG 13 in taking urgent action to combat climate change, and, finally, SDG 15 on ecosystem protection (ONU, 2023). In this context, bioprocesses and biotechnology can help reduce climate change, so they need to be increasingly studied and encouraged, especially to survive on a large scale. The environmental and energy crises demonstrate that it is essential to establish alternatives that replace oil. Biofuels, as noted, have this potential.

Arnold Demain (2009) asserts that there are solutions to energy problems and many of them are based on microorganisms, as in the case of the production of bioethanol, biobutanol, biodiesel, biohydrocarbons, and biomethane. In this sense, he concludes that these alternatives aim to reduce GHG emissions, improve the environment, and boost the economy.

In addition to the potential to provide environmental solutions, bioprocesses and biotechnologies also help reduce socio-environmental conflicts, since by offering innovative approaches and tools, they not only promote greater sustainability but also mitigate damages and natural disasters, such as exacerbated burning of CO_2 and the oil spill, just to illustrate.

It is important to highlight that the 2023 Synthesis Report on Climate Change from the Intergovernmental Panel on Climate Change presents many warnings regarding global climate change. Antonio Guterres, current Secretary-General of the United Nations, announced an Acceleration Agenda to comply with the Climate Solidarity Pact. In the aforementioned Agenda, it is proposed to end the use of coal as an energy source, net zero emissions in the electricity sector by 2035 for developed countries and by 2040 for others. Furthermore, it indicates the need to stop licensing or financing new oil and gas companies, and any expansion of oil and gas exploration (ONUBR, 2023).

On the contrary, in March 2023, the President of the United States, Jon Biden, approved the Willow Project, one of the largest oil exploration plans in history in Alaska. This authorization generated several protests and legal actions, so that recently the court in that country released the oil company ConocoPhilips to continue drilling the Willow project (Ruddy, 2023). The objective of these examples is to demonstrate that this is an issue with a strong political bias and that although job creation is important, it is impossible to justify any environmental benefit, especially in the face of climate change, which means we are facing yet another socio-environmental dispute that could be avoided if investments were focused on bioprocesses and biotechnologies, to the detriment of fossil fuels, given the damage they have proven to cause to nature.

Therefore, biotechnology and bioprocesses emerge as agents to reduce socio-environmental disputes and, in turn, play an essential role in reducing and controlling climate change. Biotechnology proves to be an excellent alternative to face challenges related to environmental degradation (which includes avoiding conflicts and environmental litigation related to climate change), so it is capable of acting at different times: in prevention, monitoring, and restoration (Jesus, 2017). The Anthropocene presents environmental challenges of broad complexity, so innovative approaches are essential to promote sustainability and mitigate conflicts related to climate change.

In this area, it is observed that bioprocesses are capable of producing energy sources that replace fossil fuels, which helps reduce GHG emissions. Thus, biotechnology is understood as fundamental in the drive to build a more sustainable future, especially considering the limits of the planet and ethical approaches from a social and regulatory point of view, ensuring that they are used in a responsible and sustainable manner, avoiding conflicts and damages monetarily compensated but environmentally non-recoverable.

Conclusion

Based on the investigation on how bioprocesses and biotechnologies can act to avoid socio-environmental disputes and help mitigate climate emergencies, the conclusion reached concerns the need for new incentives in science and technology, so that knowledge on bioprocesses and biotechnology is expanded. It cannot be said that solutions to socio-environmental adversities do not exist; on the contrary, bioenergy, bioremediation, and carbon sequestration are part of scientific culture, but they need – increasingly – support and breadth.

The fact is that to decarbonize the energy matrix, decision-makers and those in power need to support each other and encourage

the use of environmentally healthy technologies. Social relations are complex, that is, government, society, and companies should be aligned in paying attention to the planet's limits. However, a range of socio-environmental disputes, disrespect for legislation, and the duty of care was observed. In this sense, some of the factors behind a possible socio-environmental collapse are related to the inappropriate use of technology. It should be noted that, even if these technologies have the potential to solve current environmental problems, they will only make sense if they are developed and used with a strong social justice bias.

Despite the various pacts, agreements, and global objectives created in favor of sustainability, the notion of responsibility needs to be highlighted. Responsibility also involves selecting the most appropriate technologies, so investing in bioprocesses and biotechnologies over non-sustainable options is part of a choice for survival.

