sustainability

MDPI

Article

New Forms of Land Grabbing Due to the Bioeconomy: The Case of Brazil

Eva Cudlínová [1,*], Valny Giacomelli Sobrinho [2], Miloslav Lapka [1] and Luca Salvati [3]

1 Department of Regional Management, Faculty of Economics, University of South Bohemia in České Budějovice, České Budějovice, 13 CZ-37005 Studentská, Czech Republic; mlapka@ef.jcu.cz
2 Department of Economics and International Relations, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul 97105-900, Brazil; valny.sobrinho@ufsm.br
3 Department of Economics and Law, University of Macerata, Via Armaroli 43, 62100 Macerata, Italy; luca.salvati@unimc.it
* Correspondence: evacu@ef.jcu.cz; Tel.: +420-387-772-506

Received: 19 March 2020; Accepted: 9 April 2020; Published: 22 April 2020

Abstract: The present study discusses new forms of land grabbing related to biofuel production in the light of bioeconomic development. With a specific focus on Brazil, this article debates whether biofuel production is associated with (i) an expansion of agricultural land use—regarded as a process of unsustainable crop intensification or (ii) an increase in crop yield, driven by technical innovation with stable land use—intended as a form of sustainable intensification. We conclude that, in the case of Brazil, the current bioeconomy cannot be assumed to be environmentally sustainable. Starting from Brazil's experience, the (apparent and latent) relationship between bioeconomy and land grabbing requires a refined investigation in both wealthier and emerging economies, with the aim of proposing effective strategies to achieve truly sustainable development in the primary sector.

Keywords: land grabbing; bioeconomy; sustainable intensification; biofuels; sugar cane; ethanol

1. Introduction

The relationship between the bioeconomy and land grabbing is a key issue in development theory and practice, being a relevant part of a more general sustainability discourse in the global competition for biomass. In the bioeconomy and bioenergy fields, competing claims on biomass and agricultural land for production are perceived as major obstacles to increasing sustainable biomass supply in the context of food security and environmental conservation [1,2]. Based on long wave theory, Lauka et al. [3] outlined the increasing competition in almost all economic sectors, driven by the continuous development of the bioeconomy. Policymakers' attempts to combat the unsustainable consequences of bioeconomic implementation form another important topic in the bioeconomy discourse [4,5]. "As markets alone will not suffice to fulfil this path transition towards a sustainable bioeconomy, we argue that innovative governance is necessary to reduce competitive drawbacks compared to fossil resources (enabling function) and to secure ecological, social, and economic sustainability requirements (limiting function)" [4]. Actual and potential conflicts involved in the implementation of the bioeconomy are mentioned as broader consequences of the UN sustainable development goals (17th SDG) in a study by Tobias Heimann [6]. Contradictions of the bioeconomy in terms of land grabbing are shown at both the theoretical and practical levels [7,8].

Our study debates whether biofuel production is associated with (i) an expansion of agricultural land use—regarded as a process of unsustainable crop intensification or (ii) an increase in crop yield, driven by technical innovation with stable land use—intended as a form of sustainable intensification. We used empirical data for sugarcane in Brazil. The aim of this study is to discuss whether the bioeconomy per se is not a direct way to sustainability. The present work is organized as follows: Section 2 defines land grabbing in its historical and present, context and the theoretical relationship between land grabbing and the bioeconomy [9]. Section 3 is devoted to clarifying the political/institutional position of Brazil in the field of bioeconomy, and Section 4 to the specific contribution to/impact of sugarcane on local (bioeconomic) development. Section 5 describes the practical side of sugarcane production in Brazil, introducing an operational exercise with the aim of verifying the theoretical assumptions proposed above (i.e., the bioeconomy as a self-evident strategy for sustainable development). Section 6 illustrates the main results from our analysis, discussing the originality and novelty of the present approach. Section 7 offers a brief conclusion, answering the main questions of the present study and providing indications of further investigations in the bioeconomy field.

2. Land Grabbing in a Global Context

Reflecting the extensive land ownership of transnational companies in a globalized framework, land grabbing is an economic phenomenon that has attracted the interest of scholars and practitioners in recent times. Land grabbing does not just mean "control of land"; it indicates a subtler control of the associated resources, such as soil, air, and water [10–12]. Land grabbing was primarily connected with the process of land colonization and food production in past centuries. Today's forms are not so transparent as there is no need of military invasion to gain access to land. The most recent global wave of land grabs has its own specific characteristics, since it occurs in a world of sovereign states exercising, at least formally, strict control of their land [13]. Current research has demonstrated that land grabbing reveals a sharp and intensifying global competition for land control [14]. Even the land grabbing observed today is based on previous environmental contexts, incorporating specific political and economic conditions. It is in the very long history of land grabbing that one can find, according to Wily [15] (p. 752), the establishment of "the legal manipulations which continue to make [land] rushes possible." The main drivers of current land grabs lie in the dynamics of capital accumulation strategies, set off largely in response to the convergence of multiple crises of food, energy/fuel, climate, and financial systems [8]. These crises also converged with the emerging needs for resources by newer hubs of global capital, especially within the BRICS countries.

The estimated amount of land with changing ownership in recent times ranges from 45 million hectares [16] to 227 million hectares [17]. Regardless of the exact amount, the importance of land grabbing as an issue of global governance is relatively well established in the agenda of the G8 and G20 networks, and is also at the core of the World Bank's new global development agenda. There is a problem, though, with confirming the validity of the data measuring the amount of real land use. This is due to unreliable statistics available for developing countries, underpinned by political unwillingness to work with precise information [18]. In discussions of land grabbing, two terms can be found in the literature: (i) the politically loaded notion of "land grabbing," which is increasingly used by radical social movements and their sympathizers, and (ii) the depoliticized "large-scale land investments" term, a more recent concept popularized by mainstream international development institutions and governments [19]. The main problem with this second term lies in the assumption that there is marginal land that could be effectively used by foreign capital, which could create new jobs and more efficient production. The term "land grabbing" is used in the present work, since it is more appropriate for the general meaning and understanding of the relationship with the bioeconomy [20].

So-called "green land grabbing," first mentioned by John Vidal as "the appropriation of land and resources for environmental ends," such as conservation enclosures, carbon sequestration, and trading programs, is a new idea [21]. Nowadays, land governance has appeared as an important topic on the agenda of policymakers and academics alike. Land is seen as a strategic resource with competition from many fields of human activity—from former food production to energy production and urban development [22–24]. Because of this new position, the importance of land grabbing is a topic in global governance: this is on the agenda of the Group of Eight (G8)/Group of Twenty (G20), and also at the core of the World Bank's new global development agenda.

As stated by Margulis et al. [25], there is a burgeoning body of academic literature, with studies taking up different perspectives: agrarian political economy [14,26], political ecology [21], as well as (iii) food security [27], food sovereignty [28], human rights [29], land use change [30], the role of the state [31], water grabbing [32], and neoliberalism [33]. What is missing is a specific literature focused on land grabbing and the bioeconomy, although indirect forms of this connection were documented in the literature mentioning biofuels and land grabbing [34].

3. The Growth of the Bioeconomy

The bioeconomy is a relatively new area of growth considered in political documents and developmental strategies all over the world [35]. However, in scientific and political reports, no consensus has been reached on a definition of the bioeconomic sector. Based on a widely discussed and accepted definition provided by the European Commission [36], the bioeconomy was intended to be "the production of renewable biological resources and the conversion of these resources and waste streams into value added products such as food, feed, bio-based products and bioenergy." Being increasingly regarded as a hegemonic concept, policymakers have often considered the bioeconomy as a sort of panacea responding to global environmental and socioeconomic problems. Adopting economic strategies oriented toward bioeconomy principles seems to guarantee a promising (i.e., environmentally sustainable and socially cohesive) development path [37–40]. Being a win-win solution, the bioeconomic paradigm may respond to the scarcity of natural resources, counteracting climate change and providing a solution to food security for a growing global population [41]. In other words, the bioeconomy can be envisaged as the assimilation of scientific principles "oriented toward sustainable development and environmental sustainability" into business and society [35].

