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Forest-based bioeconomy in sub-Saharan Africa

Looking at benefits, barriers and burdens from a social sustainability standpoint

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Loaga village while on the road there is a zone of Baobab reforestation, Burkina Faso.

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Summary

Land use practices in the developing world, including forest resource utilization, are often unsustainable and can lead to the degradation and depletion of the resources that rural populations depend on, threatening their livelihoods. The global drive towards transforming forest-related economic activities to follow the principles of a circular bioeconomy – a long-term vision for using wood as a renewable resource, adding value to forest products and services, and optimizing value chains – might offer a win-win solution for forest conservation, sustainable management, and improved livelihoods for rural communities. Yet, bioeconomy strategies have so far focused on the technological and economic aspects of the concept, often leaving aside social sustainability, or taking it for granted. Understanding the benefits and burdens associated with a transition to bioeconomy is especially important for poor rural communities, for whom inequalities might be exacerbated due to their already fragile economic status and dependence on the natural resources and/or lands targeted by bioeconomy applications.

Through an abstract-based literature review, this study examines a sample of 360 studies published between 2000 and 2020, with a specific focus on forest-based bioeconomy in sub-Saharan Africa (SSA). The aim was to identify whether socio-economic impacts were taken into consideration in bioeconomy-related aspects of the forest sector across SSA, according to the literature reviewed. All forest activities were considered, thus encompassing both 'traditional' and 'new' forest-based bioeconomy. In other words, this included 'traditional' forest activities like household fuelwood collection and commercial timber logging, as well as innovative ('new') forest activities, like those valorizing biomass, generating new value-added products and services, and/or seeking to strengthen the use of wood as a renewable resource.

Results indicate that SSA's forest sectors remain largely informal and mostly traditional. Indeed, 51% of the abstracts analyzed referred to traditional forest bioeconomy activities and only 8% of the studies screened looked at aspects of novel/modern forest use. A sizeable body of the analyzed literature (41%), however, investigated the development of value chains and value-added products or bioenergy from forests, pointing to a bioeconomy perspective. Of the recurring themes emerging in the abstracts, the role of non-timber forest products (NTFPs) in income generation appeared to be central, followed by value chain improvement and the importance of forests for livelihoods and wellbeing. Within the limited literature that addressed novel forest activities, the most recurrent themes were bioenergy, value chain improvement, governance and initiatives, and economic policy tools. Considering the importance of NTFPs and the number of studies on value chain improvement, NTFP and value chain improvement-related activities present good opportunities for ushering in a bioeconomy in rural SSA. Likewise, poor energy security in SSA, which is associated with environmental degradation, health, gender and equality issues, could benefit from the bioenergy sector shifting more towards bioeconomy.

Social sustainability was often used to legitimize or contextualize the studies, rather than the object of the study. Income creation, quality of life (mainly inequalities pertaining to benefit sharing, or generalities relating to livelihood improvements), and resource conservation/environment were the socio-economic sustainability elements most often mentioned. The latter highlights again the well-known sustainability challenge of decoupling economic development from natural resource use and degradation, especially in a context of poverty. When the socio-economic sustainability outcomes of forest-based activities were detectable in the

abstracts (as they were in 66% of cases), outcomes were mostly positive (45%) or mixed (38%). Positive outcomes were associated with improved livelihoods, in the form of higher incomes, higher profitability, improved inter- and intra-generational benefit capture, better access to markets, education and training, conservation of natural resources so that use is sustainable, or land tenure rights. Negative outcomes were associated with loss of the natural resources needed for subsistence due to overexploitation, dispossession, and displacement (often referred to as green or land grabbing), inequalities in benefit sharing, gender issues, or elite capture.

Several challenges associated with a forest-based bioeconomy were identified in this review. Development of a bioeconomy is confronted with contradictory and uncoordinated forest policies and regulations, which disincentivize sustainable development. For example, decentralization attempts have granted more rights to rural populations but have not been supported with human and physical capital, leaving rural populations unable to pursue development. Forest policies are ignored, unknown or undermined by complex bureaucratic procedures put in place by forest agencies. At the same time, the bioeconomy is also confronted with overlaps and clashes between formal and informal systems, which impacts both land tenure and trade. While formalizing tenure and trade would foster equal access to benefit, it could also lead to the exclusion or marginalization of populations that are historically dependent on their forests. Meanwhile, both formal and informal trades are prone to corrupt practices, involving forest officials or unscrupulous entrepreneurs. A forest-based bioeconomy could also be linked to patterns of land grabbing and appropriation of smallholders' labor and financial resources by forest investors and/or state actors; these result in elite capture, spatial injustice, displacement, and disempowerment of rural populations. Finally, lack of knowledge and skills in forest sustainable management, business management or entrepreneurship, as well as lack of investment, financing opportunities or enabling policies to propel forest products and markets, all hamper the development of forest activities. These challenges are not new and have been the object of many publications regarding the forest sector in Africa. Challenges deriving from a land politics rooted in SSA's colonial legacy were highlighted in many studies and are pertinent to both traditional and modern forest-based bioeconomy.

In conclusion, while, hypothetically, a forest-based bioeconomy has the potential to enrich the forest sector in SSA and contribute to poverty reduction and natural resources conservation, solid bioeconomy strategies will first need to address the persistent forest sector challenges resulting from colonial inheritance. Traditional and novel forest uses are tightly linked, and they hold common sustainability challenges. Aiming for modern bioeconomy without resolving these issues would only reproduce (and perhaps worsen) the current pattern of burdens and inequalities in SSA's rural populations. Greater research focus on how forest bioeconomy applications could yield positive socio-economic impacts for vulnerable rural populations is critically needed. Likewise, a socio-economic sustainability analysis of past and current undertakings (identified in this study as 'transitional' FBBE activities) might help shed light on which directions to follow while providing 'good' and 'bad' practice examples. Bioeconomy-focused development initiatives are undoubtably already underway in SSA, although they were not detected by this review, perhaps because academic literature is not the best place to capture such information. It would be interesting to conduct a deeper analysis, while also analyzing grey literature on the topic to identify what kind of on-the-ground actions exist and how they might impact socio-economic sustainability, to be able to make policy recommendations on incentives or interventions.

Rationale and purpose of the study

Bioeconomy, the segment of the economy that relies on the use of renewable biological resources as an effort to develop a low-carbon, sustainable future, has been proposed as a solution to many societal challenges. It is implicitly assumed that transitioning towards bioeconomy will help to achieve the UN Sustainable Development Goals (SDGs). But as developed countries are increasingly adopting bioeconomy strategies, very little consideration has been given to the social sustainability of such a transition. Understanding the benefits and burdens associated with a transition to bioeconomy is especially important for poor rural communities, for which inequalities might be exacerbated due to their already fragile economic status and dependence on the natural resources and/or lands targeted by bioeconomy applications. This is the case in sub-Saharan Africa (SSA), where rural populations' dependence on land for income and subsistence has been consistently demonstrated. In addition, SSA states' economies also rely significantly on land resources, with agriculture, forest and fishing-related activities accounting for 15% of the GDP on average in SSA (World Bank 2019). Both rural communities and SSA states are thus bioeconomy actors by default due to their reliance on natural resources; however, their respective interests may not align.

While the research community has most often emphasized the bioeconomy potential of agriculture, the role of forests in bioeconomy has generally been overlooked. Forests, not unlike agriculture, are an important source of income and subsistence for SSA rural communities, although current practices are mostly unsustainable from an environmental point of view. Forests provide energy, food and other products such as medicine or construction material to at least 1.6 billion people around the world, including many of the world's most vulnerable populations (World Bank 2002; FAO and UNEP 2020), and have an important role in supporting agriculture, notably through agroforestry practices, by providing fertile lands, preserving biodiversity, protecting water supplies and mitigating local and global climate. Assuming it is able to reverse the pattern of unsustainable use, forest-based bioeconomy could support and enhance these important functions while providing the foundations for SSA countries and communities to progressively move away from traditional forest uses, adopt modern bioeconomy applications and develop value-added products and trade, as has happened in the Global North. In addition to an expected increase in modern bioeconomy applications, the role of SSA countries as biomass producers for the Global North, where current bioeconomy expansion might increase the demand for raw materials, is also forecasted to increase. National or regional bioeconomy objectives may therefore clash with rural populations' and forest-dependent communities' interests, instead of fostering sustainable resource management, social inclusion and poverty reduction.

Through an abstract-based literature review, the objective of this study is to identify whether socio-economic impacts were taken into consideration in the forest sectors and bioeconomy elements that have been studied in the SSA-focused literature (whether relating to the still-dominant traditional forest uses or to novel forest uses), and examine the benefits and burdens associated with such a forest-based bioeconomy (FBBE) in rural communities from the perspective of social sustainability. It aims to identify, on one hand, the socio-economic opportunities associated to a FBBE and the factors that may be enabling or hindering them, and, on the other hand, the burdens and inequities that a FBBE might create or exacerbate. This study does not intend to provide a full in-depth literature review or analysis of the bioeconomy challenges in SSA, but rather an overview of how these elements

are currently represented in the peer-reviewed literature.

This paper touches, explicitly or implicitly, upon several of the global challenges addressed in the various Global Framework Agreements adopted by the United Nations parties, including the Agenda 2030 for Sustainable Development, the Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), the UN Declaration on Human Rights (UDHR) and Guiding Principles on Businesses and Human Rights (UNGPs). But perhaps the most relevant theme here is the interlinkage of poverty reduction and sustainable use of natural resources. Fostering the protection of forest ecosystems through sustainable practices can play an important role not only in preventing poverty, but also in mitigating climate change and limiting the rise of pandemics, two of today's scourges. While the Intergovernmental Panel on Climate Change recognizes the pivotal role of forests in mitigation pathways aimed at maintaining global warming below 1.5°C (Masson-Delmotte 2018), the current COVID-19 pandemic has brought attention to how major environmental changes, such as deforestation, can lead to a rise in the occurrence of zoonotic diseases (e.g. Bloomfield et al. 2020). As poverty tends to foster unsustainable environmental behavior, developing sustainably solid, fair and equitable forest-based bioeconomy strategies in developing countries could improve the livelihoods of forest-dependent communities and constitute both a barrier against future potential epidemics and a tool for global climate mitigation. Both COVID-19 and climate change have exposed the weaknesses of social systems globally, revealing how socio-economic inequalities, such as income distribution or ethnicity, are exacerbated in time of crisis, highlighting the need for an increase in social safety nets.

1 Introduction

1.1 Bioeconomy and social sustainability

Transitioning to a bio-based economy offers the potential to reconcile economic growth with environmentally responsible actions while responding to current societal challenges such as food security, natural resource scarcity or climate change, by allowing the development of a low-carbon economy and through technological innovations in biomass production and processing. Although social sustainability is implicit in bioeconomy strategies because of the stated link to these broad societal goals and their aim to provide new growth and employment, bioeconomy approaches have mostly been technology and economy-oriented; the social sustainability aspects of the upcoming bio-based economy era are hardly addressed (Hetemäki et al. 2017; Priefer et al. 2017). Research on this topic is largely missing and scholars report a general lack of social sciences in bioeconomy studies (Priefer et al. 2017; Sanz-Hernández et al. 2019; Böcher et al. 2020; Holmgren et al. 2020; Toppinen et al. 2020). A simple database search exercise proves the point: searching for (bio*economy AND sustainability) in the Scopus database returns 443 documents, while searching for (bio*economy AND 'social sustainability') brings the number down to 12 (database accessed 19 June 2020).

Whether bioeconomy should serve uniquely as a substitute for the use of fossil fuels – a weaker sustainability approach that focuses on its industrial ecology potential – or whether it should instead take a stronger approach to sustainability, aiming to decouple growth and resource consumption while empowering its stakeholders, remains a central debate amongst bioeconomy scholars. This is exemplified by Priefer et al. (2017) who, based on a literature review examining the contrasting positions on bioeconomy, identified two types of bioeconomy implementation pathways: a technology-based approach and a socio-ecological approach. Holmgren et al. (2020) also identified in their review three rationales for promoting forest bioeconomy which are, in order of dominance in the review: decarbonizing and maintaining economic growth; forest bioeconomy as a pathway to sustainability; and forest bioeconomy as a fundamental societal transformation. According to Böcher (2020), however, the bioeconomy largely remains aimed at promoting a political way to achieve sustainability without needing to challenge existing paths. Bioeconomy strategies' generally weak approach to sustainability has been one of the main criticisms (Pfau et al. 2014; Ramcilovic-Suominen and Pülzl 2018), flagging the risk of underestimating or taking for granted its social dimensions. According to some authors, the prevailing visions on bioeconomy may only serve certain interests and not society as a whole (Levidow 2015; Priefer et al. 2017). Yet at the same time, 'sustainability' and 'sustainable development' are two of the top ten keywords most frequently associated to (forest) bioeconomy in peer-reviewed literature; indeed many definitions of the bioeconomy concept embrace the concept of sustainability (Paletto et al. 2020).

