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Global Inequalities in the Bioeconomy: Thinking Continuity and Change in View of the Global Soy Complex

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Abstract: As a proposed pathway to societal transformation, the bioeconomy is aimed at providing a sustainable alternative to the fossil-based economy, replacing fossil raw materials with renewable biogenic alternatives. In this conceptual contribution, we argue that it is impossible to transform societies into sustainable bioeconomies considering the narrow boundaries of the bioeconomy as a policy. Drawing on approaches including agro-food studies, cheap food, and agrarian extractivism, we show that the bioeconomy is entangled in a broader context of social relations which call its claim to sustainability into question. Our analysis of the global soy complex, which represents the core of the current agro-food system, demonstrates how the bioeconomy perpetuates global inequalities with regard to trade relations, demand, and supply patterns, as well as power relations between the involved actors from the global to the local level. Against this background, we propose a fundamental rethink of the underlying understanding of transformation in bioeconomy policies. Instead of thinking the bioeconomy only along the lines of ecological modernisation, its proponents should consider studies on social-ecological transformation, which would entail radical structural change of the prevailing food regime to cope with the social-ecological crisis.

Keywords: agrarian extractivism; bioeconomy; cheap food; food regime; Latin America; social-ecological transformation; soy



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1. Introduction: Bioeconomy, Flexible Biomass, and Societal Transformation

As a proposed pathway to societal transformation, the bioeconomy is aimed at developing and implementing new technologies to produce biomass and transform it into a range of products. Various forms of biomass are to replace fossil resources for energy production and industrial raw materials. Products mostly from agriculture (but also from forestry and aquaculture) are to be turned into flexible biomass for universal usage in “biorefineries” [1] (p. 95) or used to produce biofuels or recently also biomethane [2]. In addition, the bioeconomy agenda claims to provide a sustainable alternative to the fossil-based economy as fossil raw materials are to be replaced with renewable biogenic alternatives [3]. Over 60 countries have adopted bioeconomy strategies or are pursuing bioeconomy-related policies in addition to a growing number of macro-regional bioeconomy strategies such as the one drawn up by the EU [4] (p. 13). This strategy constitutes a multi-faceted global transformation project, as it sets different priorities in research funding and incentives for bioenergy.

However, various national strategies have come under criticism, since they foresee a rise in the agroindustrial production of soy, palm oil, and corn—crops that have come to dominate the contemporary global agro-food system and that are exacerbating climate change, land use change, and land grabbing [5,6]. Therefore, the bioeconomy agenda can aggravate problems already discussed in the food versus fuel debate [6,7]. Consequently, nowadays, many policymakers and expert fora recognise the conflicting socio-ecological

objectives and interests that are present in the bioeconomy from the local to the global level. This acknowledgment is clearly visible in Germany's latest bioeconomy strategy, which emphasises the need to avoid negative socio-ecological impact in order to strengthen the participation of civil society and to achieve the sustainable development goals (SDGs) [8]. Thus, transformation in this context not only involves replacing fossil fuels (the basis of modern societies) with biomass. Rather, this material transformation is now to take place in harmony with the goals of sustainable development worldwide. However, this acknowledgment at the policy level has not led to a reversal in the trend towards expansion of biomass production or even helped mitigate its negative socio-ecological impacts [9]. This, of course, conflicts with implementation of the SDGs.

Against this background, aspects of sustainability in the bioeconomy have become an increasingly important issue for research on bioeconomy policies and in related academic debates [10–12]. In this conceptual contribution, we advance the thesis that it is impossible to transform societies to sustainable bioeconomies that achieve the SDGs, considering the narrow boundaries of the bioeconomy as a policy. Insights from critical agrarian and food studies demonstrate that change and continuity in agricultural biomass production should not be thought of as isolated processes. The understanding and possible transformation of patterns in agricultural biomass production need to include analyses of historical roots, these patterns' embeddedness in wider social relations, and the relevance of power relations. Exploring this argument in detail, we show that critical analyses of the global soy complex provide an understanding of the prospects of the emerging bioeconomy as a societal transformation. The guiding questions for our study are twofold: What are the limits of bioeconomy as a strategy for societal transformation? And more specifically: What does the development of the existing global soy complex tell us about the prospect of bioeconomy transformation?

To answer these questions, we draw on concepts including agro-food-studies [13,14], agrarian extractivism [15–17], and cheap food [18]. These approaches enable us to gain a deeper understanding of historical and structural patterns from the global to the local level that shape all biomass producing industries and attempts to transform them to increase sustainability. In combination, these concepts provide an innovative theoretical framework for our conceptual contribution on the bioeconomy. The theoretical argument is empirically underpinned with data and qualitative studies on the social relations encompassing production, distribution, and consumption of soy and its derivatives. The soy sector is the empirical focus of this study because it is particularly well suited to be used to flesh out a historically rooted, global perspective on the bioeconomy. This view is based on the assumptions that (a) specific social relations, such as those in the soy sector, cannot be understood exclusively in their local context, but are globally embedded in broader social structures; (b) the global soy complex constitutes the core of the current agro-food system—The system that is to evolve into a future bioeconomy; thus, (c) the dynamics of the global soy complex foreshadow issues that would be associated with a full-scale bioeconomy; and (d) the same global social inequalities that shape the soy complex today question the socio-ecological sustainability of the bioeconomy.