The term "bioeconomy" is one of those contemporary notions that crop up regularly at the crossroads between socioeconomic and environmental dynamics. Various authors and institutions have used it in recent years to describe a new economic sector organized around industrial activities that both complement each other and compete for access to biomass [36,42]. Attaching the prefix "bio" to the term "economy" implies that this emerging sector works to bring economics and ecology together to achieve sustainable development. The bioeconomy is often mentioned as a concept very close to the circular economy. Although circular bioeconomy and bioeconomy are conceptually distinct [43], they essentially advocate the use of renewable resources to enact economy-wide changes, with the aim of offering viable alternatives to the current fossil fuel-based economy [44]. In this sense, the terms circular economy and bioeconomy are conceptually correlated [45] and can be used interchangeably.

The bioeconomy can be seen as a new branch of economics, a new paradigm, or just a specific part of the green economy based on biological resources and the application of biotechnology [46]. The bioeconomy could involve citizens, the service sector, and industrial and other economic sectors that produce, manage, and utilize resources such as agriculture, horticulture, fisheries, forestry, landscape, bioenergy, and biorefineries [1]. The "bio-based economy" tends to focus on raw materials, namely, natural and renewable biological resources, while the term "bioeconomy" tends to be used to designate biotechnology, life sciences, and other related technologies [47]. We can thus distinguish between three visions of what the bioeconomy constitutes [48].

The bioeconomy is crucial to the Sustainable Development Goals (SDGs), the core part of the 2030 Agenda for Sustainable Development [49], contributing specifically to SDG 1 (Zero Hunger), SDG 2 (Good Health and Well-Being), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). While referring to the environmentally friendly use of renewable resources [50], policymakers and scholars have increasingly considered the bioeconomy to be a self-evidently sustainable solution [51–53]. However, various authors have questioned the (supposedly) positive relationship between the bioeconomy and (general) sustainability.

More recent studies have given some critical views on the bioeconomy and its benefits to sustainability, based on three assumptions: (i) the expectation of benefits from the bioeconomy is dependent on fulfilling some conditions based on agglomeration and scale, and the specific use of local resources; (ii) potential pitfalls exist in the assumption that the bioeconomy is a truly sustainable strategy—even if the conditions mentioned above are satisfied; and (iii) the negative impact of the bioeconomy on general sustainability cannot be rejected, and some empirical evidence demonstrates that the bioeconomy is not compatible with truly sustainable development. These assumptions summarize the wider scientific debate on the relationship between the bioeconomy and sustainable development [54]. The present study assumes that the bioeconomy cannot be considered as a self-evidently sustainable strategy for regional/local development [55], arguing that its main advantage (i.e., the production of land resources) should be compared with its main disadvantage (i.e., increased environmental pressure in the form of land grabbing). In this line of thinking, this contribution will describe some potential pitfalls in bioeconomic theory and practice, specifically focusing on biofuel production and land grabbing in Brazil.

4. The Bioeconomy and New Forms of Land Grabbing

Assuming biofuels as a key outcome of the bioeconomy sector, a recent report delineated a global trend in land grabbing driven by ramped-up biofuel promotion and food-for-export initiatives [56]. Their production is tightly connected with the so-called "flex crops," a new commodity that has emerged in contemporary land grabbing. The main characteristic of the "flex crops" is their (marginal) utility. They may be used as food, feed, fuel, or as interchangeable industrial products. Examples include soya (feed, food, biodiesel), sugarcane (food, ethanol), oil palm (food, biodiesel, commercial/industrial use), and corn (food, feed, ethanol). Hence, multiple contexts of land grabs used for food, energy/fuel, and climate change mitigation strategies can be identified in each crop sector [19].

From a normative point of view, the bioeconomy and biofuel production are not always connected with land grabbing: sustainable production of biofuels is mentioned, for instance, in the European Union's Energy (EU) policy. Enhancing energy and food security and rural development at the same time, the EU qualified as a global leader in "sustainable biofuels" that can replace fossil fuels and thus reduce greenhouse gas emissions. Under the 2009 European Commission Renewable Energy Directive, 10% of all transport fuel should be based on renewable resources by 2020. In practical terms, biofuels will be a basic energy source, although there is an intrinsic lack of domestic production to fulfill this target in Europe. The EU target has been widely blamed for outsourcing its biofuel production, especially to the Global South—thus stimulating land grabs, raising food prices, and degrading natural resources [48].

Most assessments reveal that about 80% of the world's fuel wood supply is situated in Africa, Asia, and South America, and in regions that are distant from biomass markets and demand [1]. Under such conditions, the biomass could be traded internationally. The main source of biomass would likely be the regions mentioned above, which have low food security and agricultural production that is often not considered "sustainable" (e.g., due to deforestation to expand agricultural production). Such a scenario is highly controversial [57]. These economic dynamics have led to empirical studies addressing the environmental impact of agricultural productions in terms of Sustainable Intensification (SI) processes. Such cropping practices have been defined as a "radical rethinking of food production to achieve major reductions in its environmental impact" [58]. Sustainable intensification is based on the assumption that countries cannot continue to condone the expansion of cropland by forest clearcutting and the destruction of other natural ecosystems, as was common for a long time in the past [59]. Sustainable intensification could be implemented for both food and biofuel production [60]. Based on these premises, we attempt to take a broader view of the politics of land grabbing in the case of biofuel production in Brazil, with a specific focus on ethanol from sugarcane. Brazil is the second-largest bioeconomy producer in the world. Our work discusses whether biofuel production in

Brazil is based on cropland expansion or on increasing crop yields driven by innovation within the same crop surface, intended as a form of sustainable intensification [61].

5. The History and Present Situation of the Bioeconomy in Brazil

Local development based on a sort of bioeconomy strategy has been fostered in Brazil since the 1970s. In 1975, as a policy response to the 1973 oil crisis, the country started the world's first large-scale biofuel program [62]. Called "Proálcool" (an abbreviation for the National Fuel Alcohol Program [63]), this strategy was successful and 94% of the vehicles sold in Brazil were fully powered by hydrated ethanol by 1998 [64]. In the 1990s, when oil prices fell, the Proálcool program collapsed, with the removal of government quotas for sugar and ethanol production and because of the increased sugar exports. A partial recovery occurred in 2003 when the first Flexible Fuel Vehicles (FFVs), run on both gasoline and ethanol, were launched [65,66]. The current "Plan for Decadal Energy Expansion 2023" (PDE 2023) was adopted in 2014 (Figure 1).

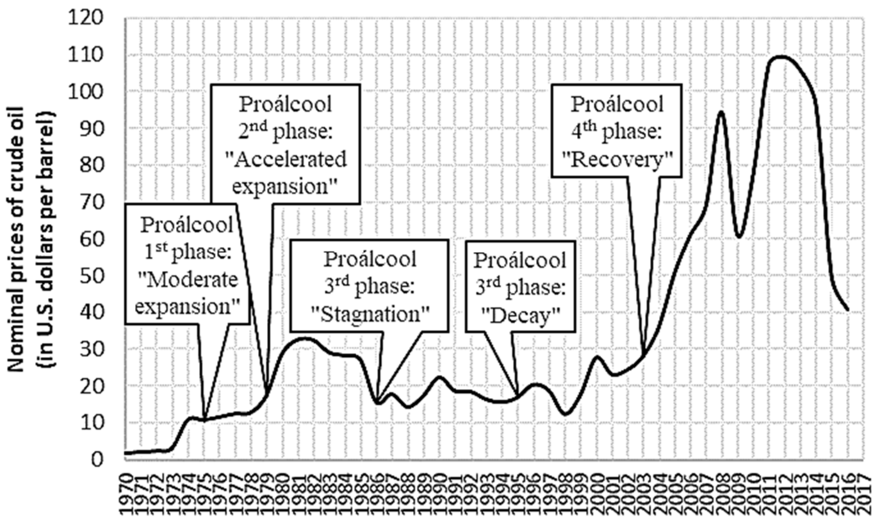

Figure 1. Proálcool phases and oil prices, 1970-2016. Sources: OPEC [67–69], Moraes et al. [65].