Bioprocesses and biotechnologies can be fundamental tools for balancing the social, economic, and environmental dimensions of sustainability and for reducing dependence on fossil fuels. The use of bioprocesses and biotechnologies tends to strongly reduce conflicts and, consequently, socio-environmental disputes. Adequate technology exists, or can be developed, but it does not receive the encouragement it should, since power relations (political and economic) often refuse to accept that the planet has limits.

It is essential to expand knowledge about the characteristics of raw materials (enzymes or microorganism cultures) capable of promoting bioprocesses with potential for wide-scale application, based on renewable resources. Biotechnology, therefore, presents itself as an innovation that requires investment to be better utilized. From the moment bioprocesses become dominant, many socio-environmental disputes can be avoided, especially those related to fossil fuels.

Authors' contributions

REATO, T.T.: conceptualization; data curation, formal analysis; investigation, methodology; writing – original draft. HARTMANN, P.: conceptualization; project administration; resources; writing – review & editing.

References

Andrade, J.A.; Augusto, F.; Jardim, I.C.S.F., 2010. Biorremediação de solos contaminados por petróleo e seus derivados. Eclética Química, v. 35, (3), 17-43. https://doi.org/10.1590/S0100-46702010000300002

Araújo, E.; Silva, M.; Ribeiro, R., 2020. Nota introdutório: sustentabilidade e descarbonização. In: Araújo, E.; Silva, M.; Ribeiro, R. (Eds.) Sustentabilidade e descarbonização: desafios práticos. Centro de Estudos de Comunicação e Sociedade. Universidade do Minho, Braga, pp. 5-8.

Assis, V.C.; Kato, D.S., 2022. Conflitos Socioambientais e Processos Educativos no Brasil: Uma revisão Bibliográfica. Revista Bio-grafía. Escritos sobre la Biología y su enseñanza. Número Extraordinario. Memorias XI Congreso Latinoamericano de Enseñanza de la Biología y la Educación Ambiental. 27 y 28 de octubre (Accessed April 4, 2024) at:. https://revistas.upn.edu.co/index.php/bio-grafia/article/download/18086/11575/57021

Barreto, L.; Freitas, A.C.; Paiva, L., 2009. Sequestro de carbono. Enciclopédia Biosfera, v. 5, (7). ISSN 1809-058351

Bennett, M.M., 2020. Ruins of the Anthropocene: the aesthetics of arctic climate change. Annals of the American Association of Geographers, v. 111, (3), 921-931. https://doi.org/10.1080/24694452.2020.1835457

Brasil, 1998a. Constituição da República Federativa do Brasil de 1988. Diário Oficial da União, Brasília (Accessed November 13, 2023) at:. https://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm

Brasil, 1998b. Decreto n. 2.519, de 16 de março de 1998. Convenção Sobre Diversidade Biológica. Promulga a Convenção sobre Diversidade Biológica, assinada no Rio de Janeiro, em 05 de junho de 1992. Diário Oficial da União, Brasília (Accessed January 16, 2024) at:. http://www.planalto.gov.br/ccivil_03/decreto/d2519.htm

Brasil, 2024. RenovaBio. Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (Accessed January 16, 2024) at:. https://www.gov.br/anp/pt-br/assuntos/renovabio

Brovkin, V.; Brook, E.J.; Williams, J.W.; Bathiany, S.; Lenton, T.M.; Barton, C.M.; DeConto, R.M.; Donges, J.F.; Ganopolski, A.; McManus, J.; Praetorius, S.K.; de Vernal, A.; Abe-Ouchi, A.; Cheng, H.; Claussen, M.; Crucifix, M.; Gallopín, G.C.; Iglesias, V.; Kaufman, D.; Kleinen, T.; Lambert, F.; Van der Leeuw, S.; Liddy, H.; Loutre, M.F.; McGee, D.; Rehfeld, K.; Rhodes, R.; Seddon, A.W.R.; Trauth, M.H.; Vanderveken, L.; Yu, Z., 2021. Past abrupt changes, tipping points and cascading impacts in the Earth system. Nature Geoscience, v. 14, (8), 550-558. https://doi.org/10.1038/s41561-021-00790-5

CLIMATE CASE CHART. Milieudefensie et al. v. Royal Dutch Shell plc (Accessed November 14, 2023) at:. https://climatecasechart.com/non-us-case/milieudefensie-et-al-v-royal-dutch-shell-plc/+

Demain, A.L., 2009. Biosolutions to the energy problem. Journal of Industrial Microbiology and Biotechnology, v. 36, (3), 319-332. https://doi.org/10.1007/s10295-008-0521-8

Dias, R., 2022. Gestão ambiental: responsabilidade social e sustentabilidade. 3. ed. Atlas, São Paulo.