The European Union Bio-Based Industries (BBI) Consortium identifies links between the bioeconomy and 12 of the 17 the United Nations Sustainable Development Goals (SDG) (Figure 1), while The Swedish Environment Institute provides us with a more targeted list of eight SDGs relating to the bioeconomy (Figure 2), to which Diaz-Chavez et al. (2019) suggest adding SDG 5 on gender equality. SDG 1 was identified as the SDG expressing synergies with most of the other SDGs, but, interestingly, other SDGs described

here as related to the bioeconomy, i.e. SDG 8 (decent work and economic growth), SDG 9 (industry, innovation and infrastructure), SDG 12 (responsible consumption and production), and SDG 15 (life on land) were shown to be those presenting the largest trade-offs for sustainable development (Pradhan et al. 2017). Indeed, environmental and socio-economic goals tend to necessitate compromises, and trade-offs related to a bio-based economy might be unavoidable.

Many frameworks and standards have been proposed to assess the sustainability of bioeconomy and, alongside an increasing awareness of the need to assess the social impacts of a transition to bioeconomy, social indicators have recently gained popularity, even though such measurements in bioeconomy's diverse sectors are still in their infancy (Karvonen et al. 2017). Most frameworks and indicators originate from the bioenergy industry, after the industry itself stirred up great concerns about the impacts of biofuel production in developing countries. Yet the focus on environmental or economic sustainability aspects is often more pronounced than the focus on social aspects. The bioeconomy monitoring systems proposed by the EC Joint Research Centre, for example, use three main criteria for socio-economic evaluation – turnover (i.e. revenue), value added and job creation – revealing the predominant focus on the economic aspects of bioeconomy (Ronzon and M'Barek 2018). Diaz-Chavez et al. (2019) suggest that integrating the dimensions of poverty with bioeconomy indicators would better unfold how a transition to bioeconomy might affect society, and more particularly its vulnerable groups. The poverty framework from the Swedish International Development Cooperation Agency

Figure 1. Bioeconomy-related SDGs
Source: Modified from the EU BBI Consortium 2018

SDGs related to bioeconomy	Global North	Global South
SDG1: poverty reduction		
SDG2: end hunger, achieve food security and improved nutrition, and promote sustainable agriculture		
SDG7: ensure access to affordable, reliable, sustainable and modern energy for all		
SDG9: build resilient infrastructure, promote inclusive and sustainable industrialization, foster innovation		
SDG12: ensure sustainable consumption and production patterns		
SDG13: take urgent action to combat climate change and its impacts		
SDG14: marine resources		
SDG15: protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss		

Impact in the region: Green/strong: bioeconomy may contribute to achieving the goal; Yellow/medium: bioeconomy may contribute to achieving the goal but may take longer or more effort; Red/weak: bioeconomy may contribute in the region but is not highly relevant.

Figure 2. Bioeconomy-related SDGs and qualitative assessment of impacts by region
Source: Diaz-Chavez et al. 2019; Gomez San Juan et al. 2019

(Sida), for instance, describes four dimensions to poverty: power over material and non-material resources (including income, skills, tools, ecosystem services); access to services and opportunities to use these resources and move out of poverty; voice to express rights and concerns; and human security (i.e. the opportunity to exercise rights in any circumstances) (Sida 2017). Such a framework could prove useful to analyze how the transition to bioeconomy could impact society as a whole. However, obtaining a clear – although never complete – picture of the potential impacts of bioeconomy requires case-specific considerations and sustainability assessments that go beyond the mere use of indicators. Nowadays, challenges in assessing sustainability are not necessarily related to the lack of methods, rather to data availability, practical applications and insufficient understanding of synergies, trade-offs and interconnections between the impacts of bioeconomy (Karvonen et al. 2017).

Although bioeconomy has the potential to contribute to sustainable development and to a more equitable society, the existence of inevitable links between bioeconomy and social sustainability cannot be assumed. It is unclear how, and even if, a transition to bioeconomy creates an enabling environment for social sustainability, or promotes the implementation of measures fostering or protecting social benefits and rights; or whether instead it could further cement current social inequalities (Diaz-Chavez et al. 2019). The current challenges of the mainstream economy, like poverty, gender and social inequalities, must all be addressed to avoid their exacerbation. To this end, examining the power structures underlying the bioeconomy (access and control over resources and/or benefits) and understanding whether bioeconomy outcomes benefit just some while marginalizing others are of the utmost importance. While, ideally, social benefits should spread to all levels of society, understanding the benefits and burdens associated with a transition to bioeconomy is especially important for poorer rural communities, for whom inequalities could be exacerbated due to their already fragile socio-economic status and dependence on the natural resources targeted by bioeconomy applications.

These considerations are even more important when looking at countries in the Global South, and SSA in particular, where historic power over natural resources may present challenges when developing a bioeconomy. In SSA, forest governance has long been associated with rights and equity concerns (Lesniewska and McDermott 2014; Ongolo et al. 2018). The 'rule of law' adopted by post-colonial regimes has served to legitimize resource extraction by powerful actors

(elite capture), giving preference to industrial exploitation and undermining the livelihoods of forest-dependent communities. Transition to a forest-based bioeconomy would thus require extreme caution so as not to perpetuate the social burdens associated with a business-as-usual that is linked to post-colonial path dependencies and institutional stickiness. For example, land tenure and access/property rights are often unclear due to the legal pluralism that has originated from colonial history. Likewise, as informal and formal economies often co-exist, the superposition of these legal systems often leads to conflicts. Under these circumstances, a transition to bioeconomy presents several risks, including land grabbing and/or rent seeking, with associated power struggles and adverse effects on the livelihoods and subsistence of forest-dependent communities; poorer communities, who do not abide by the formal economy, being excluded from benefit sharing; population displacement to use land; and exclusion from customary access to natural resources. The formalization of rights and economy would ideally be helpful for the implementation of a harmonized bioeconomy, but history has shown that formalization efforts have ultimately driven inequalities such as elite capture, marginalization of the rural poor and indigenous people, abuse of women, corruption practices, leakage or illegal logging (Wynberg et al. 2015; Acheampong and Maryudi 2020). A transition towards a forest bioeconomy will also be confronted with the challenge of fostering equitable benefit sharing. Indeed, there are inherent inequalities along the bio-based value chains, and attention must be paid to who will truly benefit from the upscaling of bioeconomy. For example, when considering biotrading or bioprospecting, a just bioeconomy would foresee benefit sharing with traditional knowledge owners and biodiversity stewards, but benefits are often captured by a handful of politically connected actors (van Niekerk and Wynberg 2012; Schroeder et al. 2020). The Global North, whose bio-based industries could become the major biomass importers from SSA countries, will also have to play a role in ensuring a fair global bioeconomy. Finally, amidst it all, the bioeconomy concept will need to gain social acceptance not only in rural areas, but also in peri-urban and urban areas, if the uncontrolled urban sprawl causing forest loss and degradation is to be minimized.

1.2 Bioeconomy and the North-South divide

As hinted in Figure 2, the potential of bioeconomy to contribute to the SDGs, and thus to society's wellbeing, differs based on the North-South divide. In the Global South, bioeconomy is expected to play a central role in poverty reduction as well as food and energy security. SDG 1 (poverty reduction) is, on the other hand, not considered in the Eurocentric BBI assessment (Figure 1). The capacity of realizing bioeconomy's potentials will be met with different challenges in the Global South and the Global North. First, the overall contexts in terms of politics and political ecology differ greatly (i.e. differences in power over natural resources), as well as governance of natural resources, and the socio-economic landscapes; social equity and equality concerns exist in the traditional forest sector in developing countries. In this context, a transition towards bioeconomy would only favor sustainable development if it ensured that these concerns were addressed, so that it maximized the benefits and minimized the negative impacts. Second, infrastructure and logistics available in the Global North, which allow value added onto forest bioeconomy raw products to be maximized, are not yet fully available in the Global South. Despite the fact that developing countries cannot yet focus on high value products, bioeconomy strategies can still improve value chains, compared to the traditional value chains of forestry, for example. Such differences in infrastructure, human capital and socio-economic characteristics have prompted the two regions to develop their own concepts of bioeconomy, with different aspirational objectives and therefore different applications of bioeconomy.

Emerging countries see bioeconomy as a means to achieve development, as opposed to industrialized countries that tend to view it as a way to preserve the environment, capitalize their natural resources and pursue a reindustrialization strategy (Overbeek et al. 2016). Indeed, SSA, which is characterized by a predominantly rural economy, has relied heavily on the primary sector and its natural resources (e.g. minerals, oil, timber, bioproducts) for economic growth. Caught in a vicious circle of resource overexploitation, overreliance on the primary sector without the concomitant development of non-resource sectors, and raw material export rather than value-added product

development, SSA's economic growth is not only unsustainable, it has also become stagnant. While SSA's growth is actually rooted in what might be defined as bioeconomy (i.e. economic activity involving the use of biological material as the primary resource base) when we consider the forest sector, its potential has not been fully realized and the adoption of an environmentally, socially and economically sustainable bioeconomy strategy could be a game changer for the developing countries and their rural populations.

Bioeconomy as it is pursued in the Global North, on the other hand, is still emerging in SSA. Addressing from the start the three pillars of sustainability is of utmost importance to avoid reproducing the current patterns of unsustainability. Elements of social sustainability, although secondary to technological and economic aspects, are found in all the bioeconomy-related strategies of emerging countries. Of course, whether – and how – these strategies are translated into policies, implemented on the ground, and impact communities' livelihoods, remains to be determined.

1.3 The bioeconomy landscape in sub-Saharan Africa: Scoping, social sustainability and the role of forests

In stark contrast to the European continent, where the EU Bioeconomy Strategy prompted a growing number of member states to develop dedicated national and regional bioeconomy strategies and initiatives (European Commission 2012, 2018, 2020), in SSA only South Africa holds a dedicated national bioeconomy strategy (Republic of South Africa 2013). Bioeconomy-related policies and initiatives, including collaborations with international partners, do exist, however; these were identified in at least twelve other countries (Figure 3). Nine countries were individuated by the German Bioeconomy Council (2018) – Nigeria, Mali, Senegal, Namibia, Mozambique, Tanzania, Kenya, Uganda and Mauritius. The additional three countries – Ethiopia, Malawi and Rwanda – emerged from a FAOLEX database search. This search focused on documents published after 2018 (date of last report of the German Bioeconomy Council) and also included green economy and green growth strategies, since the underlying ideas behind both the bioeconomy and green economy concepts overlap in their aims to reconcile economic, environmental and social goals through the development of a sustainable economy (D'Amato et al. 2017). Interestingly, with the exception of the South African Strategy, no document uses the word 'bioeconomy', suggesting that the bioeconomy as political concept is not popular in SSA yet. Nigeria, Mali, Mozambique, Uganda and Senegal focus on fostering bioenergy policies. Kenya, Namibia, Tanzania and Uganda have policies relating to biotechnology, and countries like Kenya, Mauritius and South Africa have also started to focus on bioprospecting policies. Others are adopting green growth or resilience strategies, like Ethiopia, Malawi, Kenya or Uganda. For their part, Rwanda and Mauritius have adopted specialized bioeconomy-oriented strategies, namely a tree reproductive material strategy and an ocean economy strategy, respectively.