Since ethanol covers about a quarter of total fuel consumption within the country, Brazil stands out as a global leader in the bioenergy sector [63]. Regardless of its comparative advantages and lower costs of biomass production, especially from sugarcane [70], the country still lacks a dedicated bioeconomy strategy [63]. Bioenergy planning, carried out by the Brazilian Ministry of Mines and Energy (MME), and a biotechnology policy developed by the Ministry for Development, Industry and Foreign Trade (MDIC), are currently underway. While the former seeks to reduce Brazil's dependence on foreign oil and to foster rural development, the latter focuses on food security and health. However, across the bioeconomy value chain, energy production requires a higher volume of output and yields a smaller value added than the food and health sectors [70], thereby outlining the intrinsic trade-off between growing food or fuel.

Environmental and Economic Consequences of Ethanol Production from Sugarcane

Sugarcane in Brazil stands out because of (i) its comparative advantages and lower costs of biomass production, and (ii) its flexibility in the production of both sugar and ethanol, an appreciated biofuel [71]. Sugarcane was brought to Brazil in 1532 by the Portuguese conquerors. For 400 years, the main product obtained from this plant was sugar [65]. Only recently has ethanol become an economically feasible alternative for sugarcane growers. Today, Brazil is the world's largest sugarcane producer, the largest sugar producer and exporter, and the second-largest ethanol producer and exporter, following the United States of America [65,66,72]. The domestic demand and supply of sugarcane products account for nearly one-fifth of the country's energy matrix [73]. Brazil's bioenergy potential, however, was achieved with a sudden increase in cropland surface: 94% of new ethanol came from cropland expansion and only 6% from yield increase [74].

Actually, land use is a critical factor in future bioeconomy development. In colonial times (the 16th and 17th centuries) and in the first years of the Proálcool strategy, sugarcane crops were concentrated in the northeast and southeast regions of Brazil. Conversely, the latest sugarcane expansion, between 2000 and 2010, sprawled over the Cerrado ecological biome, in the central-western region of Brazil [62,65,75]. Cerrado is a savannah-type vegetation, whose 204 Mha, nearly one-quarter of the Brazilian territory [76], are dominated by lowland. As they are supposed to be suitable for agricultural mechanization, large-scale crops, and cattle raising, they have been extensively used for farming over the last 40–50 years [77]. The empirical findings reported in Table 1 document how farmland increase (+37 Mha) between 2000 and 2018 closely equaled the area lost by deforestation (−20 Mha) and Cerrado destruction (−19 Mha). The latest push of farmland expansion has been reinforced by the increasing (purchase and lease) land prices in the southeast region, as well as by tax exemptions and subsidized loans to sugarcane millers in Cerrado [65]. As a result, nearly half of this land (99 Mha) is currently devoted to crops and pasture [78].

Table 1. The evolution of vegetation cover in Brazil by year.

Year	Land Use Class								Total *	
	Farmland		Forests		Grassland and Savannah (Cerrado)		Urban Land, Wetlands, and Others			
	Area (Mha)	Share %	Area (Mha)	Share %	Area (Mha)	Share %	Area (Mha)	Share %	Area (Mha)	Share %
1985	177	20.9	467	55.1	169	19.9	34	4.0	848	100
1986	177	20.9	467	55.0	170	20.1	34	4.0	848	100
1987	182	21.5	464	54.7	168	19.9	34	4.0	848	100
1988	187	22.1	461	54.3	167	19.7	33	3.9	848	100
1989	191	22.5	459	54.1	165	19.4	34	4.0	848	100
1990	193	22.8	458	54.0	163	19.2	34	4.0	848	100
1991	196	23.1	457	53.9	162	19.1	34	4.0	848	100
1992	199	23.5	455	53.7	160	18.9	33	3.9	848	100
1993	202	23.8	453	53.4	159	18.8	34	4.0	848	100
1994	205	24.2	451	53.1	158	18.7	34	4.0	848	100
1995	209	24.7	448	52.8	157	18.5	34	4.0	848	100
1996	213	25.1	446	52.6	156	18.4	34	4.0	848	100
1997	216	25.5	443	52.3	155	18.3	34	4.0	848	100
1998	219	25.8	441	52.1	154	18.2	33	3.9	848	100
1999	221	26.1	439	51.8	153	18.1	34	4.0	848	100
2000	224	26.4	437	51.6	153	18.0	34	4.0	848	100
2001	226	26.6	436	51.4	152	17.9	34	4.0	848	100
2002	229	27.0	434	51.2	151	17.8	34	4.0	848	100
2003	233	27.5	430	50.7	150	17.7	34	4.0	848	100
2004	237	28.0	428	50.4	148	17.5	34	4.1	848	100
2005	240	28.3	426	50.2	147	17.4	34	4.1	848	100
2006	242	28.6	424	50.0	147	17.3	35	4.1	848	100
2007	244	28.7	423	49.9	146	17.3	35	4.1	848	100
2008	245	28.9	422	49.8	146	17.2	35	4.1	848	100
2009	246	29.0	422	49.7	146	17.2	35	4.1	848	100
2010	246	29.0	422	49.8	145	17.1	34	4.0	847	100
2011	247	29.1	422	49.7	144	17.0	35	4.1	847	100
2012	248	29.2	422	49.7	143	16.9	34	4.1	847	100
2013	249	29.4	421	49.7	142	16.8	34	4.1	847	100
2014	251	29.6	421	49.6	141	16.6	35	4.1	847	100
2015	253	29.8	420	49.5	140	16.5	35	4.1	847	100
2016	255	30.1	419	49.4	138	16.3	34	4.1	847	100
2017	257	30.3	418	49.3	137	16.2	35	4.1	847	100
2018	261	30.7	417	49.1	134	15.8	35	4.1	846	100

Source: Own elaboration based on Macedo [78] (p. 122) and on data from SEEG/OC [79]. (*) The difference (in the range of 2–4 Mha) from the actual Brazil's total surface area (850 Mha) is accounted for in a category called "Reassessment" [80] (p. 11) or "Unobserved" data [79]. This gap might arise from technical mapping or imagery limitations.

Nearly 50% of Cerrado has been reported to be unsuitable for sugarcane plantations [77]. The expansion of sugarcane crops in this region has also raised sustainability concerns about land suitability, biodiversity threat, soil and water contamination by pesticides and fertilizers, inefficient waste and water management, urban sprawl, and the increased risk of infectious diseases hosted by a larger rodent population [81]. However, sugarcane crops in Brazil have mainly been grown on degraded pasture land, previously established on the Cerrado area, rather than on land covered with natural (forest) vegetation [77,78]. Therefore, the land use changes driven by sugarcane production have been moderately harmful for natural ecosystems, since only one-third of the Brazilian territory is occupied by crop and range land. There are still 106 Mha of fertile land left, of which 65 Mha is in the Cerrado [82], thus turning Brazil into one of the world's biggest agricultural reserves [78]. At the same time, land use changes have resulted in a huge expansion of arable land—evidence of significant land grabbing in Brazil. Landscape transformations reflect the pressure of sugarcane producers. Although land availability is a factor underlying a development path oriented toward the bioeconomy, this raises concerns about "land grabbing" processes in connection with the recent explosion of (trans)national commercial land transactions and speculation driven by large-scale production and the export of food and biofuels [20]. These processes have usually been associated with a worldwide commodity price spike [83], particularly in internationally traded staple foods (maize, wheat, rice, and soy), in the aftermath of the 2007 global financial crisis [84].

Earlier studies hypothesized that bioeconomy production leads to land grabbing and consequent negative effects on nature and society. Research assumed that an increase in sugarcane production would not be offset by sustainable intensification [59], but instead would be at the expense of existing cropland. In other words, sugarcane yields will increase at a slower speed than that at which savannah or forests are converted into arable land. To make predictions about future trends, we extended the investigated time interval up to the year 2030. In order to test our hypothesis, we analyzed how yields evolve over time versus the amount of acreage used for cropping in the Cerrado, Brazil. The analysis was based on data provided by Companhia Nacional de Abastecimento, Brazil (CONAB) [85] and the FAO [86] that quantified sugarcane production (1961–2018), tons (t), area harvested (1961–2018), hectares (ha), and sugarcane productivity (1961–2018), tons per hectare (t/ha). A distinction between food (sugar) and fuel (ethanol) cropland was proposed from the data provided by MAPA [87] for sugar production (1961–2007) in tons; ethanol production (1961–2006) in liters; sugar productivity (1961–2007) in kilograms per ton of sugarcane; and ethanol productivity (1961–2006) in liters per ton of sugarcane.