Dryzek, J.S., 2022. The politics of the earth: environmental discourses. Oxford University Press, Oxford.

Ferrajoli, L., 2023. Por uma Constituição da Terra: a humanidade em uma encruzilhada. Tradução: Sergio Cademartori. Emais, Florianópolis.

Ferreira, A.L.D., 2015. Culturas energéticas: produção de biomassa e bioenergia. Dissertação de Mestrado, Faculdade de Ciências e Tecnologias da Universidade de Coimbra, Coimbra, Portugal. Retrieved 2024-01-23, from https://estudogeral.uc.pt/bitstream/10316/38787/1/Culturas%20energeticas_producao%20de%20biomassa%20e%20bioenergia.pdf

Flores, B.M.; Montoya, E.; Sakschewski, B.; Nascimento, N.; Staal, A.; Betts, R.A.; Levis, C.; Lapola, D.M.; Esquível-Muelbert, A.; Jakovac, C.; Nobre, C.A.; Oliveira, R.S.; Borma, L.S.; Nian, D.; Boers, N.; Hecht, S.B.; ter Steege, H.; Arieira, J.; Lucas, I.L.; Berenguer, E.; Marengo, J.A.; Gatti, L.V.; Mattos, C.R.C.; Hirota, M., 2024. Critical transitions in the Amazon forest system. Nature, v. 626, (7999), 555-564. https://doi.org/10.1038/s41586-023-06970-0

Fraga, G.V.; Ruy, A.D.S.; Pontes, L.A.M.; Campos, L.M.A.; Teixeira, L.S.G., 2020. Perspectivas de mercado e desafios da produção do ácido itacônico a partir de biomassa. Química Nova, v. 43, 951-958. https://doi.org/10.21577/0100-4042.20170573

Frandoloso, M.A.L.; Fritsch, R.; Matana, S.; Cunha, E.G.; Colla, L.M.; Nicolodi, J.M., 2023. Utilização de fotobiorreatores em fachadas para mitigação e sequestro de carbono. In: ENCONTRO NACIONAL DE CONFORTO NO AMBIENTE CONSTRUÍDO, 17., 2023. Anais [...]. [S. l.], 2023. 1-10. https://doi.org/10.46421/encac.v17i1.3996

Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), 2003. Biotecnologia e segurança alimentar. ed. 83. Pesquisa FAPESP (Accessed November 13, 2023) at:. https://revistapesquisa.fapesp.br/biotecnologia-e-seguranca-alimentar/

Gaylarde, C.C.; Bellinaso, M.L.; Manfio, G.P., 2005. Biorremediação. Biotecnologia Ciência & Desenvolvimento, v. 34, 36-43.

Gernaat, D.E.H.J.; de Boer, H.S.; Daioglou, V.; Yalew, S.G.; Müller, C.; van Vuuren, D.P., 2021. Climate change impacts on renewable energy supply. Nature Climate Change, v. 11, (2), 119-125. https://doi.org/10.1038/s41558-020-00949-9

Gonçalves, T.M.; Aluma, E.A.; Follmann, J.I., 2019. Conflitos socioambientais: história, tempo e contexto. In: Ladwig, N.I.; Campos, J.B. (Org.), Planejamento e gestão territorial: o papel e os instrumentos do planejamento territorial na interface entre ourbano e o rural. UNESC, Criciúma, pp. 138-162.

Graham, F., 2023. Daily briefing: How to stave off climate tipping points with self-perpetuating solutions. Nature. https://doi.org/10.1038/d41586-023-03939-x

Instituto Humanitas Unisinos (IHU), 2016. Os 10 conflitos ambientais mais explosivos do mundo (Accessed January 15, 2024) at:. https://www.ihu.unisinos.br/categorias/185-noticias-2016/558702-os-10-conflitos-ambientais-mais-explosivos-do-mundo

Jesus, K.R.E., 2017. Biotecnologia ambiental: aplicações e oportunidades para o Brasil. Embrapa Meio Ambiente, Jaguariúna.

JUMA, 2023. Boletim da litigância climática no Brasil. 2. ed. iCS, Rio de Janeiro.