Soy is the most important agricultural biomass commodity to date and has globalised production and trade networks. In 2020/2021, soy was grown on 129 million hectares worldwide, almost half of which was in South America [19] (p. 32). This is leading the region to be described as “soylandia” (in English: soy land) [20] (p. 119). The ecological changes are far-reaching, compelling some researchers to speak of the “soy-isation” of agriculture [21,22]. As a flex crop [1], soy can be used in the food, fodder, energy, and other industrial sectors, depending on which form of further processing is more profitable. In addition, the soy sector has been the site of various forms of technological innovation with the aim of improving efficiency and productivity, for instance, by increasing yields through transgenic technologies as well as through better farming techniques such as no-till farming and crop rotation with corn. However, technological innovation has neither led to a halt in the expansion of cultivated areas, nor to more sustainable production [23]. This fact

highlights the limitations of a merely technology-driven transformation strategy and the need to analyse the complexity of historical global contexts.

In this study, we analyse the global soy complex and its exemplary role for a bioeconomy with the aim of grasping the transnational social relations it embodies. South America, the main production region, plays a central role in our reflections. Other world regions, which play an important role in bioeconomy visions and in biomass markets beyond soy, are therefore not within the scope of this study. In our understanding, the term “soy complex” encompasses the (mainly transnational) enterprises selling inputs (seeds, pesticides, fertilisers, and machines) necessary to grow soy, as well as (the mainly different) companies buying soy from farmers to process it into food, fodder, or biodiesel, and to store, transport, and export it. Both the upstream and downstream side of the soy complex is dominated by a handful of economic actors—despite regional differences—that have a tendency towards oligopolistic structures. The analysis of the development and prospects of the soy complex at the heart of the global agro-food system and its links to the bioeconomy serves to clarify the role and impact of bioeconomy transformation in a world of inequalities. The evidence leads to the conclusion that a just and truly sustainable transformation of the global agro-food system requires more than what current bioeconomy policies can deliver.

2. Theoretical Analysis of Socio-Ecological Inequalities in the Soy Complex

We use theoretical concepts that capture the global agro-food system in its entirety including its dynamics of transformation to fully grasp the circumstances under which bioeconomy policies operate on a global scale. Concepts embracing this perspective have been developed in the tradition of world systems analysis [24]. More specifically, and for the analysis of agriculture as a central field of biomass production with soy as a pivotal global crop, the concepts of *food regimes* [25], *cheap food* [18], and *agrarian extractivism* [16] are useful.

Food regime analysis is a perspective on global patterns of agriculture, food processing, and consumption that goes back to a seminal article by Friedmann and McMichael [25]. Food regime analysis proposes understanding the political economy of food on a global scale in relation to the process of capital accumulation: “The difference made by food regime analysis is that it prioritises the ways in which forms of capital accumulation in agriculture constitute global power arrangements, as expressed through patterns of circulation of food” [13] (p. 140). Historically different food regimes can be distinguished; food regimes are defined as temporarily stable sets of implicit and formal rules governing the global agro-food system [26] (p. 30).

Coined by Jason Moore [18], the concept of cheap food explains the structural function of the production of cheap surplus food under capitalism as central to the reproduction of the growing working classes in the urban centres. Furthermore, it draws attention to how cheap food is produced through productivity revolutions and commodity frontiers, which appropriate, sometimes dispossess, and exploit natural resources, spaces, and people all over the world. Thus, examining the issue through the lens of cheap food helps to provide an understanding of the current expansion dynamics of soy, as it conceptualises transnational interrelations between consuming and producing classes and regions at the world scale.

The concept of agrarian extractivism has been introduced to describe an economic strategy used by countries in the Global South to generate wealth via the extraction of resources from the ground, as well as by producing large quantities of flex crops for the global market. The term is mainly used to criticise the negative economic, social, and environmental consequences of such strategies. The expansion of soy in the Conosur region has been the first field beyond fossil fuels and mining where the concept of extractivism has been discussed broadly [27,28]. The debate has led to the development of the term “agrarian extractivism” [29–31]. The concept helps provide an understanding of the specific political and economic power relations that hamper socio-ecological transformations.