6. Results and Discussion

Sugarcane production has traditionally been split into sugar (food) and ethanol (fuel) production. The yields of both sugar and ethanol crops were similar and thus were merged in the analysis (Equations (1) and (2)). A detailed description of the methodology and data used is given in the Appendix A. The yields (y) of sugar and ethanol crops were regressed against time (t) and the area of sugarcane harvested (H), as illustrated in Figures 2 and 3. As these figures show, the yields of both sugar and ethanol production will reach a maximum potential of 61.10 t/ha by the year 2023. From this peak onwards, yields are expected to fall (Table 2). The years 1950 and 2096 are the "zeroes" (roots) of the estimated quadratic function for the yield as a function of time. When we set the yield to zero in Equation (1) (Figure 1), we get the years when the yields were (1950) and will be (2096) null. Of course, none of these years falls within the scope of this analysis. Rather, they are just shown as reference points. For the production of either sugar or ethanol, the maximum output (374.57 Mt) would be collected from a harvest area no larger than 6.13 Mha (Table 2). Assuming that both commodities will be continuously produced, 12.26 Mha would be needed, which corresponds to about one-fifth of the fertile land (65 Mha) in the Cerrado area [82]. The maximum yield of sugarcane for ethanol or sugar will be achieved in 2023 (61.1 tons per hectare). From that year onwards, standard production and the Proálcool program, regardless of yield decrease, are expected to continue under Brazil's bioeconomy policy. This evidence goes along with the hypothesis that land grabbing is positively correlated with bioeconomic development. Therefore, the continuous expansion of the land area devoted to sugarcane seems to be economically inefficient. This shows that extensive processes of land grabbing, instead of sustainable intensification practices, are occurring and will occur in the near future.

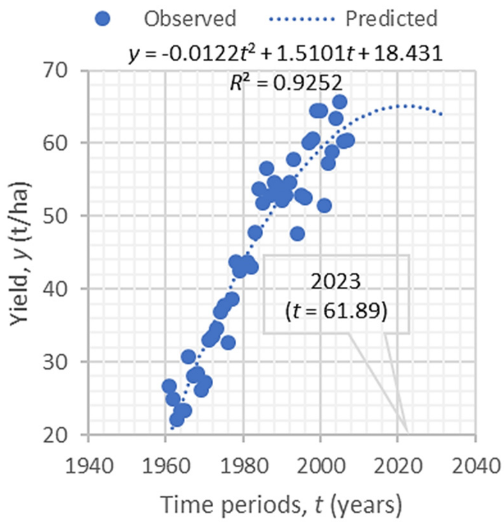

Figure 2. Yields of sugar/ethanol per year (from $t = 1 = 1961$ to $t = 80 = 2040$).

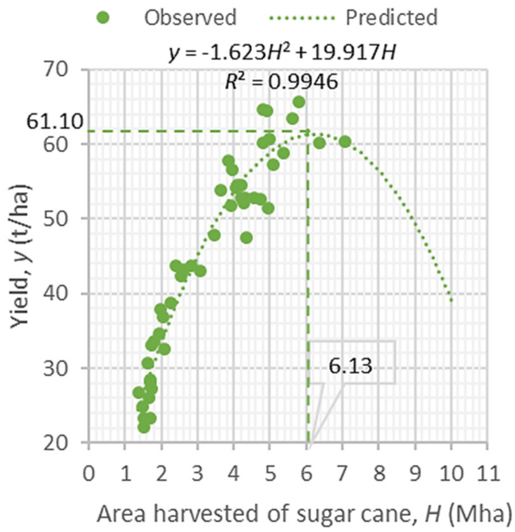

Figure 3. Yields of sugar/ethanol per area harvested of sugarcane.

Table 2. Predicted values and functions for sugar cane crop evolution in Brazil.

Functions/Variables	Sugar Cane Crop for Either Ethanol (Biofuel) or Sugar (Food)	Equation
$y = f(t)$	$y(t) = -0.0122t^2 + 1.5101t + 18.431$	(1)
$y = f(H)$	$y(H) = -1.623H^2 + 19.917H$	(2)
$y(t) = 0$	$t' = -11.2$ (1950); $t'' = 135$ (2096)	
$t_{max}(dy(t)/dt = 0)$	$t_{max} = 61.89$ (2023)	
$y(t)_{max}(dy(t)/dt = 0)$	61.10 t/ha	
$H_{max}(dy(H)/dH = 0)$	6.13 Mha	
$Q_{max}(= H_{max} \times y_{max})$	374.57 Mt	

Supposing that half of the 19 Mha of natural vegetation lost, according to Table 1, in the Cerrado area from 2000 to 2018 was devoted to growing food (sugar) and half to growing fuel (ethanol), these acreages can be substituted into Equation (2) to get $y = 42.7$ t/ha. This is a low yield estimate for both sugar and ethanol crops, as compared with the maximum of 61.1 t/ha, shown in Table 2 and Figures 1 and 2. The value we found for the maximum potential yield comes from calculus: the first derivative of a function stands for the rate at which this function changes (a crop yield is the rate at which its output changes per unit of input). We can find it by taking the first derivative of either Equation (1), with respect to time (t), or Equation (2), with respect to the area harvested (H), and by assuming it is equal to zero. In Equations (1) and (2), zero means that the function stops growing. Then, a value for either t (Equation (1)) or H (Equation (2)) is found that makes the corresponding first derivative equal to zero (Table 2). By substituting these values into the original Equation (1) or (2), we get the maximum yield. This low productivity level looks even worse when compared with the average yield of ethanol in the southeast of Brazil (82.4 t/ha), the country's largest region that specializes in sugarcane production [88].

Regardless of the methodological parsimony of the previous statistical analysis, the predictions laid out in Figures 2 and 3 keep track of the evolution of ethanol recorded in Figure 1. According to Figure 1, the ethanol economy and oil prices evolve together. Ethanol expansion follows rising oil prices, whereas ethanol decay comes after falling oil prices. Figure 1 shows that these prices have been plunging since 2013, while Figure 2 warns that the maximum yield of ethanol may be met by 2023. The likely coincidence of these two trends reinforces the pointless grabbing of land to grow sugarcane for ethanol production. Although not all land loss observed in Cerrado can be attributed to sugarcane growth, the results of this exercise outline the need for a more comprehensive analysis of intensive or extensive use of land in Brazil, and more broadly, in emerging economies under land-grabbing conditions. During 1961–2018, sugarcane yields grew by 0.92% per year, which is the difference between the growth of output (4.16% per year) and the growth of cropland (3.24% per year). As earlier studies document [62,72,77,78], the sugarcane crop has encouraged a more intensive use of land, because of a growth in productivity.

7. Conclusions

Although scholars have raised doubts about the supposedly positive relationship between bioeconomy and sustainability, this assumption remains the mainstream view in policy debates at national and supranational levels, and both policymakers and mainstream scholars still see the bioeconomy as a self-evidently sustainable solution to food scarcity and energy security. Bioeconomic development has been fostered in Brazil since the 1970s. Because ethanol covers about one-quarter of total fuel consumption within the country, Brazil stands out as a global leader in bioenergy from sugarcane. However, in the case of Brazil, the bioeconomy cannot be assumed to be a truly sustainable and environmentally friendly economic sector. This assumption requires a specific analysis, considering the benefits and constraints in a truly holistic perspective, i.e., evaluating together all the dimensions of sustainability (environment, society, economy). Under complex systems thinking [89], bioeconomy and the related production of bioresources might turn into main disadvantages, as in the case of economic pressure on land in the form of land grabbing.