Bioenergy policies have as their objectives to increase energy security, the greening of the energy sector, and the contribution to rural development (e.g. employment, advancing rural electrification). All emphasized the use of Jatropha as an energy crop. Biotechnology strategies aim to promote economic growth, healthcare and environmental security, strengthen the agricultural sector through development and application of biotechnology, and generate wealth from available natural resources when coupled with bioprospecting strategies. They link socioeconomic development to technological innovations. The green economy or green growth strategies meanwhile take a holistic approach to supporting low-carbon, resource-efficient and resilient development paths, while also fostering socio-economic wellbeing. Finally, the South African Bio-Economy Strategy (2013) builds upon the 2001 National Biotechnology Strategy to address socio-economic development goals, economic growth and the greening of the economy, which are to be achieved through the creation and growth of novel industries that generate and develop bio-based services, products and innovations. This strategy prioritizes the sectors of agriculture, health and bio-based industry and follows a technology-push and market-pull approach. Shifting from the original biotechnology focus, it aims to take a holistic cross-sectorial approach, joining forces with the ICT sector, environmental agencies and the social sciences.

Comparable to the EU Bioeconomy Strategy, the South African Bio-Economy Strategy – as well as the diverse biotechnology strategies identified – focus on technology and economy and give considerably less weight to the social dimensions of a bioeconomy transition, accentuating mainly job creation. Of particular interest to this study, the use of forest resources is largely ignored in these documents (Table 1) and the role of rural areas is only sporadically addressed when underlining job creation in the biofuel and agriculture industry. Bioenergy policies tend to pay more attention to social elements, probably because of the much-discussed impact of biofuel development on food security and local communities. Forests are mentioned here, but the focus is more often placed on relieving them from extraction pressure caused by bioenergy production, rather than on their sustainable use for economic ends. Green economy strategies meanwhile have the widest socioeconomic scope, considering forestry and agroforestry as important sectors to achieve their goals. This does not come as a surprise, as green economy strategies are overall more comprehensive than bioeconomy strategies, including more varied social elements and a greater variety of disciplinary perspectives (D'Amato et al. 2017). Interestingly, the range of stakeholder types involved in the design of the strategies varies. While most biofuel policies tend to be limited to government actors, sometimes also including business actors, the green economy strategies, biotechnology and research policies, as well as the South African bioeconomy strategy, sought out the collaboration of more varied stakeholders, including international experts, NGOs, research institutions, civil society and development agencies.

A brief analysis of bioeconomy-related documents reveals which elements of social sustainability are considered in these 13 countries (Table 1). They aim at improving livelihoods and wellbeing by: fostering inclusive growth; water, food and nutrition security; education and training; market and income diversification; social protection; food safety and hygiene; poverty alleviation; health care; inclusion of women and vulnerable groups; and the protection of natural resources use and indigenous/traditional knowledge systems. Analysis also reveals that the recognition of the role of forest varies, from being inexistent or scarce in many of these bioeconomy-oriented strategies to being fully embraced in the case of green growth and resilience policy documents.

A macro-regional bioeconomy strategy for eastern Africa, BiSEA ('Developing an Innovation-led Bioeconomy Strategy for Eastern Africa') is also under development, with a project output expected in 2021. The partners are South Sudan and the six countries belonging to the BioInnovate Africa network – Ethiopia, Burundi, Kenya, Rwanda, Tanzania and Uganda (Figure 3). Now in charge of working on the Eastern African knowledge-based bioeconomy strategy, the BioInnovate Africa network (BioInnovate Africa network n.d), supported by the Swedish International Development Agency (Sida), has had as a core activity the development and commercialization of bio-based innovations. Most of their projects have so far concerned agricultural bioeconomy.

Another example of a bioeconomy initiative supported by international partners is the BiomassWeb project in Ethiopia, Ghana, Kenya and Nigeria, which aimed to increase the productivity and efficiency of producing, processing and trading biomass (BiomassWeb n.d). The BiomassWeb research projects, which were concluded in 2018, were demand-driven so as to respond to development priorities. As for BioInnovate, the projects also mostly cover agricultural bioeconomy, from angles as varied as technical procedures, value chain development and agriculture extension services, but studies on agroforestry systems are also found (Partey et al. 2017; Akoto Sarfo et al. 2018; Jemal et al. 2018). International and local NGOs, as well as the private sector, are also involved in bioeconomy initiatives (see Gomez San Juan et al. 2019 for examples). Initiatives related to the sustainable use of forest resources or the creation of such resources have existed long before the emergence of the bioeconomy concept, however. For SSA forest-dependent communities, 'bioeconomy', referring to the use of biological resources, is directly linked to subsistence and development. The Great Green Wall project, for example, launched by the African Union and largely funded by the United Nations, the World Bank and the EU, has been aiming since 2007 to plant trees in the Sahel region in order to curb desertification and restore fertile lands, thereby providing jobs and reducing mass migration.

Table 1. Bioeconomy-related policies identified in sub-Saharan Africa and their social sustainability aspects

Country	Perspective	Documents	Socio-economic aspects	Inclusion of forest bioeconomy	Source*
Ethiopia	Holistic low-carbon economy development	Ethiopia's Climate Resilient Green Economy National Adaptation Plan (2011–2025) Ethiopia's Climate Resilient Green Economy – Climate Resilience Strategy for Agriculture and Forestry (2011–2025)	Food security; income; resource conservation; climate resilience; social protection; improved health; economic growth	Yes. Forestry is a main sector considered in the climate resilience strategy. One of the four pillars of the strategy is to protect and re-establish forests for their economic and ecosystem services, as well as improve the resilience of forest product value chains. Enhancing sustainable forest management is also considered an adaptation option, as well as promoting value-added commercialization of timber and non-timber forest products along with payment for ecosystem services (PES), acknowledging and mainstreaming the contribution of forest resources to other production sectors, mainly energy, agriculture and industry, and enhancing the adaptive capacity of forests and forest landscapes and improving forest-based incomes.	Legal text obtained from FAOLex database
Kenya	High-tech	National Bioprospecting Strategy (2011) National Biotechnology Development Policy (2006)	Economic growth; healthcare; food and environment security; research and development	Scarce: environmental biotechnology objectives of reforestation and afforestation	https://www.isaaa.org/resources/publications/pocketk/28/default.asp
	Holistic low-carbon economy development	Green Economy Strategy Plan 2016–2030	Food security; quality of life; income, work safety, social protection, health care; social dialogue; women and vulnerable groups; training and education; local knowledge; poverty alleviation	Yes. Encompasses the forestry sector; Objective 2.2-iii: Grow -fast-maturing high value trees that have multiple commercial uses; promote establishment of nature-based enterprises including eco-tourism and community conservancies	Legal text obtained from FAOLex database

continued on next page

Table 1. Continued

Country	Perspective	Documents	Socio-economic aspects	Inclusion of forest bioeconomy	Source*
Malawi	Cross-sectorial policy for economic and environmental resiliency	National Resilience Strategy (NRS): Breaking the Cycle of Food Insecurity (2018–2030)	Inclusive growth; water, food and nutrition security; improved wellbeing; education and training; market and income diversification; social protection; climate resilience; food safety and hygiene; poverty alleviation; women and vulnerable groups; resource conservation	Yes. Sustainable forestry; forest restoration; forestry products and agroforestry considered for income and market diversification; building demand for forest-based enterprises; create value addition from NTFP	Legal text obtained from FAOLex database
Mali	Bioenergy	National Energy Policy (2006) (*Politique Energétique Nationale, PEN (2006)*)	Food and energy security; rural development (electrification and decentralized jatropha production); emphasis on sustainable aspects of jatropha production	Production of biofuel (jatropha) to relieve pressure on forest resources; rural wood market deemed unsustainable	https://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Profil_ER_Mal_Web_light.pdf
		National Biofuel Development Strategy (2009) *(Stratégie Nationale de Développement des Biocarburants en Mali (2009))*			
		National Strategy for the Development of Renewable Energy (2009) *(Stratégie Nationale pour le Développement des Energies Renouvelables (2009)*)			
Mauritius	Blue economy	Ocean Economy (2013)	Economic growth and diversification, job creation, socioeconomic development of fishing communities; resource conservation	Restoration of mangroves	World Bank (2017). The Ocean Economy in Mauritius: Making it happen, making it last.

Country	Perspective	Documents	Socio-economic aspects	Inclusion of forest bioeconomy	Source*
Mozambique	Bioenergy	Biofuel Policy and Strategy (2009) *(Politica e Estrategia de Biocombustiveis (2009))*	Energy security; poverty alleviation; employment and income generation in rural areas; avoidance of land conflicts; food security considered in the context of biofuel development; inclusion of environmental and social sustainability criteria (e.g. labor rights, health, customary rights, access to land and resources, biodiversity)	Production of biofuel (jatropha)	Schut et al. (2013) Mozambique's policy framework for sustainable biofuels: A reflection on the development of the first African policy framework for sustainable biofuels
Namibia	Research and innovation	National Programme on Research, Science, Technology and Innovation (2015)	Involvement of multiple stakeholders (including civil society) in strategy development; socioeconomic development; health and living standard improvements; food and water security; resource conservation; research capacities and technical skills; indigenous knowledge systems	None identified	Namibia National Committee on Research, Science and Technology, https://www.ncrst.na/
Nigeria	Bioenergy	Biofuel Policy and Incentives (2007)	Rural development; job creation	None except in the definition of 'biomass' as "agriculturally produced raw materials which are available on a renewable or recurring basis, including trees, crops, plant fiber, cellulose based materials"	Ohimain (2013). A review of the Nigerian biofuel policy and incentives (2007). *Renewable and Sustainable Energy Reviews*,22; Federal Republic of Nigeria Official Gazette

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Table 1. Continued

Country	Perspective	Documents	Socio-economic aspects	Inclusion of forest bioeconomy	Source*
Rwanda	Research	National Tree Reproductive Materials Strategy (2018–2024)	Enhance economic and ecological functions of natural resources to improve socioeconomic development	Yes: aims at sustainable production and supply of genetically adapted tree reproductive materials for the establishment of healthy and productive forest and agroforestry plantations that secure goods and services for enhanced socio-economic development and environmental protection	Legal text obtained from FAOLex database
Senegal	Bioenergy	Energy Sector Development Policy (2008, 2012) *(Lettre de Politique de Développement du Secteur de l'Energie (2008, 2012))*	Energy security; decentralized energy provision for electrification of rural areas (local refineries), thereby improving living standards	Production of biofuel (jatropha)	Dafrallah and Ackom (2016). Analysis of national Jatropha biodiesel programme in Senegal. *AIMS Energy*, 4(4)
		National Biofuel Strategy (2006) National Jatropha Programme (2006)			
South Africa	Holistic bioeconomy development	The Bio-Economy Strategy (2013)**	Involvement of multiple stakeholders in strategy design; socioeconomic development; intellectual property management; job creation; food and water security; social inclusion; social cohesion; education and training; healthcare; indigenous knowledge systems	Scarce: recognizes (1) the need to source second generation biofuels from woody biomass, and (2) the value of plant biodiversity and plant biomass for market diversification and commercial cultivation (e.g. in bioprospecting strategy). The word 'forest' does not appear	Legal text obtained from www.gov.za
Tanzania	High-tech	National Biotechnology Policy (2010)	Involvement of multiple stakeholders in strategy development; poverty alleviation; economic diversification of rural areas; food security; healthcare improvement; natural resource conservation	Scarce: identifies forestry as an area of activity (p.17) but the only reference found in the text is about biotechnology applications to create more resilient and productive tree species	Legal text obtained from tzonline.org

Country	Perspective	Documents	Socio-economic aspects	Inclusion of forest bioeconomy	Source*
Uganda	Bioenergy	Biomass Energy Strategy (2014)	Socioeconomic growth; energy security; healthcare; food security; poverty alleviation; natural resource conservation; multiple stakeholder involvement; social inclusion; training and research and development; indigenous knowledge	Yes. Energy and forestry sectors are linked (e.g. charcoal value chain). One of the targeted impacts is: "Forestry management plans developed and silvicultural assistance for both woodlots and natural wood formations on private land provided"	Legal text (google search)
		The Renewable Energy Policy for Uganda (2007)		Limited. Recognizes the role of forests in energy production (biomass defined as whole or part of a vegetable matter from agriculture or forestry, including firewood, shrubs, grasses, forest wastes) and try to reduce pressure on forests due to energy needs (e.g. support renewable energy technologies like improved wood fuel and charcoal stoves)	Legal text (google search)
	High-tech	National Biotechnology and Biosafety Policy (2008)		Creation of improved plants species; production of biofuel	Legal text (google search)
	Holistic low-carbon economy development	Uganda Green Growth Development Strategy (2017/18, 2030/31)	Income and livelihood enhancement; poverty reduction; green jobs creation; climate resilience; sustainable environment and natural resource management; water, food and nutrition security; social inclusiveness; economic transformation	Yes: Natural capital management and development which focuses on tourism development, sustainable forestry, wetlands and optimal water resource management; increase forestry coverage from 15% in 2010 to 24% by 2040 (reforestation and afforestation activities; agroforestry (with incentives) for green jobs creation; PES, including for landscape restoration; collaborative forest management	Legal text obtained from FAOLex database

Notes: * Lists sources additional to the German Bioeconomy Council; locating the full legal text was not always possible, thus authors refer to related peer-reviewed literature.