On the basis of their common lineage from word-systems analysis, the three concepts provide an understanding of the historically developed structures and inequalities of global capitalism and its roots in colonialism. In this understanding, modern capitalism has historically developed with and through the incorporation of the Americas into the world system. Colonialism and the extraction of raw materials from Latin America and the Caribbean (world systems analysis stresses the importance of the colonisation of the Americas for the world system and the emergence of capitalism. Nevertheless, this does not mean that colonialism in Africa and Asia was less brutal or less important. For Wallerstein's analysis of colonialism in Africa, see [32].) has been crucial to the development of wealth in Europe and the constitution of the capitalist world system. On this basis, the three approaches complement each other effectively as part of our analysis: the food regime serves as an overall framework to understand the rules governing agriculture and food production on a global scale. It also highlights the connection to broader social relations in global capitalism. The cheap food perspective helps us gain a deeper understanding of the political economy of consumption patterns by analysing the underlying relations of production. Finally, agrarian extractivism provides an understanding of the specific social relations entailed in the soy complex in South America.

Despite their diverging focus, all three concepts emphasise similar dimensions that are important for our analysis. First, they underline the historical roots of contemporary societies and the weight of past processes (such as colonialism) in shaping social relations. Second, they stress structural inequalities as defining features of society from the global to the local scale. Third, they acknowledge the role of collective actors and the power relations between them in reproducing or transforming social structures. The following analysis is structured by these three dimensions.

In the first chapter, we outline how the food regime (and the soy complex as a part of it) has evolved historically. In the second chapter, we explain the expansion dynamics of soy using Moore's argument about the structural need to produce cheap food. In the third chapter, we show which actor constellations and power relations support the continued expansion of this sector by looking at the main cultivation regions in South America. To this end, we evaluate the current research on soy in the region. At the end of each chapter, we directly link the findings to the emerging bioeconomy and its impact.

3. Historical Contextualisation: Deep-Rooted and Continuous Inequalities

An understanding of the historical roots and trajectory of the global soy complex and the wider agro-food system is fundamental to our perspective. As mentioned above, colonialism and its role in the development of the modern capitalist world system is a central aspect. Food regime analysis, which we use as a framework, emphasises that this historical relationship is not a linear development but needs to be seen as a succession of qualitatively different periods and respective food regimes. Friedmann and McMichael [25] initially identified two food regimes: A first "imperial" regime under British hegemony ranging from 1870 to 1914 (McMichael and other authors later extended the period of the first food regime from 1870 to 1930; see [13,20].) and a second "developmental" regime under U.S. hegemony from 1945 to 1973. A vivid debate is taking place about whether a third food regime (for the period since 1973) is emerging or has already established itself and how it is to be conceptualised [33] (pp. 18–21). McMichael suggests that a "corporate food regime" began in the 1980s, and this seems to be an accurate assessment from the vantage point of the global soy complex. There are substantial differences between the present and earlier food regimes when it comes to the role of soy.

In the first "imperial" food regime under British hegemony, soy was a supplementary, albeit relatively cheap source of protein and fat for the European working classes, and it was produced mainly by Chinese settler families and sold to Europe as part of the British free-trade paradigm and the gold standard [20] (p. 140). As a whole, the imperial food regime was centred around the British state and capital and included two major global food flows [13] (pp. 144–145). Tropical foods such as sugar, coffee, and fruit were imported

from plantation colonies to Europe, while temperate foods, mostly wheat and meat, were imported from settler colony states such as the USA, Argentina, Australia, and South Africa. Extracting relatively cheap foodstuffs along with other raw materials in different colonial frontiers at the expense of local populations (over-exploitation of paid labour and appropriation of unpaid labour) as well as nature (appropriation of untilled land, exhaustion, and degradation of soils) enabled British and European capital to provision a growing industrial labour force [13] (p. 145). The two food flows were part of two contemporary dynamics in the world system: “the culmination of European colonialism in Asia and Africa (colonies of ‘occupation’) and the ‘rise of the nation-state system’ in which (former) colonies of ‘settlement’ were now independent” [33] (p. 3). The institutional rules of the imperial food regime were suspended during WW1 and finally crumbled during the 1929 global economic crisis [20] (p. 121).

By the second “developmental” food regime (1945–1973), soy had already become a central ingredient in the transformation of agriculture and the post-WW2 international division of labour [25] (p. 110). In this U.S.-centric regime, soy was produced by an expanding U.S. agro-industrial complex and partially shipped under GATT tariff exemption to Europe as feed for the growing meat production in the post-war era [25] (p. 107). Simultaneously, soy surpluses such as other cheap foods were used politically by the USA during the Cold War to influence the growing number of newly independent nation states in the Global South [20] (p. 122). The expansion of the soy complex in the USA started in the 1930s after the exhaustion of the family-farming model based on wheat during the “Dust Bowl”, and this provided it with a dominant position on the world market until the 1970s [14] (p. 252). As the physical expansion of farming in the USA had ended during the previous food regime, the growth of the soy complex took place primarily through the displacement of other crops, as well as through mechanisation and the application of new (agrochemical) technologies [14] (p. 252). This perceived U.S. model of national development based on modernising the farm sector in conjuncture with industry was publicly promoted but also forcibly implemented as an example for the rest of the world under the label of the “Green Revolution” [13] (pp. 145–146). The fictitious picture of national sovereignty conveyed by the U.S. development model stood in contrast to the construction of increasingly transnational commodity chains in agriculture that penetrated national economies under the control of U.S. agribusiness.