Kothari, A., 2021. Half-Earth or Whole-Earth? Green or transformative recovery? Where are the voices from the Global South? Oryx, v. 55, (2), 161-162. https://doi.org/10.1017/S0030605321000120

Laboratório Nacional de Biorrenováveis (LNBR), 2023. A espinha dorsal da biotecnologia para a produção de compostos bioativos (Accessed January 15, 2024) at:. https://lnbr.cnpem.br/divisoes-de-pesquisa/processos-tecnologicos/bioprocessos/#:~:text=Bioprocessos%20%C3%A9%20a%20espinha%20dorsal,a%20produtos%20de%20origem%20renov%C3%A1vel

Lenton, T.M., 2020. Tipping positive change. Philosophical Transactions of the Royal Society B, v. 375, (1794), 20190123. https://doi.org/10.1098/rstb.2019.0123

Little, P.E., 2001. Os conflitos socioambientais: um campo de estudo e de ação política. In: Bursztyn, M. (Org.), A difícil sustentabilidade. Editora Garamond, Rio de Janeiro.

March, H., 2023. La emergencia climática en el contexto de los límites planetarios. Oikonomics, (21). https://doi.org/10.7238/o.n21.2313

Maiorano, A.E., 2018. Desenvolvimento de bioprocessos perspectivas. Instituto de Pesquisas Tecnológicas do Estado de São Paulo, São Paulo.

Mass.gov., 2019. Attorney General's Office Lawsuit Against ExxonMobil (Accessed January 15, 2024) at:. https://www.mass.gov/lists/attorney-generals-office-lawsuit-against-exxonmobil

Montràs-Janer, T.; Suggitt, A.J.; Fox, R.; Jönsson, M.; Martay, B.; Roy, D.B.; Walker, K.J.; Auffret, A.G., 2024. Anthropogenic climate and land-use change drive short- and long-term biodiversity shifts across taxa. Nature Ecology & Evolution, v. 8, 739-751. https://doi.org/10.1038/s41559-024-02326-7

Morais, L.A.; de Freitas, L.S., 2023. Relação democracia e meio ambiente: revisão integrativa da literatura de 1944 a 2019. Revista Jurídica da UFERSA, v. 7, (13), 208-237. https://doi.org/10.21708/issn2526-9488.v7.n13.p208-237.2023

Moro, S.C.; Fassheber, J.R.M.; Leme, S.V.D., 2023. Comunidades Indígenas no litoral do Paraná e os Conflitos Socioambientais: uma Revisão Sistemática. Diálogos Possíveis, v. 22, (1), 272-291.

Mota, C.J.A.; Monteiro, R.S., 2013. Química e sustentabilidade: novas fronteiras em biocombustíveis. Química Nova, v. 36, 1483-1490. https://doi.org/10.1590/S0100-40422013001000002

Neomundo. Shell e Eni causaram desastre ambiental de US $ 12 bi à Nigéria, estudo conclui (Accessed November 14, 2023) at:. https://neomondo.org.br/2023/05/17/shell-e-eni-causaram-desastre-ambiental-de-us%EF%BC%84-12-bi-a-nigeria-estudo-conclui/

Nogrady, B., 2024. The world has warmed 1.5°C, according to 300-year-old sponges. Nature. https://doi.org/10.1038/d41586-024-00281-8

Nogueira, L.A.H.; Capaz, R.S.; Lora, E.S., 2021. Bioenergia no Brasil: onde estamos e quais nossos horizontes. Revista Brasileira de Energia, v. 27, (3). https://doi.org/10.47168/rbe.v27i3.640

Organização das Nações Unidas (ONU). Objetivos do Desenvolvimento Sustentável (Accessed November 14, 2023) at:. https://brasil.un.org/pt-br/sdgs

Organização das Nações Unidas Brasil (ONUBR). Ações urgentes contra mudança climática são necessárias para garantir um futuro habitável, alerta IPCC (Accessed November 15, 2023) at:. https://brasil.un.org/pt-br/224004-a%C3%A7%C3%B5es-urgentes-contramudan%C3%A7a-clim%C3%A1tica-s%C3%A3o-necess%C3%A1rias-para-garantir-um-futurohabit%C3%A1vel

Ramesh, M.; Deepa, C.; Kumar, L.; Sanjay, M.; Siengchin, S., 2022. Life-cycle and environmental impact assessments on processing of plant fibers and its bio-composites: a critical review. Journal of Industrial Textiles, v. 51, (4). https://doi.org/10.1177/1528083720924730