**Other relevant documents for South Africa bioeconomy include the Biodiversity Economy Strategy (2015), the Biofuel Industrial Strategy (2007) and the Biotechnology Strategy (2001).

Source: Modified from version adapted from German Bioeconomy Council 2018.

Figure 3. Sub-Saharan African countries with bioeconomy-related policies and initiatives

Many elements of social sustainability can be identified in the objectives of the projects led by international initiatives, NGOs and the private sector. These projects clearly aim at improving the quality of life of smallholders and local communities by tackling issues such as food and nutrition security, energy security, health (e.g. workshops for efficient cook stove building or use of bio-resources for protection against malaria), market and income diversification (e.g. biomass-based value chains of plantains, cassava; small-scale community biorefining) or women's rights. This is not surprising as development is their *raison d'être*. While some may argue that developing solutions to local problems may limit the scope of such projects, it is important to remember that the often unique ecological, socioeconomic and political contexts existing within SSA do call for targeted actions.

2 Contextual background for the abstract-based literature review

In our attempt to give an overview of the benefits and burdens associated with a forest-based bioeconomy (FBBE) in sub-Saharan Africa's (SSA) rural communities from the standpoint of social sustainability, the concept of FBBE and its relation to rural economy are narrowed down, and the different sectors that may participate in a FBBE are identified and put into context for SSA.

2.1 Definition of forest-based bioeconomy

Forest-based bioeconomy (FBBE) is a sub-sector of bioeconomy in which forest biomass constitutes the key renewable biological resource. As for the term 'bioeconomy', no universal definition exists (Hetemäki et al. 2017; Priefer et al. 2017; Winkel 2017; Hetemäki and Hurmekoski 2019; Befort 2020). Bioeconomy can be defined as "production, utilization and conservation of biological resources, including related knowledge, science, technology and innovation, to provide information, products, processes and services across all economic sectors aiming towards a sustainable economy" (Global Bioeconomy Summit 2018), but it is a boundary concept whose interpretation varies according to local realities and needs, availability of forest resources, existing industrial infrastructures and technological readiness. In addition, different

Table 2. Examples of traditional forest sectors and new forest-based bioeconomy sectors

<table>
<tr><th colspan="2">Traditional forest/ forest-based bioeconomy (FBBE) sectors</th><th colspan="2">New FBBE sectors</th></tr>
<tr><td colspan="4">Forestry- and industry-related services (research and development, education, training, sales, marketing, IT, legal services, extension, forest management planning, forest inventory, communications consulting, corporate governance, patents and licensing)</td></tr>
<tr><td>Use of woody biomass</td><td>Forest services</td><td>Novel or improved use of woody biomass and side streams from traditional sector</td><td>Novel forest services</td></tr>
<tr><td>Examples: forestry, agroforestry, woodwork, pulp and paper, bioenergy</td><td>Examples: recreation, tourism, provisioning, regulating, and cultural ecosystem services, NTFP</td><td>Examples: value-added wood-based products, biorefinery models to produce biochemicals, biofuels, biopharmaceuticals, cosmetics, textiles, novel wood-based materials (e.g. plastics and packaging), engineered wood products (e.g. construction)</td><td>Examples: ecotourism, eco-certification, PES/ REDD+, biodiversity and carbon schemes (stewardship), social forestry</td></tr>
<tr><td colspan="2"></td><td colspan="2">Novel business models and social innovations (servitization, open innovations, value co-production, business ecosystem concept, industrial symbioses, communal engagement such as social biomass plants)</td></tr>
</table>

Sources: Hetemäki 2014; Pelli et al. 2017; Hurmekoski et al. 2018; Hetemäki and Hurmekoski 2019; Ludvig et al. 2019.

forestry sector visions and strategies will shape the definition of bioeconomy, and vice versa. A report from the European Forest Institute defines FBBE as "the utilization of forests to create products and services that help economies to replace fossil-based raw materials, products and services" (Wolfslehner et al. 2016). These definitions remain Eurocentric however and, in this study, FBBE will instead be broadly defined as any activity based on the direct and indirect use of forests, forest biomass, and side-streams of forest biomass resulting from industrial activities. The emphasis on technology and innovation, replacement of fossil-based materials, and on the sustainability aspect of a bioeconomy in the above definitions are left aside, considering that they might not be prominent in SSA bioeconomy activities. We likewise did not want to assume that bioeconomy automatically fostered sustainability under all circumstances. Ideally, under a bioeconomy regime, the traditional forest industry would valorize biomass and go beyond its classical applications by creating new value chains, resulting in high added-value forest-based products and services, with the help of new technologies and/or innovations and by demonstrating progress on SDGs. This is what can be referred to as 'modern' or 'new' FBBE. However, because modern biomass processing is still in an early stage in SSA, and studies addressing modern FBBE were suspected to be few, both new FBBE and traditional forest activities were considered in our literature search, so as to address all forest uses in our analysis (Table 2). Traditional forest activities are hereafter referred to as traditional FBBE, in line with our definition of forest bioeconomy, which accommodates all forest uses and activities. In Table 2, we see that FBBE innovations can take place at the level of the general services (e.g. marketing innovation), use of biomass (novel/improved production, processing or products, including technologies), forest services and business practices.

2.2 Forest-based bioeconomy sectors relevant for this study

The sectors of FBBE that were examined are listed below, and as mentioned in paragraph 2.1, both traditional and new forest activities were considered. These activities were identified through initial literature scoping on bioeconomy activities in SSA, with agroforestry and bioenergy sectors appearing most often and the tourism sector appearing the least. It is worth noting that novel bioeconomy activities in SSA remain focused on the agricultural sector (food and feed biomass, use of waste, food security, nutrition) rather than on the forest-based sector, although the amount of forests and forest-dependent communities is significant, and forest activities can be combined to agriculture, notably through agroforestry.

2.2.1 Bioenergy

Bioenergy is key to improving the sustainability of the energy sector and achieving the Paris Agreement goals. However, current bioenergy production is mostly unsustainable, contributing to climate change, human health problems, notably for women (e.g. open cooking fires; charcoal production), and food insecurity (e.g. energy crop plantations) (AFREA 2011), and the bioenergy sector faces the risk of being discarded as backwater technology instead of being or becoming part of a modern energy mix. The term 'bioenergy' often refers to solid biofuels (e.g. wood, charcoal), while the term 'biofuel' usually refers to liquid biofuels (e.g. bioethanol, biodiesel). Here, we use the term 'bioenergy' to refer to both solid and liquid energy from biological sources.

a. Solid biofuels

In Africa, the production of fuelwood, comprising of firewood and charcoal, makes up about 90% of the total roundwood production. For comparison, fuelwood production in the EU is just 21% of total domestic production (FAOSTAT, 2018). Over 70% of the population in SSA relies on fuelwood for energy (Sola et al. 2017). Firewood is used mostly by rural households for cooking and heating and by small-scale industries for manufacturing, but charcoal is the main energy source used in cities and, as result, the charcoal industry is an important economic sector (AFREA 2011). However, bioenergy from woody biomass not only constitutes an inefficient use of roundwood, the heavy reliance on woodfuel significantly threatens to deplete forest resources. The use of outdated stoves also contributes to the inefficient use of wood, and is responsible for a large part of SSA countries' emissions (Adkins et al. 2010; Chidumayo and Gumbo 2013), in addition to the associated health problems and death toll. Improvement opportunities in the bioenergy sector and bioeconomy go hand in hand.

A more efficient bioenergy production could also free up roundwood for more valuable uses, reduce unsustainable pressure on forests, and reduce dependence on timber imports.

b. Liquid biofuels

Biofuel production in SSA most often relies on the use of agro-waste and of dedicated sugary, starchy or oily crops cultivations, such as sugarcane, Jatropha and oil palm plantations. Examples of woody biomass use for biofuel production in Africa are difficult to find, and a survey showed limited technical readiness for this type of activity (IRENA 2017). Conversion of lignocellulose requires more complex technology and experience, but progress is to be expected (Stafford et al. 2019). Interestingly, the aviation industry, which is a key candidate for biofuels because technological fixes are not enough to reduce all of their emissions, is showing growing interest in sourcing biofuels from SSA, with all the sustainability challenges this entails. SSA's projected contribution was estimated to be between 30% and 90% of the global aviation biofuel demand (Bole-Rentel et al. 2019).

2.2.2 Forestry and agroforestry

Sustainable, multifunctional forestry and agroforestry systems are key to a forest-based bioeconomy. The sustainable use of forests offers multiple business opportunities (timber production and processing, NTFPs, services), while contributing to climate change mitigation through carbon sequestration, storage and material substitution and providing ecosystem services, as well as climate change adaptation through a switch to more sustainable production systems, increasing resilience. While timber exports (e.g. Gabon mahogany, African white wood, sapeli) have led to a substantial timber industry, particular attention should be paid to NTFPs, reported to have had a more important role than timber in the development of regions like Central Africa (FAO 2017). NTFPs include both food and non-food products and may be harvested in their natural environment or produced on forest plantations or agroforestry settings (e.g. fruit trees).

Agroforestry, small-scale and industrial plantations play an important economic role. Plantations serve both NTFP and timber production needs. Commercial plantations for timber production have been seen as a solution to face a foreseen wood shortage on the African continent and relieve the pressure on natural forests. Examples include *Acacia senegal* plantations for production of gum arabic (used in the production of adhesives, confectionary and pharmaceuticals) in Eastern Africa, rubber and teak plantations in West Africa, and Eucalyptus plantations for uses as varied as pulp, sawn timber or woodfuel throughout the continent. Jacovelli (2014) claims that large-scale forest plantations will be necessary considering the increasing importance placed on natural forests in the context of climate mitigation and environmental protection. Land grabbing, community displacement and negative environmental consequences of plantations (e.g. excessive water and nutrient use degrading the land, creation of ecological deserts, exotic species) have been flagged as issues, but it has equally been argued that well managed plantations bring more benefits than harm (Jacovelli 2014).

Plantations of tree crops such as tea, coffee, cocoa, shea (e.g. for the cosmetic industry), bamboo (e.g. for construction) and cassava (for food as well as raw material for bio-based products such starch, flour, ethanol and feed formulations) are an important source of revenue for rural farmers (Chalfin 2004; Jasaw et al. 2015; Khumalo et al. 2015; Poku et al. 2018; Sonwa et al. 2019) and, when combined in agroforestry systems, also play their part in climate mitigation and biodiversity conservation (Kumar 2016). For example, cocoa agroforests in Central and West Africa contribute to reducing emissions from deforestation and forest degradation (REDD+) (Sonwa et al. 2019). Co-certification of cocoa and coffee production, providing a price premium to farmers and alleviating forest degradation, is also becoming increasingly common in response to consumers' awareness of the socio-ecological issues linked to these activities (Takahashi and Todo 2017), even though the double win of environmental and socio-economic outcomes is still under debate (Vanderhaegen et al. 2018).

There are many challenges associated with the sustainable management of forest and agroforests in tropical Africa, including tenure systems, environmental impacts, deforestation and illegal logging. Just 1% of African tropical forests are certified as abiding by PEFC or FSC sustainable forest management principles, for example

(Teketay et al. 2016). Despite this, forest-related activities have been and will continue to be an asset for socio-economic development. They currently account for 6% of the GDP in Africa on average (excluding the direct dependence of rural populations on forests, a rate which is the highest in the world (Zaikowski 2008)).

2.2.3 Pulp and paper

The pulp and paper industry derives from forestry and timber processing, but deserves its own paragraph considering the historic importance of this economic sector. Even though a global decline of the graphic paper industry is foreseen (Hurmekoski et al. 2018; Berg and Lingqvist 2019; Hetemäki and Hurmekoski 2019), other products in high demand are expected to fill the gap, like tissue paper and packaging. A new market for pulp is also developing, particularly for hygiene products and the textile sector.