Sugarcane production in Brazil has led, at least partially, to land grabbing with an impact on nature and society. This assumption is grounded on the evidence that growing sugarcane production is not covered by sustainable intensification, while depending on natural land conversion to cropland. The long-term bioeconomic development in Cerrado definitely supports the hypothesis that land grabbing has been intrinsically linked with bioeconomic production, despite the fact that the value added from bioeconomic crops for food and health products is higher per unit of output than for energy production from ethanol. Our results support the argument that the bioeconomy is not sustainable by itself and depends on external conditions, such as territorial characteristics and the history of development, as well as on local culture and its relationship with nature. To have a truly sustainable bioeconomic production system, some specific conditions should be fulfilled; a sustainable use of land, nature conservation, and sustainable intensification of agriculture are key aspects of this issue. A comparative (country-specific) analysis of the relationship between the bioeconomy and sustainability should take account of peculiar territorial characteristics, technologies, and crop systems over a sufficiently longtime horizon.

Author Contributions: Conceptualization, E.C. and M.L.; Database and Formal analysis, V.G.S.; Writing, L.S. and E.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by two projects: "Diversification of the influence of bioeconomy on forestry-timber sector strategic documents as a basis for state administration and proposal of strategic goals up to 2030"—Grant number NAZV QK1920391 and "POWER4BIO—emPOWERing regional stakeholders for realizing the full potential of European BIOeconomy," part of the European Union's Horizon 2020 research and innovation program, under Grant Agreement No. 818351.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The methodological approach proposed in this article relies on a statistical regression analysis of productivity levels of sugar/ethanol crops (γ, in Equation (A1)) in particular, as compared with those of sugarcane crops (y, in Equation (A2)) in general. Of course, there are several other factors (production costs and revenues; land prices; land ownership structure; food, ethanol and oil prices; interest and exchange rates) that might be included to create a more elaborate model. However, this simpler analytical tool focuses on an acknowledged key driver of land use change. The first question is whether and to what extent the increase in crop yields might avoid land grabbing of forests and savannahs [74]. In addition to farmland expansion, recent agrarian policies that are required to demonstrate the "productive" use of land in Brazil have encouraged both deforestation [90] and the clearance of vegetation coverage. So, in any event, land productivity has been an important driver of land use change. Moreover, crop yield can help with assessing the widespread claim that the development of export-led farmland in Brazil has not been taking over any additional land, but just overriding unproductive pasture land [62,72,75,91]. Therefore, the sprawl of sugarcane within the country is supposed to result from a combination of cropland expansion and productivity increase [91]. The present analysis is based on data provided by a few sources. From the FAO [86], data on area harvested (in Mha – megahectares), production (in Mt—megatons), and yield (in t/ha—tons per hectare) of sugarcane were obtained. Additionally, data on output (in liters, L, or tons, t) and yield (in liters per ton, L/t, or kilograms per ton, kg/t, of sugar cane) of ethanol and sugar were supplied by MAPA [87].

$$Q_i = q_i/\gamma_i \tag{A1}$$

$$y_i = Q_i/H_i, \tag{A2}$$

where i stands for the output type (ethanol or sugar) per crop; Q is the total supply of sugar cane (in tons, t); q is the total production of either ethanol (in liters, L) or sugar (in kilograms, kg); γ is the productivity, per ton of sugar cane, of growing the output type i (ethanol, in *L/t*, or sugar, in *kg/t*); H is the area harvested of sugarcane (in hectares, *ha*); and y is the land productivity of growing sugarcane (in *t/ha*). A simplifying assumption is that all sugarcane cropland is allotted to produce either ethanol or sugar. Based on this information, some calculations (Equations (A1) and (A2)) were carried out to arrive at figures of yield (land productivity, y_i), for either kind of output (ethanol and sugar) produced by sugar cane crops, in terms of tons per hectare (*t/ha*). Observed and worked-out quantities are displayed in Table A1.

This is a necessary step to estimate yield functions (Table 2) over time (Equation (1)) and with respect to the area harvested of sugar cane (Equation (2)). Provided that the time and level of the maximum yield can be determined, it is possible to estimate how much land is needed and when for sugar cane crops to reach their maximum productivity (and output), either to produce food (sugar) or biofuel (ethanol) (Figures 1 and 2). Beyond this point, productivity levels will go down, and hence any additional use of agricultural land is economically inefficient and ecologically ineffective. If all this additional land is used for bioenergy production, the bioeconomy, in this case, will lead to an unsustainable crop intensification (land grabbing). Finally, the roots of the yield function with respect to time estimate the years when productivity levels were (1961 − 11.2 ≈ 1950) and will be (1961 + 135 = 2096) zero.

Table A1. Area harvested, output, and yields for sugar cane crops in Brazil.

Year	H [a]	q (ethanol) [c]	q (sugar) [c]	γ (ethanol) [c]	γ (sugar) [c]	Q Equation (A1)	y Equation (A2)
	(Mha) [b]	(L)	(kg)	(L/t)	(kg/t)	(Mt)[b]	(t/ha)
1961	1.37	456,302,000	3,260,920,000	12.48	89.22	36.55	26.74
1962	1.47	427,520,000	3,385,946,000	11.73	92.90	36.45	24.85
1963	1.51	343,717,000	3,064,701,000	10.32	91.99	33.32	22.08
1964	1.52	405,476,000	3,098,650,000	11.45	87.51	35.41	23.30
1965	1.71	386,962,000	3,565,239,000	9.69	89.29	39.93	23.42
1966	1.64	602,707,000	4,558,836,000	12.01	90.86	50.17	30.68
1967	1.68	727,478,000	4,115,837,000	15.36	86.93	47.35	28.17
1968	1.69	676,262,000	4,215,588,000	14.07	87.73	48.05	28.49
1969	1.67	473,645,000	4,111,744,000	10.86	94.30	43.60	26.08
1970	1.73	461,609,000	4,332,853,000	9.82	92.22	46.98	27.24
1971	1.73	637,150,000	5,119,866,000	11.16	89.70	57.08	33.03
1972	1.80	613,068,000	5,386,635,000	10.13	88.98	60.54	33.58
1973	1.96	680,972,000	5,932,698,000	10.03	87.41	67.87	34.65
1974	2.06	665,979,000	6,683,180,000	8.78	88.12	75.84	36.88
1975	1.97	594,985,000	6,720,846,000	7.99	90.20	74.51	37.84
1976	2.09	555,627,000	5,887,832,000	8.13	86.18	68.32	32.63
1977	2.27	664,322,000	7,208,502,000	7.56	82.08	87.82	38.69
1978	2.39	1,470,404,000	8,307,942,000	14.05	79.40	104.63	43.75
1979	2.54	2,490,603,000	7,342,718,000	23.14	68.22	107.63	42.43
1980	2.61	3,396,452,000	6,646,226,000	30.15	59.00	112.65	43.20
1981	2.83	3,706,375,000	8,100,269,000	29.97	65.49	123.69	43.77
1982	3.08	4,240,123,000	7,935,321,000	31.91	59.72	132.88	43.08
1983	3.48	5,823,039,000	8,857,127,000	35.04	53.30	166.17	47.77
1984	3.66	7,864,246,000	9,086,084,000	39.97	46.18	196.75	53.82
1985	3.91	9,192,329,000	8,818,155,000	45.31	43.47	202.86	51.85
1986	3.94	11,931,599,000	7,819,255,000	53.46	35.03	223.22	56.59
1987	4.31	10,506,712,000	8,157,204,000	46.11	35.80	227.85	52.88
1988	4.11	11,458,396,000	7,985,222,000	51.04	35.57	224.49	54.58
1989	4.07	11,644,882,000	8,070,184,000	52.91	36.67	220.08	54.10
1990	4.27	11,920,475,000	7,214,049,000	53.48	32.36	222.93	52.18
1991	4.21	11,515,151,000	7,365,341,000	51.77	33.11	222.45	52.83
1992	4.20	12,722,233,000	8,530,462,000	55.50	37.21	229.25	54.55
1993	3.86	11,729,491,000	9,264,149,000	52.49	41.46	223.45	57.83
1994	4.35	11,292,185,000	9,162,135,000	54.67	44.36	206.54	47.53
1995	4.56	12,765,910,000	11,700,465,000	53.00	48.58	240.85	52.83
1996	4.75	12,716,759,000	12,651,084,000	50.89	50.63	249.87	52.60
1997	4.81	14,430,449,000	13,631,888,000	49.84	47.08	289.55	60.15
1998	4.99	15,422,253,000	14,847,044,000	51.03	49.13	302.20	60.61
1999	4.90	13,926,821,000	17,960,587,000	44.12	56.90	315.65	64.43
2000	4.80	13,077,765,000	19,380,197,000	42.17	62.49	310.13	64.55
2001	4.96	10,517,535,000	16,020,340,000	41.26	62.84	254.94	51.42
2002	5.10	11,467,795,000	18,994,363,000	39.23	64.98	292.31	57.31
2003	5.37	12,485,426,000	22,381,336,000	39.50	70.80	316.12	58.86
2004	5.63	14,639,923,000	24,944,434,000	41.00	69.85	357.11	63.41
2005	5.81	15,207,909,000	26,632,074,000	39.87	69.82	381.44	65.70
2006	6.36	15,808,184,000	26,214,391,000	41.33	68.54	382.47	60.18
2007	7.08	—	30,629,827,000	41.89	71.65	427.49	60.37

Sources: MAPA [87], FAO [86]; (a) FAO [86]; (b) Mha = 10^6 ha, Mt = 10^6 t; (c) MAPA [87].