Richardson, K.; Steffen, W.; Lucht, W.; Bendtsen, J.; Cornell, S.E.; Donges, J.F.; Drüke, M.; Fetzer, I.; Bala, G.; Von Bloh, W.; Feulner, G.; Fiedler, S.; Gerten, D.; Gleeson, T.; Hofmann, M.; Huiskamp, W.; Kummu, M.; Mohan, C.; Nogués-Bravo, D.; Petri, S.; Porkka, M.; Rahmstorf, S.; Schaphoff, S.; Thonicke, K.; Tobian, A.; Virkki, V.; Wang-Erlandsson, L.; Weber, L.; Rockström, J., 2023 Earth beyond six of nine planetary boundaries. Science Advances, v. 9, (37), eadh2458. https://doi.org/10.1126/sciadv.adh2458

Ritchie, P.D.L.; Clarke, J.J.; Cox, P.M.; Huntingford, C., 2021. Overshooting tipping point thresholds in a changing climate. Nature, v. 592, (7855), 517-523. https://doi.org/10.1038/s41586-021-03263-2

Rockström, J.; Gupta, J.; Qin, D.; Lade, S.J.; Abrams, J.F.; Andersen, L.S.; McKay, D.I.A.; Bai, X.; Bala, G.; Bunn, S.E.; Ciobanu, D.; DeClerck, F.; Ebi, K.; Gifford, L.; Gordon, C.; Hasan, S.; Kanie, N.; Lenton, T.M.; Loriani, S.; Liverman, D.M.; Mohamed, A.; Nakicenovic, N.; Obura, D.; Ospina, D.; Prodani, K.; Rammelt, C.; Sakschewski, B.; Scholtens, J.; Stewart-Koster, B.; Tharammal, T.; van Vuuren, D.; Verburg, P.H.; Winkelmann, R.; Zimm, C.; Bennett, E.M.; Bringezu, S.; Broadgate, W.; Green, P.A.; Huang, L.; Jacobson, L.; Ndehedehe, C.; Pedde, S.; Rocha, J.; Scheffer, M.; Schulte-Uebbing, L.; de Vries, W.; Xiao, C.; Xu, C.; Xu, X.; Zafra-Calvo, N.; Zhang, X., 2023. Safe and just Earth system boundaries. Nature, v. 619, 102-111. https://doi.org/10.1038/s41586-023-06083-8

Ruddy, G. Justiça libera projeto Willow: Entenda as discussões sobre a produção de petróleo no Alasca (Accessed November 15, 2023) at:. https://epbr.com.br/justica-libera-projeto-willow-entenda-as-discussoes-sobre-a-producao-de-petroleo-no-alasca/

Sarlet, I.W.; Wedy, G.; Fensterseifer, T., 2023. Curso de Direito Climático. Thomsom Reuters, São Paulo.

Shiva, V., 2020. Reconstruir a verdadeira segurança na era da insegurança. In: Dawson, J.; Norberg-Hodget, H.; Jackson, R. (Ed.), Economia de gaia: viver bem dentro dos limites planetários. Editora Roça Nova, Rio de Janeiro.

Silva, B.R.; Madeiros, L.F.; Palheta, A.R.; Souza, M.C.; Galvão, M.I.; Oliveira, L.J.; Reis, C.L.; Picanço, M.A.; Moreira, I.R.; Santos, E.F.; Oliveira, H.P., 2023. A sustentabilidade na mineração do Amapá: revisão de literatura. Revista Multidisciplinar do Amapá, v. 3, (2), 72-80. https://doi.org/10.56856/remap.v3i2.435

Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S.E.; Fetzer, I.; Bennett, E.M.; Biggs, R.; Carpenter, S.R.; de Vries, W.; de Wit, C.A.; Folke, C.; Gerten, D.; Heinke, J.; Mace, G.M.; Persson, L.M.; Ramanathan, V.; Reyers, B.; Sörlin, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science, v. 347, (6223). https://doi.org/10.1126/science.1259855

Veiga, J.E., 2023. A desgovernança mundial da sustentabilidade. Editora 34, São Paulo.

Viera, A.W., 2022. Utilização do bagaço de malte em bioprocessos: prospecção de potenciais bioprodutos por via biotecnológica. Course completion work, Department of Chemical Engineering, Federal University of Rio Grande do Sul, Porto Alegre. Retrieved 2024-02-12, from https://lume. ufrgs.br/bitstream/handle/10183/266031/001155868.pdfced42ed76c6bfdc5f0694a91429d0b6cMD5110183/2660312023-10-18;jsessionid=5BD061F1C45B5ABE8BBC2DF12CE36E8C?sequence=1

WEDY, G.T., 2021. Litígio climático: Shell perde ação na Holanda (Accessed February 16, 2024) at:. https://www.conjur.com.br/2021-jun-19/ambiente-juridico-litigio-climatico-shell-perde-acaoholanda/