2.2.4 Sustainable construction

Also deriving from forestry and timber processing, engineered wood products such as cross-laminated timber (CLT) have allowed a revisit of traditional wood construction using modern technology. This trend is on the rise in some developed countries, notably in a sustainability-driven effort to lower emissions from the construction sector via material substitution (Toppinen et al. 2018). Indeed, wood construction was shown to produce lower emissions than concrete construction (Pittau et al. 2019). In developing countries, modern wooden constructions are far from being mainstream. Just one example was identified in South Africa and was associated with luxury goods and the tourism industry (EcoLogHomes 2017). However, wood remains a basic building material, and modern wooden construction is therefore a potential emerging market for bioeconomy (Metsä Wood 2018).

Other less technologically demanding contributions of wood-based products to the construction industry are easily identified in the literature concerning developing countries. For example, tropical wood saw dust resulting as industrial wastage can be used in concrete mix to improve concrete's sustainability value (Adnan et al. 2020), while bamboo is used as construction material (Dje Bi et al. 2020) and was even shown to deliver more sustainable and healthy solutions than traditional housing materials (von Seidlein et al. 2017).

2.2.5 Biochemicals, biopharmaceuticals, medicinal bioprospecting and biotrading

Both the technology and market for biochemicals have evolved, as an increasing number of leading consumer brands are setting targets on replacing fossil-based chemicals with more sustainable options. Biochemicals (a term that also refers to liquid biofuels) and biopharmaceuticals originate from new wood-based value chains using sawmill or pulp mill industry by-products; there are relative degrees of complexity in the processes leading to the end products (e.g. primary platform biochemicals like ethanol, secondary platform chemicals like ethylene, polymers, fine chemicals) and/or purposes (drop-in, smart drop-in or dedicated biochemicals) (Hurmekoski et al. 2018). They remain largely unexplored and technologically demanding. In SSA, there are few examples of biomass refinery. One biorefinery exists in South Africa, while in Kenya, a former first-generation biofuel refinery has been diversified into a bio-ethanol plant producing spirits and CO_2, yeast and animal feed (https://acfc.co.ke). Although biomass refinery is still practiced on a limited scale, a modular biorefinery model has been proposed for West Africa, based on the availability of feedstock in the region, in order to produce bioethanol, biopharmaceuticals and other biochemicals, and explore new market avenues (Fletcher et al. 2017). Cascading use of cassava biomass – a versatile woody shrub imported in Africa in the 1600's – converted into staple crop, has also been proposed as a promising bioeconomy model, with potential production of bio-products such as biogas, biofuel, solvents, pharmaceuticals and bioplastics (Poku et al. 2018).

Bioprospecting can be defined as the exploration of biodiversity for genetic and biochemical resources to develop commercially valuable products, while biotrade includes the activities of collection, production, transformation and commercialization of goods and services derived from biodiversity. As such, they rely on natural resources and fall under the category of bioeconomy (Gomez San Juan et al. 2019). A well-known example is the native South African *Pelargonium sidoides*, a plant once used in traditional remedies that was

propelled to international fame by the German pharmaceutical Schwabe. The founding pillar of South Africa's bioeconomy strategy is the 'Farmer-to-Pharma' concept, identified in 2008 as one of the five Grand Challenges of South Africa's Ten-year Development Plan, which aims to take advantage of the country's rich biodiversity as a means for rural communities to increase their income through medicinal plant markets and pharmaceutical development (Republic of South Africa 2013). The concept integrates biological resources, traditional knowledge and biotechnology. The topics of biodiversity-derived products and traditional knowledge give rise, however, to many questions regarding equity, benefit sharing and intellectual property rights (van Niekerk and Wynberg 2012; Wynberg et al. 2015).

2.2.6 Tourism (sustainable tourism, ecotourism)

Tourism is an important sector in tropical Africa. Its diversification and development into sustainable ecotourism can contribute to a forest-based bioeconomy, as already exemplified in many instances (e.g. Mudzengi et al. 2020).

2.2.7 Provision of forest ecosystem services (climate mitigation, biodiversity), forest restoration, eco-certifications

The restoration of degraded forest landscapes is seen as an opportunity to drive economic development through employment and wood security (ITTO 2019). Likewise, conservation, climate and sustainability objectives (e.g. REDD+, PES schemes, eco-certifications) add value to forestland and agroforestry systems, whether they yield additional income, financial and technical support for landowners and local communities, or increase the attractiveness of deforestation-free markets, respectively (Prokofieva 2016; Kroeger et al. 2017).

A number of new, interconnected and cross-sectoral wood-based value chains are progressively being established, exemplifying today's circular bioeconomy vision. While in the global North, construction, textiles, biofuels, platform chemicals and packaging materials are considered the most important new wood-based markets (Hurmekoski et al. 2018; Hetemäki and Hurmekoski 2019), the bioeconomy landscape in tropical Africa is rather different. There, countries are often characterized by a strong primary sector and very weak high-tech sector, with consequent low availability of skilled labor force and bioproductive land (Biber-Freudenberger et al. 2018). High added-value specialized forest-based applications (e.g. new materials from wood like bioplastics, cosmetics), associated with high production costs and high technology levels, are at this time virtually absent in the prevalently rural SSA, with the exception perhaps of South Africa (mentioning for example bio-based cosmetics in its 2013 Bioeconomy Strategy), highlighting the North-South technology divide. Global demand for raw material for bioeconomy applications is however expected to increase and is likely to affect rural communities.

3 Methods

The abstract-based literature review was guided by the systematic review methodology suggested by the Collaboration for Environmental Evidence (CEE) (2013). This study does not intend to deliver a full in-depth systematic review, however; as such, it does not follow all the elements presented in the CEE guidelines. Rather, we intend to provide a general overview of the social outcomes, benefits and burdens of a forest-based bioeconomy in the SSA context. Only abstracts of the reviewed papers were considered, rather than the full texts. Specifically, this review intended to: scan the academic popularity of different FBBE sectors in SSA, whether traditional or novel/emergent; identify negative and positive social impacts of forest bioeconomy in SSA; and examine to what extent FBBE-related literature incorporates elements of social sustainability, as well as what type of social sustainability is most represented.

3.1 PE(C)O definitions as applied to this study

Literature review research questions can usually be divided into four components: population (P), exposure (E), comparators (C) and outcomes (O). Our main research question is the following:

> What are the socio-economic benefits, barriers and burdens associated with a forest-based bioeconomy in sub-Saharan African rural communities?

With this in mind, we define P as sub-Saharan African rural communities; E as forest bioeconomy activities (traditional and new); C as lack of activities relating to forest-based bioeconomy (i.e. lack of use of forest resources for any reason); and O as socio-economic benefits and burdens. Only the P, E and O components were used for eligibility screening and coding in the study; more detail on the specific definitions we use for each component in this study is given below.

3.1.1 Population: subject upon which an intervention or exposure is applied

The target population is the rural communities of SSA as actors, beneficiaries and victims of current and future FBBE activities, i.e. those involved in subsistence activities, collectors, producers, traders and consumers. South Africa is taken into consideration along with tropical African states, based on the fact that it is the only country in SSA to have adopted an official national bioeconomy strategy and can therefore be thought of as a role model.

Table 3 shows a list of the 49 countries (tropical Africa and South Africa) that are relevant to this study. Tropical Africa is comprised of 48 countries distributed across the sub-regions of West Africa (16 states), East Africa (9 states), Central Africa (10 states), parts of Southern Africa (7 states), and the Indian Ocean islands (6 states) (PROTA Foundation 2008; Awodoyin et al. 2015).

3.1.2 Exposure: management regime, policy, action or any external variable applied to the subject

'Exposure' can be described as the presence of FBBE activities (see Table 2 and paragraph 2.3), initiatives and policies (Table 4).

3.1.3 Outcome: Outcomes and impacts resulting from the population being exposed to an intervention

Outcomes refer to direct and indirect socio-economic impacts resulting from forest-based bioeconomy activities and leading to improvement or degradation of the populations' wellbeing

Table 3. List of relevant sub-Saharan African countries (tropical Africa plus South Africa)

Regions	Countries
West Africa	Benin, Burkina Faso, Capo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Niger, Nigeria, Mali, Mauritania, Senegal, Sierra Leone, Togo
Central Africa	Burundi, Cameroon, Central Africa Republic, Chad, Congo, Sao Tome and Principe, Democratic Republic of Congo, Equatorial Guinea, Gabon, Rwanda
East Africa	Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan, South Sudan, Tanzania, Uganda
Southern Africa	Angola, Botswana, Malawi, Mozambique, Namibia, South Africa, Zambia, Zimbabwe
Indian Ocean Islands	Comoros, Madagascar, Mauritius, Mayotte, Reunion, Seychelles

Table 4. Exposure to aspects of forest-based bioeconomy

1. Traditional forestry and forest industry: forest management for extractive resources Examples: • Sustainable forest management (incl. forest restoration/afforestation) • Sawmills • Pulp and paper mills • Plantations
2. Community forestry
3. Agroforestry systems: agrisilvicultural, silvopastoral, agrosilvopastoral systems
4. Construction industry: traditional and composite construction techniques
5. Subsistence and income diversification through the use of forest-based products Examples • Bioenergy needs from biomass (woodfuel, charcoal use and sales) • Timber and NTFP use and sales • Carpentry, arts and crafts • Eco-certification schemes • Participation in PES and carbon forestry schemes
6. Modern/emerging forest industry markets: production of value added forest products; improved value chains Examples • Bioenergy • Biofuels • Biochemicals, pharmaceuticals, biocomposites • Biorefineries
7. Forest services: forest management for non-extractive resources Examples: • Provision of ecosystem services • Recreational activities • Ecotourism • Cultural and spiritual value creation • Social forestry
8. Forest-based bioeconomy governance elements Examples • Enabling initiatives/policies for forest use • Enabling initiatives/policies/investments for education, training and stakeholder participation • Forest laws, reforms and trade laws impacting forest use • Forest access and property rights impacting forest use

(quality of life), as defined by the socio-economic sustainability criteria listed in Table 5.

The framework and socio-economic criteria that we used in this study (Figure 4, Table 5) are based on and adapted from several sources: (1) an FAO framework that evaluates bioeconomy sustainability (Bracco et al. 2019); (2) an EFI framework focused on forest-based bioeconomy indicators (Wolfslehner et al. 2016); (3) the BioSTEP (Hasenheit et al. 2016) and (4) UNEP-SEPAC (Benoît-Norris et al. 2011) frameworks, which are commonly applied in bio-based economy evaluations; (5) Rafiaani et al. (2018), who identified the 10 most common socio-economic criteria used in bio-based industry. Our framework was designed with the intention to use at least these 10 criteria. Next, we combined the FAO and EFI frameworks in such a way to place the focus on forest bioeconomy, in the context of international bioeconomy principles. Both sources were needed, because neither was directly applicable to our context of forest bioeconomy in SSA: the EFI framework, while specifically examining forest bioeconomy, is applied in the context of the 2018 updated EU strategy objectives; the FAO framework, meanwhile, although not concerning forests specifically, analyzes bioeconomy using the bioeconomy principles defined in 2016 by the International Sustainable Bioeconomy Working Group (ISBWG), which are more suitable for our study. Finally, attention was also paid to the context of tropical Africa when defining the criteria.

3.1.4 Context: Factors that are likely to influence the outcome and explain their heterogeneity

Besides the PECO elements, the impacts of forest-based bioeconomy activities can be affected by the following contextual factors: environmental (e.g. landscape type); sectorial (any one sector of a forest-based bioeconomy can impact the communities in its own way); and institutional (political regime and institutional setup, level of decentralization, land tenure regime).

3.2 Criteria for inclusion of literature in the study

The publications identified through our literature search had to meet the above-defined PE(C)O criteria based on the population, exposure and outcome components. The 'comparator' aspect was not considered under our eligibility criteria, however, as we believed this would considerably restrict the proportion of accepted studies, notably because the literature review was not based on full text analysis, but rather on abstract analysis (see below). Only publications in English were considered. We considered relevant populations to be rural (including remote vulnerable and/or indigenous) populations from the SSA countries mentioned in Table 3. They must have a direct or indirect link to forest use and/or forest bioeconomy activities, initiatives or policies, whether they rely on forest resources for subsistence, are engaged in business activities, or consume forest-based products.