As the global economy entered a prolonged crisis in the mid-1970s, including the regulation of global markets for food commodities, a new phase began in the globalisation of soy. The liberalisation of these markets and the increasingly dominant position of TNCs (ABCD group, see below) in the 1980s, marked a shift towards what McMichael calls the “corporate food regime” [34]. In this context, soy has been transformed into an increasingly flexible crop, and cultivated under the control of transnational agribusiness mostly in South America to be channelled through liberalised global markets to Europe and China to provide the growing labour forces with a meat/protein-rich diet [34] (pp. 288–289).

From the 1970s onwards, soy producers in South America posed increasing competition to the soy farmers in the USA [14] (p. 258). In the context of the corporate food regime, Brazil and the other countries in the Southern Cone region became the main producers of soy for the world market. This was achieved through the expansion of land used for soy farming but more importantly through the application of new technologies such as GMO soy, which is resistant to specific pesticides that are intensively used in soy cultivation [14] (pp. 259–263). After a few years, it became clear that the main beneficiaries of this model were the transnational companies that sell the “technological package” of GMO seeds and pesticides [35] (p. 67).

As soy production in South America is primarily directed at the global market under the control of agribusiness TNCs and because these activities contain few linkages to local production and consumption, they constitute an exemplary form of agrarian extractivism [29]. High volumes of raw or semi-processed materials are shipped out of the country to fulfil global demands for resources. This form of production is based on the extraction of nutrients from soils, which are degraded in the long term by soy cultivation [36],

as well as increasing land demands, leading to displacement of subsistence farmers and indigenous groups and significant environmental impact such as deforestation, erosion, and contamination of water sources [37] (p. 51).

The soy complex in South America was one of the first fields in which the corporate food regime developed an entirely flexible crop. Only 6% of soy is currently used to feed people; most of it is used for agro-industrial feedstock including fodder as well as for biodiesel and industrial products [23] (p. 252). Through the lens of food system analysis, soy, among other crops, constitutes a biomass resource, which is seen as interchangeable:

“The corporate food regime has progressively modelled a form of agriculture valuing its product solely as a commodity. The bio-economy represents the highest stage of commodification in the fact of crop substitutability. Here, exchange value erases use value, and crops become fungible investments as the multiple uses of corn, soy, palm oil and sugar, for example, whether as foods, feeds, fuels, cosmetics, stabilizers and so on. For the crops mentioned, their conversion from food to exchange-value is the ultimate fetishization of agriculture, as an input-output process geared to indiscriminate production of commodities for profit.” [38] (p. 132)

As the quote shows, the main aim of the bioeconomy—to replace fossil resources for industrial uses and energy production with biogenic resources (see the Introduction)—leads crops such as soy to be conceptualised as interchangeable inputs in a global economy; this strengthens unequal and extractivist relations at the sites of production. Moreover, the emergence of soy as a flex crop rests upon the extractive relations established in Latin America since colonial times and the historic shift from a developmental to a corporate food regime on a world scale. These historical roots are deepened in a bioeconomy that relies on flex crops and other established agro-industrial practices found in the soy complex and throughout the corporate food regime. The next chapter demonstrates that the difficulty of changing such practices is and has been exacerbated by the current and historical structural inequalities that pervade social relations in and beyond the agro-food system.

4. Cheap Food and Structural Inequalities

Contrary to the soy sector’s claims to contribute significantly to feeding a growing world population, numerous studies demonstrate that soy is used to feed livestock to provide meat and animal products to the world’s growing middle classes and not to feed the poor [23]. Tony Weis argues that soy and other grain and oilseed production is deeply intertwined with the livestock industry within the current food regime, and that this contributes to the “meatification of diets” [39] (p. 127). Today, meat consumption worldwide is twice as high as it was two generations ago, even though there are twice as many people on the planet. However, it would be short-sighted to equate growing meat consumption with the growing world population as meat consumption is highly unequal and even exacerbates social inequalities on a global scale: “People in high-income countries consume over twice as much meat per year as the world average” [40] (p. 562). In 2018, annual per capita meat consumption in the USA was 145 kg; in Nigeria, it was just under 7 kg [41]. Simultaneously, the production of crops and oilseeds for fodder exacerbates food insecurity in poor countries as “nearly one-third of cropland is devoted to producing livestock feed” [40] (p. 564). Hence, growing livestock and meat consumption exacerbates hunger and malnutrition of the poor.