References

1. Lewandowski, I. Securing a sustainable biomass supply in a growing bioeconomy. *Glob. Food Sec.* **2015**, *6*, 34–42. [CrossRef]
2. Lewandowski, I. (Ed.) *Bioeconomy: Shaping the Transition to a Sustainable, Biobased Economy*; Springer: Cham, Switzerland, 2018. [CrossRef]
3. Lauka, D.; Slisane, D.; Ievina, L.; Muizniece, I.; Blumberga, D. When Bioeconomy Development Becomes a Biomass Energy Competitor. *Environ. Clim. Technol.* **2019**, *23*, 347–359. [CrossRef]
4. Gawel, E.; Nadine Pannicke, N.; Hagemann, N. A Path Transition Towards a Bioeconomy—The Crucial Role of Sustainability. *Sustainability* **2019**, *11*, 3005. [CrossRef]
5. Dietz, T.; Börner, J.; Förster, J.J.; Von Braun, J. Governance of the Bioeconomy: A Global Comparative Study of National Bioeconomy Strategies. *Sustainability* **2018**, *10*, 3190. [CrossRef]

6. Heimann, T. Bioeconomy and SDGs: Does the Bioeconomy Support the Achievement of the SDGs? *Earths Future* **2018**, *7*, 43–57. [CrossRef]
7. Kitchen, L.; Marsden, T. Constructing sustainable communities: A theoretical exploration of the bio-economy and eco-economy paradigms. *Local Environ.* **2011**, *16*, 753–769. [CrossRef]
8. McMichael, P. The land grab and corporate food regime restructuring. *J. Peasant Stud.* **2012**, *39*, 681–701. [CrossRef]
9. Lazarus, E.D. Land grabbing as a driver of environmental change. *Area* **2014**, *46*, 74–82. [CrossRef]
10. Carlini, M.; Mosconi, E.M.; Castellucci, S.; Villarini, M.; Colantoni, A. An economical evaluation of anaerobic digestion plants fed with organic agro-industrial waste. *Energies* **2017**, *10*, 1165. [CrossRef]
11. Marucci, A.; Zambon, I.; Colantoni, A.; Monarca, D. A combination of agricultural and energy purposes: Evaluation of a prototype of photovoltaic greenhouse tunnel. *Renew. Sustain. Energy Rev.* **2018**, *82*, 1178–1186. [CrossRef]
12. Monarca, D.; Cecchini, M.; Guerrieri, M.; Colantoni, A. Conventional and alternative use of biomasses derived by hazelnut cultivation and processing. *Acta Hortic.* **2009**, *845*, 627–634. [CrossRef]
13. Sassen, S. Land grabs today: Feeding the Disassembling of National Territory. *Globalizations* **2013**, *10*, 25–46. [CrossRef]
14. Peluso, N.L.; Lund, C. New frontiers of land control. *J. Peasant Stud.* **2011**, *38*, 667–681. [CrossRef]
15. Wily, L.A. Looking back to see forward: The legal niceties of land theft in land rushes. *J. Peasant Stud.* **2012**, *39*, 751–775. [CrossRef]
16. Deininger, K.; Byerlee, D.; Lindsay, J.; Norton, A.; Harris, S.; Stickler, M. *Rising Global Interest in Farmland: Can it Yield Sustainable and Equitable Results?* World Bank, U.S.: Washington, DC, USA, 2010. Available online: https://siteresources.worldbank.org/DEC/Resources/Rising-Global-Interest-in-Farmland.pdf (accessed on 13 March 2020).
17. Oxfam. *Land and Power: The Growing Scandal Surrounding the New Wave of Investments in Land, Available*; Oxfam: Oxford, UK, 2012. Available online: https://oxfamilibrary.openrepository.com/bitstream/10546/142858/32/bp151-land-power-rights-acquisitions-220911-en.pdf (accessed on 13 March 2020).
18. Franco, J.; Borras, S.; Fradejas, A.A.; Buxton, N.; Herre, R.; Kay, S.; Feodoroff, T. *The Global Land Grab. A Primer*, revised ed.; Transnational Institute (TNI) Agrarian Justice Programme: Amsterdam, The Netherlands, 2013. Available online: https://www.tni.org/files/download/landgrabbingprimer-feb2013.pdf (accessed on 10 May 2018).
19. Borras, S.M., Jr.; Franco, J.C.; Gomez, S.; Kay, C.; Spoor, M. Land grabbing in Latin America and the Caribbean. *J. Peasant Stud.* **2012**, *39*, 845–872. [CrossRef]
20. Borras, S.M., Jr.; Franco, J.C. Global Land Grabbing and Trajectories of Agrarian Change: A Preliminary Analysis. *J. Agrar. Chang.* **2012**, *12*, 34–59. [CrossRef]
21. Fairhead, J.; Leach, M.; Scoones, I. Green Grabbing: A New Appropriation of Nature? *J. Peasant Stud.* **2012**, *39*, 237–261. [CrossRef]
22. Anifantis, A.S.; Colantoni, A.; Pascuzzi, S.; Santoro, F. Photovoltaic and hydrogen plant integrated with a gas heat pump for greenhouse heating: A mathematical study. *Sustainability* **2018**, *10*, 378. [CrossRef]
23. Boubaker, K.; Colantoni, A.; Marucci, A.; Longo, L.; Gambella, F.; Cividino, S.; Cecchini, M. Perspective and potential of CO_2: A focus on potentials for renewable energy conversion in the Mediterranean basin. *Renew. Energy* **2016**, *90*, 248–256. [CrossRef]
24. Cecchini, M.; Cossio, F.; Marucci, A.; Monarca, D.; Colantoni, A.; Petrelli, M.; Allegrini, E. Survey on the status of enforcement of European directives on health and safety at work in some Italian farms. *J. Food Agric. Environ.* **2013**, *11*, 595–600.
25. Margulis, M.E.; McKeon, N.; Borras, S.M. Land grabbing and global governance: Critical perspectives. *Globalizations* **2013**, *10*, 1–23. [CrossRef]
26. White, B.; Borras, S.M.; Hall, R.; Scoones, I.; Wolford, W. The new enclosures: Critical perspectives on corporate land deals. *J. Peasant Stud.* **2012**, *39*, 619–647. [CrossRef]
27. Robertson, B.; Pinstrup-Andersen, P. Global land acquisition: Neo-colonialism or development opportunity? *Food Secur.* **2010**, *2*, 271–283. [CrossRef]
28. Rosset, P. Food Sovereignty and alternative paradigms to confront land grabbing and the food and climate crises. *Development* **2011**, *54*, 21–30. [CrossRef]