In addition, publications were considered relevant only when related to tropical and subtropical forests, including managed and unmanaged natural forests, man-made forests, plantations (including non-native species plantation) and agroforestry settings. Hence, forests relevant to this study encompass systems that the FAO defines as 'forest' as well as 'other wooded land' (FAO 2020). As per the FAO definition, forests can be defined as: "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ". Under this definition, plantations established for forestry purposes but that have yet to reach a crown cover of 10% and adequate height are included under forests, as well as areas in the course of reverting to forests after human interventions or natural disasters. Likewise, the definition includes mangroves in tidal zones, rubberwood tree plantations, and areas with bamboo and palms, providing that they meet the height and canopy cover criteria. However, agroforestry systems and tree stands in agricultural production (e.g. fruit trees, palm oil, coffee) are not defined as forest but rather fall under the FAO definition of 'other wooded land': "Land not classified as 'forest', spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds *in situ*; or with a combined cover of shrubs, bushes and trees above 10%. It does not include land that is predominantly under agricultural or urban land use." This land use criterion will be relaxed for the purpose of this study so as to include, for example, the cultivation of the woody shrub Jatropha.

Table 5. Socio-economic sustainability criteria, as relevant to forest-based bioeconomy

Principles of bioeconomy	Relevance to forest-based bioeconomy	Socio-economic sustainability criteria
Principle 1: Bioeconomy should support food security	Role of forests in watershed management and the provision of water for agriculture and fisheries to secure sustainable food production	Food security; quality of life; income
	Edible non-wood forest products	
	Agroforestry systems (increased yield in agricultural plantations)	
	Subsistence for food needs	Land/resource access and property rights
	Forage and feed for livestock	
Principle 2: Bioeconomy should ensure that natural resources (forests) are protected, conserved and enhanced	Sustainable Forest Management	Resource conservation; profitability
	Forest Ecosystem Services	Food security; health and safety; quality of life; income; social acceptability
	Degradation of forests is prevented, stopped or reversed (land use change)	Resource conservation; food and energy security; income
	Afforestation/reforestation	Resource conservation; income; profitability
	Invasive species, pests (economic impact)	Resource conservation
	Illegal logging	Income; land/resources access and property rights
	Subsistence (energy needs)	Land/resources access and property rights; energy security
	Social services (health/wellbeing/ recreation)	Quality of life
	Environmental safety of activities	Health and safety; quality of life
Principle 3. Bioeconomy should support competitive and inclusive economic growth (economic development fostered by forest sector)	Forest holdings	Income; profitability
	Employment in rural and peri-urban areas (traditional forest sector and green jobs)	Employment
	Household income	Income
	Quality of working conditions (occupational health and safety, rights, discrimination)	Workplace; health and safety
	Equality (including gender issues)	Human rights, quality of life; gender issues
	Equity - inclusiveness (benefit sharing)	Quality of life; health and safety; income
	Rural income diversification (multiple uses of forest)	Income; new markets and business opportunities; social acceptability
	Linkages between rural, peri-urban and urban economy	New markets and business opportunities; access to knowledge
	Growth of forest bio-based sectors, technologies, processes or products	New markets and business opportunities; employment
	Innovations in forest-based products and services (research, start-up, financing opportunities, patents)	Income; profitability; new markets and business opportunities
	Resilience of biomass producers and rural and peri-urban communities	Social protection; new markets and business opportunities

continued on next page

Table 5. Continued

Principles of bioeconomy	Relevance to forest-based bioeconomy	Socio-economic sustainability criteria
	Emerging societal trends and new markets (e.g. wooden construction, biorefinery)	Social acceptability; profitability; employment; new markets and business opportunities
Principle 4. Bioeconomy should make communities healthier, more sustainable, and harness social and ecosystem resilience	Education	Access to knowledge ; quality of life
	Climate change mitigation and adaptation	Food security; resource conservation; health and safety
	Protective forests	Health and safety; resource conservation
	Territorial identity	New markets and business opportunities; stakeholder participation
Principle 5. Sustainable bioeconomy should rely on improved efficiency in the use of resources and biomass	Efficiency in use of forest biomass (e.g. wood fuel use and abuse, efficient agroforestry systems, efficient multiple uses of forests to create additional income, harnessing of SFM practices for better yields)	Income; profitability; food and energy security
Principle 6. Responsible and effective governance mechanisms should underpin sustainable bioeconomy	Harmonization of policies, regulations and institutional set up relevant to forest bioeconomy sectors	Social protection
	Inclusive consultation for forest-based activities	Social protection; stakeholder participation
	Funding availability	Employment; access to knowledge;
Principle 7. Sustainable bioeconomy should make good use of existing relevant knowledge and proven sound technologies and good practices,and, where appropriate, promote research and innovation	Tree plantations, GM trees	Profitability; health and safety
	Value existing local or indigenous knowledge	Social acceptability
	Promote innovation (including social innovation and open innovation)	Social acceptability; access to knowledge
	Capacity development, education, training	Access to knowledge; quality of life; employment
Principle 8. Bioeconomy should use and promote sustainable trade and market practices	Illegal logging prevention	Resource conservation; quality of life
	Ecocertification schemes	Social acceptability; resource conservation; new markets and business opportunities
	Trade of value-added forest products	Profitability
Principle 9. Bioeconomy should address societal needs and encourage sustainable consumption	Consumption patterns of forest goods match sustainable supply levels of biomass and there is policy coherence between supply and demand	Social protection; resource conservation
	Communication with stakeholders, education	Access to knowledge; stakeholder participation
Principle 10. Bioeconomy should promote cooperation, collaboration and sharing between interested and concerned stakeholders in all relevant domains and at all relevant levels	International cooperation (transfer of resources, skills and technologies)	Access to knowledge; new markets and business opportunities; employment
	Collaboration between private sector actors/farmers/community	Stakeholder participation; access to knowledge; new markets and business opportunities
	Information sharing (organized groups, platforms) at local/regional/national levels	Access to knowledge
	Inclusion of all stakeholders	Stakeholder participation

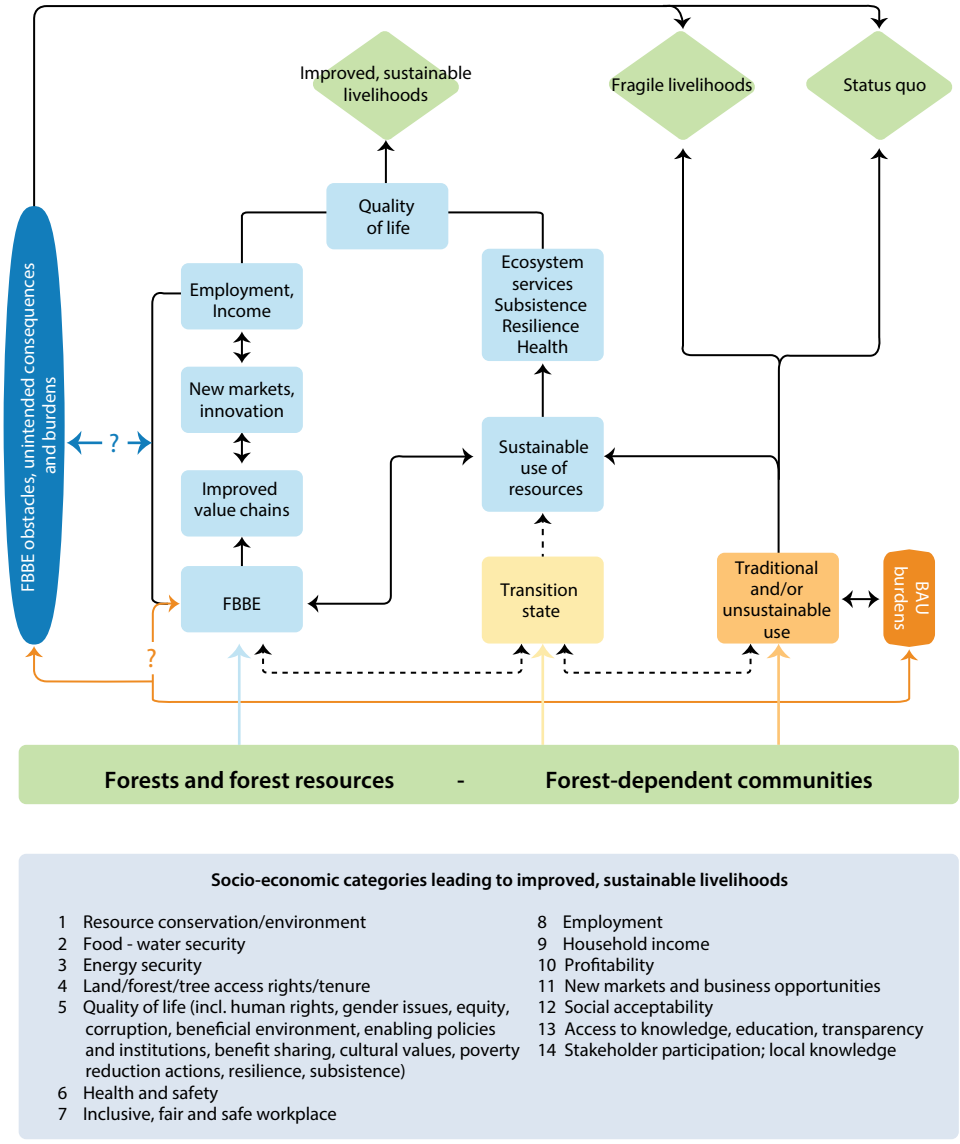

Figure 4. Socio-economic framework and categories to assess forest-based bioeconomy impacts

Regarding the exposure element, publications must mention any formal or informal forest-related productive activities, whether they apply to bioeconomy, livelihood subsistence, or any initiatives or policies regarding the use of forest for economic development.

Publications should consider any direct or indirect socio-economic impacts of forest-based activities on the relevant populations. At least one out of the 14 criteria displayed in Figure 4 and Table 5 should be addressed. These include: resource conservation; food security; energy security; resource access and property rights; quality of life (including human rights, gender issues, equity, corruption, healthy environment, social protection); health and safety; quality of workplace; employment; income (which can be represented by monetary forest income from sales of forest products, wage labor or value addition to forest products); profitability; new market and business opportunities; social acceptability; access to knowledge (including education); and stakeholder participation.

Finally, although not an inclusion criterion per se, studies were categorized as being traditional or new FBBE activities (Table 2), by evaluating whether activities had resulted in a change in habitual forest use and led to improved value chains and value-added products and services. A third category – transitional FBBE – was added in the screening phase, as many studies were found to address how traditional forest activities could be improved and suggested a need for transition towards new FBBE.

3.3 Literature research

3.3.1 Databases, keywords and search strings

Searches for relevant peer-reviewed scientific literature were conducted using the general scientific databases Scopus, Web of Science and CAB Abstracts; these searches were limited to studies published in English from the year 2000 onwards.

Keywords and search strings were designed based on the PE(C)O elements and adapted to the different databases. Search strings were tested, and the results evaluated so as to adjust the search strings to reflect appropriate findings (Table 6).

3.3.2 Screening, data extraction and analysis

The screening was performed based on titles and abstracts only, due to time restrictions and because the goal of this study was to give an overview of social sustainability aspects within FBBE in SSA, rather than an in-depth analysis. Inclusion criteria were applied to selected publications with the help of the AbstrackR software (Rathbone et al. 2015).