There are many reasons for the growing demand for meat such as taste, beliefs about the need to consume animal protein, cultural veneration, and ideas of masculinity [40] (p. 562). The sole focus on consumption habits, however, obscures the structural background. Therefore, we draw on the political economy of consume patterns to analyse the dialectic relations between demand and supply in capitalist economies [40] (p. 563). Examining the subject through this lens reveals that chronic grain surpluses caused by subsidised production were pivotal in linking the soy complex to the livestock industry, since the crops were absorbed by “fast-rising populations of concentrated livestock, starting

with chickens and followed by pigs" [40] (p. 563). At the same time, markets for standardised grain and meat products emerged, making crops and meat the basis of financial instruments, which, in turn, have exacerbated the standardisation, homogenisation, and industrialisation of the respective agricultural products (ibid.). This shift began as part of a transnational restructuring of agricultural sectors in the context of the second food regime [25] (pp. 105–108). Meat developed into a central product-category in the post-war agro-food system:

"Like the automobile, meat was a key product in the mass production and consumption of standardized products that provide the central dynamic of post-war capitalism in advanced capitalist economies; and like petroleum [. . .] soy was a critical input to mass production." [25] (p. 106)

Moore provides an additional explanation for the rise of the food regime and its specific consumption patterns with his emphasis on the structural function of *cheap food* in capitalism; the intrinsic logic of capitalism is to extract more value by increasing labour productivity to produce more commodities with less labour. In this understanding, cheap food means that "more calories are produced in less average labour-time in the commodity system" [42] (p. 10). Furthermore, cheap food is essential to keep the wage-bill low. Moore argues that it is a specificity of capitalism that the exploitation of paid labour can be successfully intensified by appropriating unpaid labour (e.g., care work, subsistence farming, slavery) and natural resources (e.g., soil nutrition) for the production and trade of cheap food. In this context, Moore refers to wages, which remained stable while food prices continued to fall in OECD countries, especially during the 1990s [43].

Moore views the development of modern industrial agriculture as decisive for the emergence and development of capitalism: on the one hand, its enclosures have contributed to the continuous displacement of small-scale agriculture over the last five centuries, and this led to large-scale migration to the cities. On the other hand, the combination of major productivity revolutions through technological innovation and the expansion of the frontiers of agro-industrial agriculture (which, in turn, has provoked new enclosures) has provided cheaper food to the growing urban population. In this view, it is not industrialisation in England that enabled the rise of capitalism, but a change in the food system; only the production of surplus food enabled the creation of labour outside of agriculture. The conquest of the Americas, in combination with the emergence of plantation economies, was central to producing this food surplus. As Moore shows in his historical analysis, the importance of the global expansion of capitalist agriculture has become apparent since the conquest of the Americas and the later colonisation of Asian countries, in particular: "problems with English agricultural productivity in the eighteenth century, for example, were never resolved within England, but rather through successive frontier movements, especially in North America" [42] (p. 274). The history of the last few centuries reveals that food security is essential to stabilising great empires [44] (pp. 92–93). The opening up of new frontiers to produce cheap food, therefore, is crucial for social peace and, at the same time, remains an engine of imperial expansion. Soy is a "petrochemical hybrid complex" that combines "new plants, fertilisers, pesticides, and irrigation schemes" ([45] cited in [42] (p. 251)). Consequently, the growing demand for soy pushes forward frontiers in different regions: on the one hand, the horizontal frontiers of the growing plantations appropriate more and more land in South America. On the other hand, vertical frontiers include the growing consumption of underground fossil resources for fertiliser and transport, and potable water [42] (p. 254).

In the early globalised supply chains of cheap food, labour relations in the emerging industrial nations were combined in a completely new way with unpaid labour by slaves in the colonised peripheries. As Sidney Mintz shows, the production of cheap sugar on the sugar cane plantations in the Caribbean was a crucial cheap source of calories for the proletarians in the industrial centres of Europe [46]. Today, the question is how these entanglements of different labour relations and classes are reproduced or reconfigured within and between countries; precarious working conditions and modern slavery are

still central pillars of the global production of cheap food. Using the example of cheap chicken in Mexico, Patel and Moore underline the centrality of cheap meat in establishing and maintaining social peace in emerging economies [43]. Patel and Moore demonstrate that chicken became cheap and affordable as a direct consequence of the North American Free Trade Agreement (NAFTA), technological innovation, and the U.S. soy industry [43]. However, Mexican smallholder agriculture paid a very high indirect price; NAFTA plunged smallholder agriculture into crisis and forced many farmers to migrate to the U.S. agricultural sector where they became part of the precarious labour force and consumers of cheap food.