29. De Schutter, O. How not to think of land-grabbing: Three critiques of large-scale investments in farmland. *J. Peasant Stud.* **2011**, *38*, 249–279. [CrossRef]
30. Friis, C.; Reenberg, A. *Land Grab in Africa: Emerging Land System Drivers in a Teleconnected World. GLP Report No. 1*; The Global Land Project (GLP-IPO): Copenhagen, Denmark, 2010. Available online: https://www.academia.edu/16977510/Land_Grab_in_Africa_Emerging_land_system_drivers_in_a_teleconnected_world (accessed on 20 January 2020).
31. Wolford, W.; Borras, S.M.; Hall, R.; Scoones, I.; White, B. Governing global land deals: The role of the state in the rush for land. *Dev. Chang.* **2013**, *44*, 189–210. [CrossRef]
32. Mehta, L.; van Veldwisch, G.; Franco, J.C. Introduction to the special issue: Water grabbing? Focus on the (re)approriation of finite water resources. *Water Altern.* **2012**, *5*, 193–207.
33. Araghi, F.; Karides, M. Land dispossession and global crisis: Introduction to the special section on land rights in the world-system. *J. World-Syst. Res.* **2012**, *18*, 1–5. [CrossRef]
34. Støen, M.A. Beyond Transnational Corporations, Foodand Biofuels: The Role of Extractivism and Agribusiness in Land Grabbing in Central America. *Forum Dev. Stud.* **2016**, *43*, 155–175. [CrossRef]
35. OECD. *The Bioeconomy to 2030: Designing a Policy Agenda*; OECD Publishing: Paris, France, 2009. Available online: http://www.oecd.org/futures/long-termtechnologicalsocietalchallenges/thebioeconomyto2030designingapolicyagenda.htm (accessed on 13 March 2020).
36. European Commission. *Innovating for Sustainable Growth: A Bioeconomy for Europe (COM(2012) 60 final)*; European Commission: Brussels, Belgium, 2012. Available online: https://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf (accessed on 13 March 2020).
37. Salvati, L.; Zitti, M. Regional convergence of environmental variables: Empirical evidences from land degradation. *Ecol. Econ.* **2008**, *68*, 162–168. [CrossRef]
38. Salvati, L.; Perini, L.; Sabbi, A.; Bajocco, S. Climate Aridity and Land Use Changes: A Regional-Scale Analysis. *Geogr. Res.* **2012**, *50*, 193–203. [CrossRef]
39. Ferrara, A.; Salvati, L.; Sabbi, A.; Colantoni, A. Soil resources, land cover changes and rural areas: Towards a spatial mismatch? *Sci. Total Environ.* **2014**, *478*, 116–122. [CrossRef] [PubMed]
40. Colantoni, A.; Ferrara, C.; Perini, L.; Salvati, L. Assessing trends in climate aridity and vulnerability to soil degradation in Italy. *Ecol. Indic.* **2015**, *48*, 599–604. [CrossRef]
41. BECOTEPS. *The European Bioeconomy in 2030. Delivering Sustainable Growth by Addressing the Grand Societal Challenges*; BECOTEPS—Bio-Economy Technology Platforms: Brussels, Belgium, 2011. Available online: http://www.epsoweb.org/file/560 (accessed on 13 March 2020).
42. OECD. *Biomass for a Sustainable Bioeconomy: Technology and Governance (No.DSTI/STP/BNCT(2016)7/FINAL)*; Organisation for Economic Co-operation and Development, OECD: Paris, France, 2016. Available online: https://one.oecd.org/document/DSTI/STP/BNCT(2016)7/en/pdf (accessed on 7 February 2020).
43. Leipold, S.; Petit-Boix, A. The circular economy and the bio-based sector: Perspectives of European and German stakeholders. *J. Clean. Prod.* **2018**, *201*, 1125–1137. [CrossRef]
44. D'Amato, D.; Korhonen, J.; Toppinen, A. Circular, Green, and Bio economy: Ow do companies in land-use intensive sectors align with sustainability concepts? *Ecol. Econ.* **2019**, *158*, 116–133. [CrossRef]
45. Korhonen, J.; Honkasalo, A.; Seppala, J. Circular economy: The concept and its limitations. *Ecol. Econ.* **2018**, *143*, 37–46. [CrossRef]
46. Maciejczak, M.; Hofreiter, K. How to define bioeconomy? *Rozczniki Nauk.* **2013**, *15*, 243–248. Available online: http://maciejczak.pl/download/15-4-Maciejczak.pdf (accessed on 7 February 2020).
47. Staffas, L.; Gustavsson, M.; McCormick, K. Strategies and policies for the bioeconomy and bio-based economy: An analysis of official national approaches. *Sustainability* **2013**, *5*, 2751–2769. [CrossRef]
48. Levidow, L. EU criteria for sustainable biofuels: Accounting for carbon, depoliticising plunder. *Geoforum* **2013**, *44*, 211–223. [CrossRef]
49. Bioeconomy World Summit. *Innovation, Growth and Sustainable Development: Bioeconomy World Summit 2018*; Federal Ministry of Education and Research: Berlin, Germany, 2018. Available online: http://gbs2018.com/home/ (accessed on 12 October 2018).
50. Salvati, L.; Carlucci, M. The economic and environmental performances of rural districts in Italy: Are competitiveness and sustainability compatible targets? *Ecol. Econ.* **2011**, *70*, 2446–2453. [CrossRef]
51. Tanksale, A.; Beltramini, J.N.; Lu, G.M. A review of catalytic hydrogen production processes from biomass. *Renew. Sustain. Energy Rev.* **2010**, *14*, 166–182. [CrossRef]