For each selected abstract, these elements were recorded:

- Basic information: authors, year, title, journal
- Country
- FBBE sector (according to categories and subcategories in Table 4)

Table 6. Search strings used in database searches (using Scopus syntax)

Population keywords • Communities	(rural **OR** peri*urban **OR** rural*urban **OR** rurban **OR** hinterland **OR** suburb* **OR** periphery **OR** outskirt* **OR** "local communit*" **OR** "small*holder*" **OR** tribal **OR** farmer **OR** "land*holder*" **OR** indigenous OR "forest*-dependent communit*" **OR** ("communit* W/10 forest*"))
• Geography	(africa **OR** "west africa" **OR** "tropical africa" **OR** "central africa" **OR** "east africa" **OR** "sub*saharan africa" **OR** benin **OR** "Burkina Faso" **OR** "C?te d'Ivoire" **OR** gambia **OR** ghana **OR** "Guinea Bissau" **OR** guinea **OR** liberia **OR** niger **OR** nigeria **OR** mali **OR** mauritania **OR** senegal **OR** "Sierra Leone" **OR** togo **OR** burundi **OR** cameroon **OR** "Central Africa Republic" **OR** chad **OR** congo **OR** "S?o Tome and Principe" **OR** "Democratic Republic of Congo" **OR** "Equatorial Guinea" **OR** gabon **OR** rwanda **OR** djibouti **OR** eritrea **OR** ethiopia **OR** kenya **OR** somalia **OR** sudan **OR** "South Sudan" **OR** tanzania **OR** uganda **OR** angola **OR** botswana **OR** malawi **OR** mozambique **OR** namibia **OR** zambia **OR** zimbabwe **OR** comoros **OR** madagascar **OR** mauritius **OR** mayote **OR** r?union **OR** seychelles)
Imperative context	(forest* **OR** tree*)
Exposure keywords • Bioeconomy	((bio* W/10 econom*) **OR** (forest* W/10 econom*) **OR** "green econom*" **OR** greening **OR** "circular econom*" **OR** ("green W/2 deal") **OR** ("natur* W/5 solution*") **OR** "bio*based econom*" **OR** bio*econom* OR "value chain" OR ("value W/1 added"))
• Forest-based bioeconomy activities	(bio*energy **OR** bio*fuel **OR** bio*refinery **OR** (eco* W/10 tourism) **OR** "forest service*" **OR** (ligno*cellulo* W/10 biomass) **OR** (tree* W/30 plantation*) **OR** plantation* **OR** rubber **OR** bamboo **OR** rattan **OR** coffee **OR** cocoa **OR** tea **OR** palm **OR** Jatropha OR shea OR eucalyptus **OR** agro*forest* **OR** "non*timber forest product*" **OR** "non*wood forest product*" **OR** certification **OR** pes **OR** (redd* W/30 (incentive OR payment)) **OR** "ecosystem service*" **OR** bioprospect* **OR** woodwork* **OR** saw*mill* **OR** pulp **OR** paper **OR** (bio W/10 pharmac*) **OR** (bio W/10 chemical*) **OR** bio*chemical **OR** biologic **OR** timber **OR** *wood* **OR** (bio W/2 based) **OR** silvicultur* **OR** pulpwood **OR** incentive **OR** biotechnology **OR** innovation* OR ("bio* W/10 innovation*") **OR** "engineered wood" **OR** "wood-based product*")
Outcome keywords	(subsistence **OR** (development W/6 economic*) **OR** socio*econom* **OR** "social* sustainab*" **OR** sustainab* **OR** benefit* **OR** land*grab **OR** right* **OR** well*being **OR** welfare **OR** health **OR** safety **OR** infrastructure **OR** "food security" **OR** "energy security" **OR** employment **OR** income **OR** "quality of life" **OR** equalit* **OR** equity **OR** fair* **OR** gender)

- Aspects of socio-economic sustainability (according to Figure 4)
- PE(C)O aspects (see above)
- Whether it addresses traditional, transitional or new FBBE
- Whether it mentions positive, negative or mixed socio-economic consequences

Considering the nature of the screening, there was no assessment of the quality of the studies.

3.4 Study limitations

Several limitations must be taken into consideration with this type of study. First, the database searches were based on bibliographic records (title, abstract, keywords), which lowers the likelihood of finding all relevant articles when compared to full text indexing (Lin 2009). Analyses of abstracts are also known to underperform when compared to analyses using full-text articles (Westergaard et al. 2018). Indeed, in an abstract-based literature review, the comparatively lower level of detail offered by the information analyzed is prone to bias. Information considered to be missing might very well be present in the full text, and information emphasized to justify the research could in fact not be the actual object of analysis. Here, for example, this translates into the risk of overlooking existing social sustainability analyses if they were not mentioned as such in the abstract, despite such analysis being part of a particular study. On the other hand, when social sustainability is mentioned in the terms of, for example, 'improved livelihood' or 'reduced poverty', as is often the case, only a full text analysis could reveal whether such indicators were indeed examined. Positive and negative outcomes might also have been more nuanced and detailed in the full text. Likewise, our categorization based on FBBE sectors and thematic study areas is also subject to a certain degree of bias, as important information could have been overlooked in the abstracts. Despite these limitations, as our interest was in providing a quick overview of these issues, we deliberately decided to keep the analysis at this level.

A selection effect might also occur as a result of the choice of keywords in the search strings. This perhaps explains the lack of publications addressing certain forest sectors or applications, as will be mentioned below. Technical reports on innovations might, for example, fail to mention anything to do with an innovation's social sustainability implications, and therefore not be identified by our searches, leading to an underestimation of novel FBBE activities in SSA.

Another source of bias lies in the overlap between the categories of 'new', 'traditional' and 'transitional' FBBE; studies often overlap and this categorization ultimately relies on the researcher's own judgment and, again, would benefit from an analysis of the full texts to grasp the topics accurately.

Finally, grey literature was not considered for the sake of time, but could be very informative on the topic of sustainability and forest activities. Indeed, numerous NGOs, international development agencies, national or regional initiatives, as well as research institutes, may lead such projects in SSA; analysis of documentation produced by these stakeholders could well further inform research.

4 Results

4.1 Database screening

After removing duplicates, a total of 486 publications from three research databases (Scopus, Web of Science and CAB Abstracts) were selected for eligibility screening; 360 of these were examined using AbstrackR (abstracts generated randomly). The remaining 126 abstracts were not considered due to time constraints; analysis was thus limited to a total of 360 abstracts (74% of the eligible studies). A total of 226 of the 360 abstracts analyzed were deemed eligible based on the defined criteria (Figure 5).

When looking at the entire library (N=486), we see an increase in the number of publications from 2006, with the most publications appearing in 2019 (Figure 6). This trend is also verified in the sample library (N=360), and the set of eligible publications (N=226). The most represented journal is *Forest Policy and Economics* (Figure 7).

An analysis of the keywords used in the retrieved publications reveals that, apart from the terms 'livelihood', 'sustainability' and 'poverty', which appear in the keywords of at least 10% of the publications, other keywords associated with elements of social sustainability are not widely

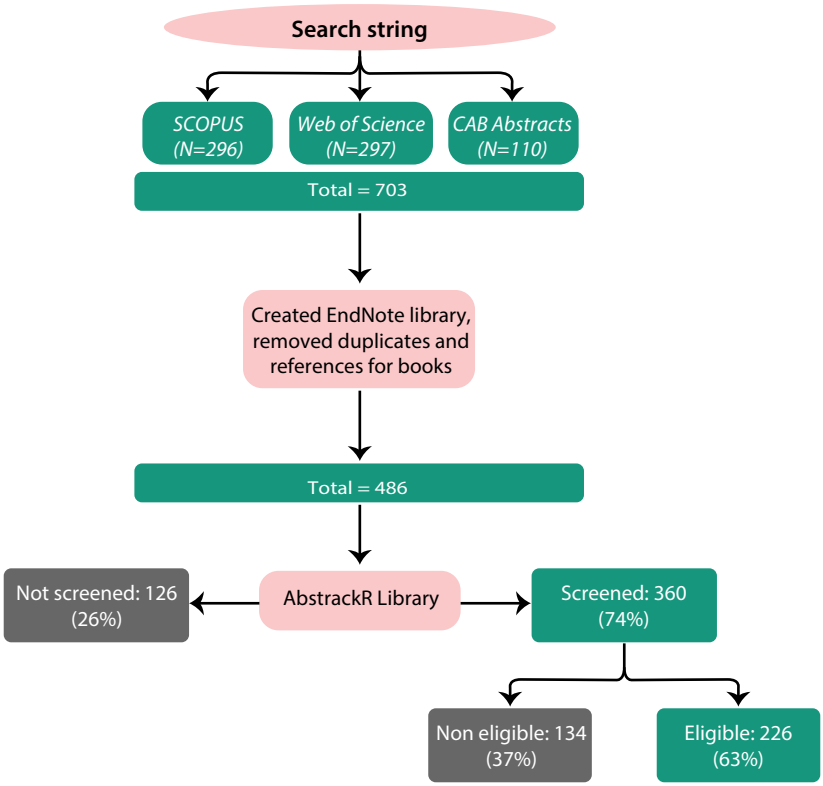

Figure 5. Results of database searches and eligibility screening

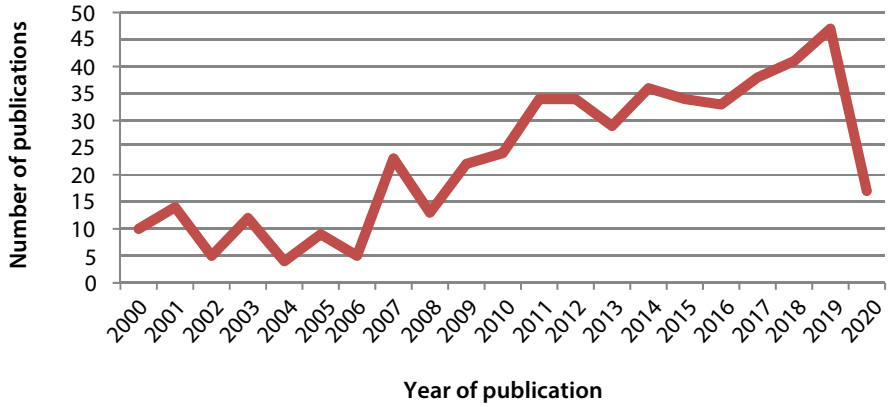

Figure 6. Retrieved publications' year of publication (between 2000-2020)

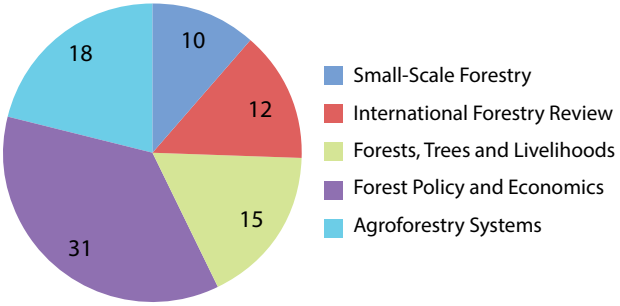

Figure 7. Scientific journals where most retrieved studies were published (based on journals with at least 10 entries).

used, and appear in less than 5% of the publications (Figure 8). For example, 'gender' is mentioned in the keywords of less than 2% of the publications; equity in less than 1%; (in)equality in about 1%; and food and water security in about 4%. Indeed, while many abstracts do mention aspects relating to social sustainability, these are most often used to legitimize or contextualize the study performed, rather than being the direct object of the study.

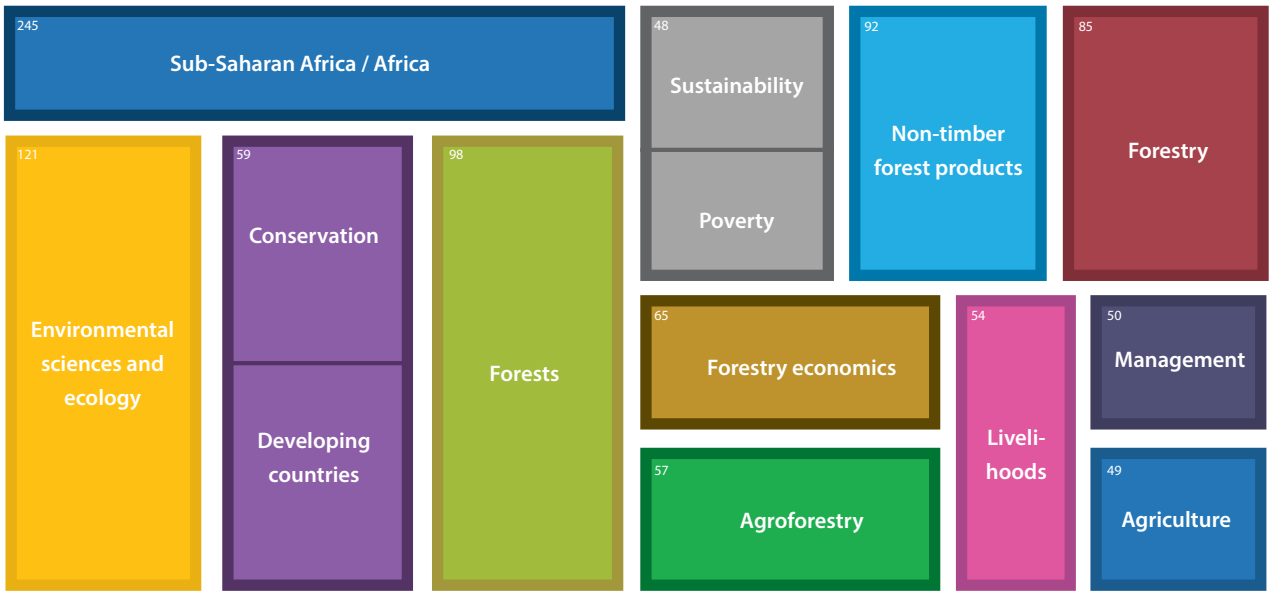

Figure 8. Keywords appearing in at least 10% of the retrieved publications

Number in upper left corner corresponds to the number of publications in which a keyword was found

4.2 Profile of eligible abstracts

Upon applying the above-defined criteria, 226 publications were considered eligible and 134 were rejected, mostly due to a wrong geographical area, or a focus on agricultural practices, forestry technicalities or forest conservation. A total of 30 sub-Saharan African countries were represented in the selected publications. However, just a few of these countries were represented in more than five publications (Figure 9). The most studied country was Ethiopia, followed by Tanzania and Cameroon (Figure 10); studies in these countries focused on forest-dependent communities and rural populations and households. Particular attention was also given in the abstracts to smallholders, farmers and producers/collectors; interactions with other actors also appeared occasionally, depending on the study topic. These other actors included urban populations (e.g. adopting a role in resource processing, marketing, trading or crafts; urban dwelling; or consumption of forest ecosystem services); government and state forest administrations; the private sector (e.g. the tree seed sector); and supply chain or value chain actors.