However, soy as the “supercrop” of the green revolution also illustrates the limits of productivity growth and cheap food. The large productivity gains made during the last few decades can no longer be met because soils have been depleted; “superweeds” are threatening plantations; investments for seeds, fertiliser, and pesticides are growing; and climate change is aggravating the socio-ecological crisis. In Brazil, the largest global soy producer, the cost of soy production has been rising by 5 percent annually since 2009 [42] (p. 268). Globally, food prices are rising again, and this led Moore to argue that cheap food, as a key pillar of capitalism, has entered a deep crisis in the 2000s that cannot simply be resolved through technological innovation [42] (pp. 268–276).

Examining the issue through the lens of cheap food draws attention to the political economy of consumption patterns that cannot simply be met by pleas to consumers or more sustainable soy production but that has to involve profound changes to the whole food regime. Even if the change in eating habits envisaged by the bioeconomy, such as meat substitutes, is an important starting point, it will not be enough. Synthetic meat cannot be developed in ahistorical spaces but is based on substances produced within existing structures of the global food regime. A bioeconomy would thus not only have to overcome the food regime’s dependence on fossil raw materials, but also to transform the inner logic of cheap food, because it is based on the exploitation of labour as well as the appropriation of unpaid labour and natural resources. Whether or not these relations are addressed in transformation processes such as the bioeconomy is also a question of power. The following looks at the situation in South America—the main production site of the global soy complex—and demonstrates how the power relations in this complex shape social and environmental relations and how this situation transpires into bioeconomy policies.

5. Actors and Power Relations in the Soy Complex and the Bioeconomy

The global soy complex is dominated by a handful of powerful transnational companies that produce most of its inputs (seeds, pesticides, fertilisers, machines), control the export and import relations, and are so powerful that they are able to influence the research agenda and political regulations within the soy sector in diverse countries [47]. The ABCD companies (ADM, Bunge, Cargill, and Louis-Dreyfus) now operate as cross-sectoral “value chain managers” on a truly global scale [48]. In 1996, Argentina became one of the first countries to permit the cultivation of GMO soy. GMO seeds from Argentina have been smuggled to Brazil, Paraguay, and Bolivia and were approved in these countries between 2003 and 2005 [23] (p. 254). This led to the establishment of highly profitable monocultures of soy based on increasing pesticide use and no-till farming. The Argentinian government strongly supported agricultural biotechnology. Both neoliberal (ca. 1990–2002) and developmentalist (2003–2015) administrations enthusiastically endorsed GM crops in Argentina and encouraged farmers to plant soy [49] (p. 706). Empirical studies have shown that soy exports in Argentina disproportionately benefit the elite [50], although they have also generated state revenues. Local farmers and agribusiness aligned with transnational companies such as Monsanto in the 1990s and 2000s to make large profits by using their land for the boom in soy production [49] (p. 701). In the 1970s and 1980s, state-owned agricultural institutes in Brazil and Argentina played a key role in developing a type of soy that is adapted to the specific weather and soil conditions in South America, but these institutes have been displaced by transnational companies and their seeds, which have

dominated the region since the 1990s [23] (pp. 253–254), [51]. In the 1990s, Brazil and Argentina were focused on exports, the deregulation of the banking system, and attempts to attract foreign direct investment in trade infrastructure such as ports, warehouses, and crushing facilities [23] (p. 254).

The most important resource for the soy complex is control over land. Industrial actors in the soy complex (e.g., large-scale farmers, corporations) have appropriated the land (independently from those who formally own it) and control land use [37] (p. 50), [52] (p. 62). In Paraguay and Bolivia, soy-isation went hand in hand with processes of land grabbing [31] (p. 65); in Argentina, farmers started leasing land to the emerging “sowing pools”, which are investment networks. This attracted all kinds of capital to the agricultural sector, most of it foreign, and generated large profits for the large-scale farmers and investors [35] (p. 68). This practice was partly exported to neighbouring countries [23] (p. 265). As soy production needs very few workers, smallholder farmers living in regions transformed by soy lose their opportunity to work and are often forced to move elsewhere—a process described as “productive exclusion” by McKay and Colque [37] (p. 50). Therefore, the expansion of soy in the Southern Cone has exacerbated existing social inequalities [31] (p. 152). These inequalities are difficult to overcome for multiple reasons: First, as shown above, they build on historical processes that have deeply shaped social structures in South America. Second, the elite is profiting from agrarian extractivism and has no interest in overcoming it and governments strongly support the strategy. This has led to the re-primarisation of soy-exporting countries [53] (p. 10), which are becoming ever more dependent on these exports. On the other side of the spectrum, the poor and marginalised are negatively affected by these strategies. Especially poor rural populations face health risks from agrochemical spraying, (partly violent) displacement, and expropriation [54] (p. 200). Among the peoples who are losing (access and control over) land, indigenous groups are disproportionately affected. Indigenous environmental activists who fight against extractivism face violence more often and more intensively than other people [55] (p. 9), [56] (p. 15).