52. Bruins, M.E.; Sanders, J.P.M. Small-scale processing of biomass for biorefinery. *Biofuels Bioprod. Biorefin.* **2012**, *6*, 135–145. [CrossRef]
53. Navia, R.; Mohanty, A.K. Resources and waste management in a bio-based economy. *Waste Manag. Res.* **2012**, *30*, 215–216. [CrossRef] [PubMed]
54. Pfau, S.F.; Hagens, J.E.; Dankbaar, B.; Smits, A.J.M. Visions of Sustainability in Bioeconomy Research. *Sustainability* **2014**, *6*, 1222–1249. [CrossRef]
55. Salvati, L.; Carlucci, M. A composite index of sustainable development at the local scale: Italy as a case study. *Ecol. Indic.* **2014**, *43*, 162–171. [CrossRef]
56. GRAIN. *Seized: The 2008 Land Grab for Food and Financial Security*; GRAIN: Barcelona, Spain, 2008. Available online: https://www.grain.org/article/entries/93-seized-the-2008-landgrab-for-food-and-financial-security (accessed on 13 March 2020).
57. Cudlínová, E.; Lapka, M.; Vávra, J. Bioeconomy as a New Perspective for Solving Climate Change? In *The Role of Integrity in the Governance of the Commons: Governance, Ecology, Law, Ethics*; Westra, L., Gray, J., Gottwald, F.T., Eds.; Springer: Cham, Switzerland, 2017; pp. 155–166. [CrossRef]
58. Garnett, T.; Appleby, M.C.; Balmford, A.; Bateman, I.J.; Benton, T.G.; Bloomer, P.; Burlingame, B.; Dawkins, M.; Dolan, L.; Fraser, D.; et al. Sustainable Intensification in Agriculture: Premises and Policies. *Science* **2013**, *341*, 33–34. [CrossRef] [PubMed]
59. McDonagh, J. Rural geography III: Do we really have a choice? The bioeconomy and future rural pathways. *Prog. Hum. Geogr.* **2014**, *39*, 658–665. [CrossRef]
60. Petrick, M.; Wandel, J.; Karsten, K. Rediscovering the virgin lands: Agricultural investment and rural livelihoods in a Eurasian frontier area. *World Dev.* **2013**, *43*, 164–179. [CrossRef]
61. Cudlínová, E.; Giacomelli Sobrinho, V.; Lapka, M.; Vávra, J. Bioeconomy as a New Phenomenon in Land Grabbing: The Case of Brazil. In *Ecological Integrity and Land Uses: Sovereignty, Governance, Displacements and Land Grabs*; Westra, L., Bosselmann, K., Zambrano, V., Eds.; Nova Science Publishers, Inc.: Hauppauge, NY, USA, 2019.
62. Assunção, J.; Chiavari, J. Towards Efficient Land Use in Brazil. Climate Policy Initiative, the New Climate Economy, the Global Commission on Climate and Economy. 2015, pp. 1–27. Available online: http://newclimateeconomy.report/2015/wp-content/uploads/sites/3/2015/09/Towards-Efficient-Land-Use-Brazil.pdf (accessed on 13 March 2020).
63. German Bioeconomy Council. *Bioeconomy in Brazil*; German Bioeconomy Council, Bioökonomie.de: Berlin, Germany, 2015. Available online: https://biooekonomie.de/en/article-map (accessed on 27 September 2018).
64. Ohashi, F.H. *The Adevent, Growing, Crisis and Abandonnment from Proalcool*; Unicamp: Campinas, SP, Brazil, 2008.
65. De Moraes, M.L.; Rumenos, M.; Bacchi, P. Ethanol: From the Beginning to the Production Starting Stage. *Rev. Polit. Agric.* **2014**, *23*, 5–22.
66. Scheiterle, L.; Ulmer, A.; Birner, R.; Pyka, A. From Commodity-Based Value Chains to Biomass-Based Value Webs: The Case of Sugarcane in Brazil's Economy. *J. Clean. Prod.* **2018**, *172*, 3851–3863. [CrossRef]
67. Organization of the Petroleum Exporting Countries (OPEC). *OPEC Annual Statistical Bulletin 2017*; OPEC: Vienna, Austria, 2017. Available online: https://www.opec.org/opec_web/static_files_project/media/downloads/publications/ASB2017_13062017.pdf (accessed on 10 September 2018).
68. Organization of the Petroleum Exporting Countries (OPEC). *OPEC Annual Statistical Bulletin 2013*; OPEC: Vienna, Austria, 2013. Available online: https://www.opec.org/opec_web/static_files_project/media/downloads/publications/ASB2013.pdf (accessed on 10 September 2018).
69. Organization of the Petroleum Exporting Countries (OPEC). *OPEC Annual Statistical Bulletin 2005*; OPEC: Vienna, Austria, 2006. Available online: https://www.opec.org/opec_web/static_files_project/media/downloads/publications/ASB2005.pdf (accessed on 10 September 2018).
70. HBR Brasil, (Harvard Business Review Analytical Services) HBR. *Bioeconomy: An Agenda for Brazil*; National Confederation of Industry (CNI): São Paulo, Brazil, 2013. Available online: http://arquivos.portaldaindustria.com.br/app/conteudo_24/2013/10/18/411/20131018135824537392u.pdf (accessed on 13 March 2020).
71. Gazzoni, D.L. *The Impact of Using the Soil in the Sustainability of Biofuel*; Embrapa Soya: Londrina, PR, Brazil, 2014. Available online: https://www.infoteca.cnptia.embrapa.br/bitstream/doc/976599/1/Doc347.pdf (accessed on 13 March 2020).
72. Assunção, J.; Pietracci, B.; Souza, P. *Fueling Development: Sugarcane Expansion Impacts in Brazil*; INPUT (Land Use Initiative), Climate Policy Initiative: Rio de Janeiro, Brazil, 2016; pp. 1–55.

73. EPE, Brazilian Energy Research Office. *Brazilian Energy Balance 2017: Year 2016*; EPE, Energetical Research Enterprise: Rio de Janeiro, Brazil, 2017.
74. Sant'Anna, M. *How Green Is Sugarcane Ethanol?* Department of Economics, Yale University: New Haven, CT, USA, 2015. Available online: https://economics.yale.edu/sites/default/files/santanna-how_green_is_sugarcane_ethanol.pdf (accessed on 25 September 2018).
75. De Arruda, M.R.; Giller, K.E.; Slingerland, M. Where Is Sugarcane Cropping Expanding in the Brazilian Cerrado, and Why? A Case Study. *An. Acad. Bras. Ciênc.* **2017**, *89*. [CrossRef]
76. MMA, Environment Department. *Brazil. Savanna Using and Cover Mapping: TerraClass Project Savanna 2013*; MMA/Secretaria de Biodiversidade e Florestas (SBF): Brasília, DF, Brazil, 2015.
77. Goldemberg, J.; Coelho, S.T.; Guardabassi, P. The Sustainability of Ethanol Production from Sugarcane. *Energy Policy* **2008**, *36*, 2086–2097. [CrossRef]
78. Macedo, Isaias de Carvalho (org.). *The Sugar Cane's Energy: Twelve studies on Brazilian Sugar Cane Agribusiness and Its Sustainability*; UNICA, Sugar Cane Agroindustry Union: São Paulo, Brazil, 2007. Available online: https://sugarcane.org/wp-content/uploads/2018/04/Sugar-Canes-Energy-Full-book.pdf (accessed on 13 March 2020).
79. SEEG/OC, System of Greenhouse Gases Estimates of the Observatory of Climate. MapBiomas. Coleção 4.1. 2020. Available online: https://plataforma.mapbiomas.org/stats (accessed on 20 March 2020).
80. IBGE, Brazilian Institute of Geography and Statistics. *The Changes in the Cover and in the Use of The Brazilian Soil 2000–2010–2012–2014*; IBGE/Coordination of Natural Resources and Environmental Studies: Rio de Janeiro, Brazil, 2016.
81. Prist, P.R.; Uriarte, M.; Fernandes, K.; Metzger, J.P. Climate Change and Sugarcane Expansion Increase Hantavirus Infection Risk. *PLoS Neglect. Trop. D* **2017**, *11*, e0005705. [CrossRef] [PubMed]
82. Manzatto, C.V.; Assad, E.D.; Bacca, J.F.M.; Zaroni, M.J.; Pereira, S.E.M. *Agroecological from Sugarcane: Expand the Production, Preserve Life, Ensure the Future*; Technical Report 110; Documentos. Embrapa Solos: Rio de Janeiro, Brazil, 2009. Available online: https://www.embrapa.br/busca-de-publicacoes/-/publicacao/579169/zoneamento-agroecologico-da-cana-de-acucar-expandir-a-producao-preservar-a-vida-garantir-o-futuro. (accessed on 13 March 2020).
83. Lambin, E.F.; Meyfroidt, P. Global Land Use Change, Economic Globalization, and the Looming Land Scarcity. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 3465–3472. [CrossRef] [PubMed]
84. Edelman, M.; Oya, C.; Borras, S.M., Jr. Global Land Grabs: Historical Processes, Theoretical and Methodological Implications and Current Trajectories. *Third World Q.* **2013**, *9*, 1517–1531. [CrossRef]
85. CONAB, Brazilian National Company of Agriculture, Livestock and Supply. *Agriculture and Animal Raising Information—Historical Collection about the Harvest: Sugarcane*; CONAB: Brasilia, Brazil, 2018. Available online: https://www.conab.gov.br/info-agro/safras/serie-historica-das-safras?start=30 (accessed on 26 September 2018).
86. United Nations Food and Agriculture Organisation (FAO). *FAOSTAT*; FAO: Rome, Italy, 2018. Available online: http://www.fao.org/faostat/en/ (accessed on 26 September 2018).
87. MAPA, Agriculture, Livestock and and Supply Department Brazil. *Sugarcane and Agroenergy National Balance*; MAPA/SPAE Production and Agroenery Secretariat: Brasília, DF, Brazil, 2007.
88. Nogueira, L.A.H.; Moreira, J.R.; Schuchardt, U.; Goldemberg, J. The Rationality of Biofuels. *Energy Policy* **2013**, *61*, 595–598. [CrossRef]
89. Pili, S.; Grigoriadis, E.; Carlucci, M.; Clemente, M.; Salvati, L. Towards sustainable growth? A multi-criteria assessment of (changing) urban forms. *Ecol. Indic.* **2017**, *76*, 71–80. [CrossRef]
90. Arezki, R.; Deininger, K.; Selod, H. *What Drives the Global "Land Rush"?* Working paper WPS 5864. Policy Research Working Paper; World Bank: Washington, DC, USA, 2011. Available online: https://openknowledge.worldbank.org/handle/10986/3630 (accessed on 29 March 2020).
91. Souza, G.M.; Victoria, R.L.; Joly, C.A.; Verdade, L.M. *Bioenergy and Sustainability: Bridging the Gaps*; FAPESP, SCOPE: São Paulo, Brazil, 2015.