Some studies have shown that agrarian extractivism also increases gender inequalities. The agribusiness sector and state institutions promoting the large-scale soy model are dominated and led by men. In the last few decades, women have been excluded from commercial agrarian production, a tendency that has been reinforced by the strong entry of financial investors and male-dominated techno-science into commodity production in general and the soy model in particular [54] (p. 206). Agrarian extractivism, therefore, has a gendered structure—an argument also made by other researchers looking into other flex crops such as palm oil production in Colombia, sugarcane, and oil in Ecuador. Diana Ojeda argues that agrarian extractivism in Colombia relies on, and deepens, gender disparities and gender-based violence. Men are often hired to work on the plantations and earn a salary, whereas the reproductive work of women subsidize the plantation model, exacerbating unequal gender relations [57]. A similar argument is made by Landívar García [58] analysing the gendered structure of agrarian extractivism concerning sugarcane in Ecuador. Looking at the chikungunya epidemic in the refinery city of Esmeraldas in Ecuador, a recent study concludes: “Extractivism exacerbates the already heavy burden of women’s care work, thus forming a central mechanism of the ‘illness-poverty trap’ by which ill health is both a consequence of and a contributor to inequalities” [59] (p. 169).

Soy expansion in Argentina and Brazil and its socio-ecological impact has generated discontent and protests among the negatively affected. In both countries, social movements are campaigning against the intensive use of pesticides associated with the soy model, question GMOs, and fight for food/seed sovereignty [49,60,61]. Nevertheless, as most of these protest movements operate on a local scale, they have been unable to stop the entire dynamic, and—at best—have only been able to limit local pesticide use. The soy economy can still count on support from the population because of its use of powerful narratives such as “feeding the world”, and because of the employment it generates in the countryside, as well as its contribution to “industrialisation” [37] (p. 45). Especially

during the pink tide, left-wing governments argued that soy exports were generating state revenues and that these enabled social welfare programs to be established and therefore helped reduce poverty and inequality. Despite the fact that soy exports do not reduce inequalities [62] (p. 33), [63] (p. 106), this narrative is still powerful and the social movements questioning the soy model have difficulties in gaining a voice.

Additionally, agribusiness has developed a strategy of presenting their activities as sustainable and as contributing to the fight against the climate crisis. Powerful actors from the agribusiness and biotechnology sectors in Argentina have appropriated the narrative of the bioeconomy and play a key role in the development of public policies on bioeconomy in the country [64,65]. This has contributed to a situation in which actors from these sectors have powerful voices in bioeconomy fora and they are the ones with which European bioeconomy proponents collaborate. In contrast, civil society actors that are more critical of the soy economy and its socio-environmental impact are not invited to these dialogues or networks. As such, contentious issues such as pesticides, environmental damage, the lack of decent jobs, and the re-primarisation of South American economies are not being tackled. This is even more dubious given that the bioeconomy is promoted as a strategy of transformation towards sustainable development—a goal which cannot be reached without the participation of civil society and marginalised groups and without addressing the aforementioned critical issues.

6. Results: Continuity and Change in the Global Soy Complex and Its Implications for the Bioeconomy

During this analysis, we have unfolded the conceptual thesis that the transformation of societies towards a sustainable bioeconomy, as envisioned by the German and other bioeconomy strategies, is unachievable in the narrow confines of existing bioeconomy policies. Focusing on the soy complex as a pivotal area in the agro-food system and an unavoidable background for such transformation, we have explored three dimensions of this argument.

1. We have shown how the soy complex developed during the changing historical context of successive food regimes that took place before the emergence of the current corporate food regime. This latest regime has increasingly transformed soy into a flex crop, and it has been instrumental in transnationalising global food markets and placing them under corporate control. The emergence, configuration, and crisis of food regimes shows the ways in which the development of the global agro-food system is embedded in fundamental processes of societal change on a historical scale.
2. Examining the issue through the lens of cheap food reveals that the consumption of cheap meat (produced with cheap soy) is intertwined with the production relations constituted by globalised supply chains. In terms of structural inequalities, we argued how the profits and the socio-ecological costs of the soy complex tend to be unevenly distributed between the centre and the periphery of the world system but also how transnational relations of exploitation and appropriation are not only intertwined but also constitutive of the agro-food system. The case of soy illustrates how the appropriation of unpaid labour and of natural resources in the production regions of this flex crop are entangled with the exploitation of wage labourers in urban centres around the world through the provision of cheap food or more specifically cheap meat. Against the backdrop of global inequalities, more empirical research is needed into the centrality of cheap meat to social peace, and the reproduction of the precarious workforce in the Global South and North, and how these relations are interrelated.
3. Finally, with respect to the power relations in the soy complex, a more detailed analysis of the situation in the central production areas in Latin America shows how transnational agribusiness mostly control the technological inputs and global trade of the soy complex, whereas national agrarian elites control the production of soy on expanding land areas. These groups are powerful political actors and can be contrasted with local farmers and social movements that are side-lined even under

left-wing governments. The power asymmetry in favour of agribusiness actors in countries such as Argentina transpires into the emerging bioeconomy as bioeconomy strategies are shaped under their influence.

These three dimensions describe the current shape of the soy complex that is at the heart of the global agro-food system and locate it in its societal context. It should be noted that other sectors of the global agro-food system have not been a subject of this article, which implies that no general overview of global inequalities across sectors and world regions was intended. Moreover, the dynamics identified in the soy complex and thereof derived findings cannot necessarily be transferred to other crop's production systems and their local and regional contexts. However, the social structures of the global soy complex and their historical trajectory, which we analysed as a key example for the global agro-food system, contradict most of the bioeconomy's claims to aspire towards sustainable development. The limitations of bioeconomy strategies are evident in their avoidance of the fundamental question of how the global interconnections and inequalities constituting the food regime can be addressed and changed. Instead, they focus on technological innovation ranging from the digitalisation of agriculture and the use of residues for bioenergy to artificial meat substitutes. In line with Moore, we have doubts about whether a bioeconomy could succeed in producing cheap food if it were not part of a food regime based on the exploitation of wage labour as well as appropriation of unpaid labour and natural resources.

7. Conclusions and Outlook: Limits and Perspectives of a Socio-Ecological Transformation towards a Sustainable Bioeconomy

In light of these findings, the question arises as to whether references to sustainability provide bioeconomy strategies with anything more than a "selling point" [66]. For example, the German strategy recognises that "Securing a global supply of food is and has always been a priority, and ethical principles and socially recognised goals such as environmental protection, landscape conservation and animal welfare must be accorded similarly high valuation" [8] (p. 10). However, the German strategy and even more so that of the European Commission stress that the bioeconomy is also about strengthening a country's own technological leadership in new biotechnological fields while securing jobs and green growth. Like most other official bioeconomy strategies, the German and EU strategies remain firmly within the framework of green capitalism [67]. In this perspective, the bioeconomy can be seen as an attempt to "green" the food regime without changing the underlying societal and power relations that have led to socio-ecological problems such as hunger and climate change. As has been shown elsewhere [68], a growing bioeconomy in Germany and the EU should be expected to aggravate these problems because of increased import demand for biomass. Bioeconomy policies which continue to rely on fundamental mechanisms of the current food regime and global capitalism more broadly, such as economic growth or extractivism, and which primarily seek innovative technological solutions to complex societal problems seriously limit the room for a transformation towards sustainability. These shortcomings of the bioeconomy as a strategy for societal transformation are recognised not least by many scientists from this field as a recent German survey by Zeug et al. [69] has shown:

"[M]ost respondents from the stakeholder group science encourage this vision, disagree with current developments, but as active carriers and advocates of ongoing social change hope for a more social and ecological sustainable bioeconomy and societal transformation. We conclude that according to most of the respondents, for a bioeconomy to be socially assertive and a successful sustainability transformation, it needs to go beyond business-as-usual and claim a global responsibility to provide a good life for all within planetary boundaries." [69] (p. 14)

We tend to agree with this view, but we do not expect a more sustainable bioeconomy to grow out of current policies. While other contributions explore ways to increase public involvement and stakeholder engagement in order to foster the democratic legitimacy and thus social sustainability of the bioeconomy [2,70], we propose instead a fundamental

rethink of the underlying understanding of socio-ecological transformation in bioeconomy strategies: the bioeconomy is more closely linked to classical ecological modernisation than transformation studies, which would demand radical structural change [71] (pp. 9–10). A democratic social-ecological transformation requires a deep understanding of the economic, political, and cultural structures of the prevailing food regime as part of modern capitalist society [72]. This type of analysis, which is also used in this study, demonstrate that the logics of expansion, appropriation, and growth need to be discarded. These logics form the foundation of—not least—current bioeconomy policies. Furthermore, political action is needed to ensure the decommodification of nature and the democratisation of society and societal nature relations in order to cope with the social-ecological crisis at hand [73] (pp. 169–170). Degrowth and decolonial environmental justice can be further guiding principles for a fundamental social-ecological transformation [74]. Especially in the Global North, a strategy of shrinkage and the reduction of raw material consumption is needed, in line with a perspective of sufficiency, resting on the insight that also bioeconomies need to acknowledge planetary boundaries in terms of land and energy. This would be the kind of radical change of the economy and society implied in the original concept of a bioeconomy as defined by Georgescu-Roegen in the 1970s [75]. From this vantage point, working towards social-ecological transformation means identifying and strengthening starting points for radical societal change on the basis of alternative designs and fields of experimentation, such as those used by social movements and agroecology. The overarching goal should be nothing less than reshaping the economy and the interrelation between society and nature in a democratic and just manner.

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