Over half of the studies (51%) addressed traditional forest-based activities, while a very low percentage (8%) referred to new forest-based activities (Figure 11). Although looking at traditional forest-based activities, the remaining 41% were studies that were either aiming to improve the value of forest products, or whose conclusions suggested that a transition was needed to reach higher sustainability and population resilience; these studies were thus classified as studies addressing transitional activities. These

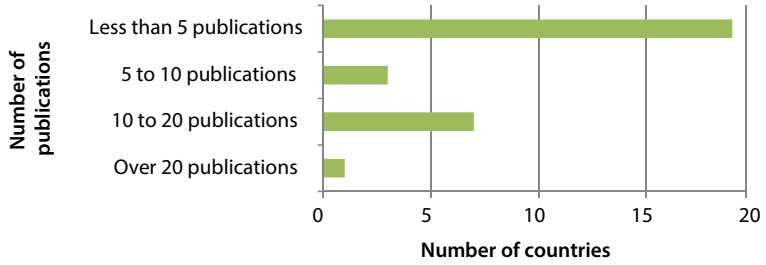

Figure 9. Representation of sub-Saharan African countries in eligible publications (N=226).

Figure 10 . Countries represented in eligible studies

The categories 'Africa, SSA, developing countries', 'regional' and 'global' correspond to studies that considered more than one country.

include, for example, studies concerning: the domestication of forest plants or trees for a more sustainable exploitation (e.g. Leakey et al. 2003); the trade and market access for non-timber timber forest products (e.g. McMullin et al. 2012; Aworh 2015); the greening of activities (e.g. Nhantumbo and Camargo 2016); analyses of how forest policy instruments and management regimes influence, for good or for worse, sustainability and livelihoods (e.g. Scheba and Mustalahti 2015; Mengesha et al. 2019; Gnych et al. 2020); and biomass exploitation aiming at more efficient energy production (Chitawo et al. 2018).

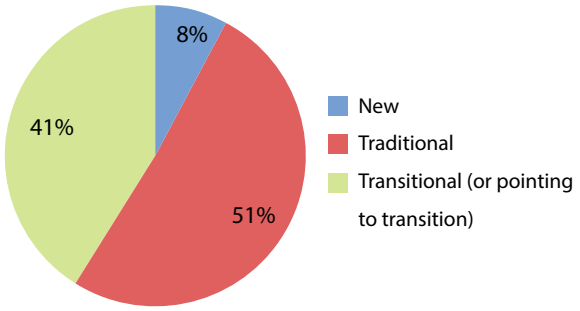

Figure 11. Ratio of forest-based bioeconomy types, as observed in the eligible studies

The abstract analysis exposed a number of recurring study areas; these included: NTFPs as income generators; value chain analyses; the importance of forests for livelihoods and the wellbeing or economy of local communities; community and participatory forestry; conservation and development; bioenergy; social issues (such as the role of women, inequalities or cultural aspects); perceptions, socio-economic determinants and behaviors relating to forest resource uses and activities; economic policy instruments (PES, carbon markets, certification); governance and development initiatives; forest sciences; and land tenure and access. The dominant study area in eligible studies was NTFPs as income generators; this was followed by value chain analyses and studies stressing the importance of forest resources for populations' wellbeing (Figure 12). The order of importance of these themes varied slightly across the three categories of forest activities (i.e. new, transitional, traditional). Studies addressing modern/emerging forest activities (i.e. 'new' forest-based activities) looked at: (i) bioenergy; (ii) value chain improvement; (iii) governance and initiatives; and (iv) economic policy instruments. In traditional forest-based activities, research concerning: (i) NTFPs as income generators;

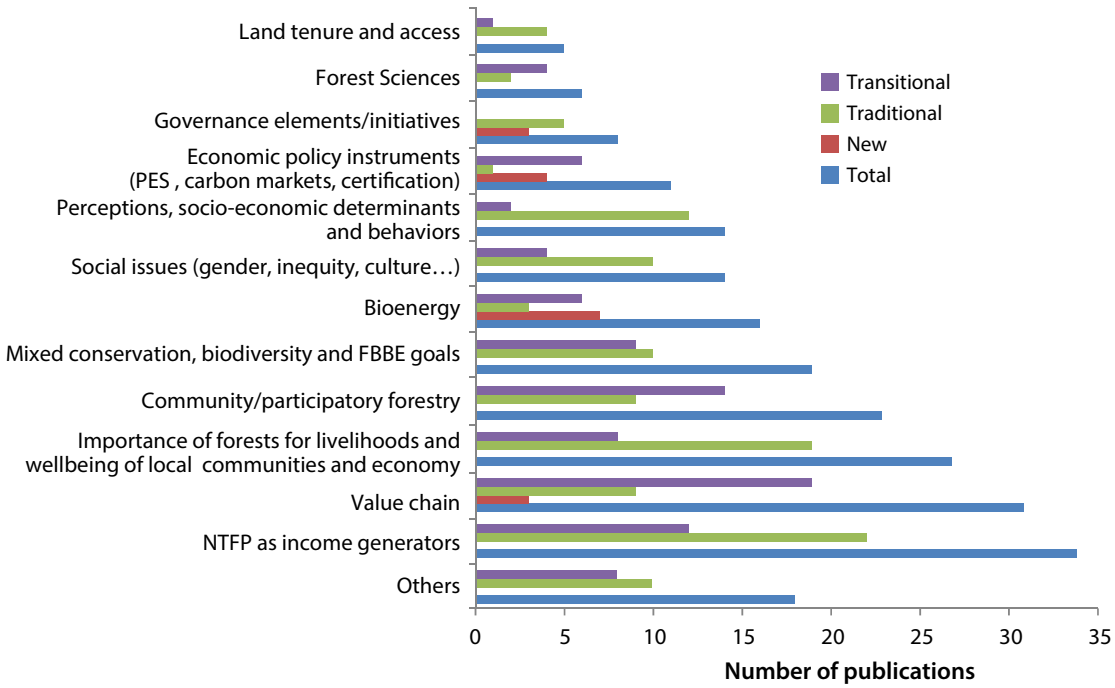

Figure 12. Recurring study areas in publications on new (N=17), traditional (N=116) and transitional (N=93) forest-based bioeconomy

and (ii) the importance of forest resources for the livelihoods of local communities clearly dominate; whereas in publications indicating a transition, the category of 'value chain analysis' is predominant (Figure 12).

In terms of 'exposure' to forest-based bioeconomy (i.e. the presence of FBBE activities, initiatives and policies), exposure-related aspects (as listed in Table 4) were coded into types for each abstract, in order to evaluate their academic popularity. As seen in Figure 13, the detected forest activities were mostly connected with subsistence and income diversification through the use of forest-based products (36%); this was followed by activities relating to the traditional forest industry (18%). The share of all other aspects of FBBE exposure is comparatively small – varying between 1% and 12% (Figure 13). Modern or emerging forest activities represent just 12% of this FBBE exposure overall. If only the publications categorized as 'new' FBBE, i.e. publications in which a change in habitual forest use is suggested, are considered, this figure however rises to 52% (Figure 14).

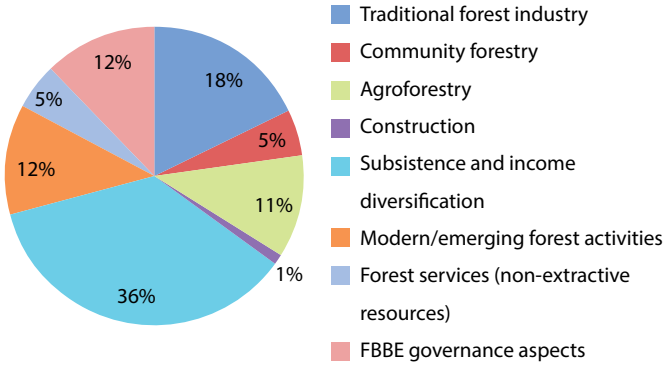

Figure 13. Types of 'exposure' to forest-based bioeconomy, as detected in eligible abstracts

The 14 elements of socio-economic sustainability described in the Method section (see Figure 4 and Table 5) were also recorded for the eligible abstracts (Figure 15), as well as any outcomes and/or obstacles hindering them, whenever enough information on these points was present. 'Quality of life' – which includes gender rights, human rights, equality and equity (notably concerning benefit sharing), enabling institutions, social protection and cultural values, as well as more general notions like poverty reduction, improved livelihoods, community resilience and subsistence – was the most frequently found element in the abstracts, even though most abstracts referenced 'quality of life' generally, or referred to benefit capture (Figure 16). The second most frequently mentioned element was 'income', followed by 'resource conservation'. No reference to 'quality of the workplace' was found, and only one abstract made a clear reference to the social acceptability of bioeconomy-related activities.

Quality of life' and 'income' are predominant across all publications regardless of whether their focus is on 'new', 'traditional' or 'transitional' FBBE. While 'new markets and business oportunities' and 'profitability' are less represented in the traditional forest-based activity category, several social sustainability elements were not found at all in publications categorized as focusing on new FBBE, although this could be due to the significantly lower number of abstracts in that category (N=17). Besides this, no major

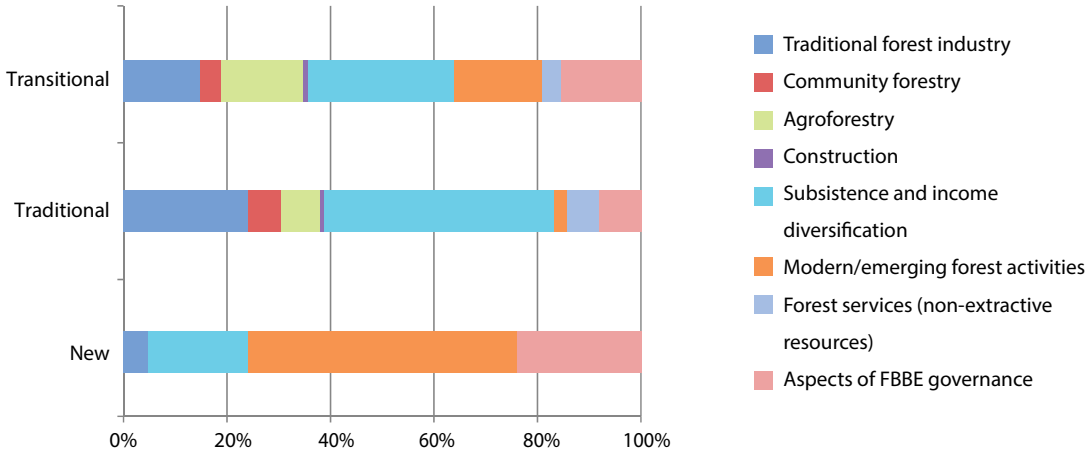

Figure 14. Types of 'exposure' to forest-based bioeconomy, as detected in publications focused on 'new', 'traditional' and 'transitional' forest-based bioeconomy

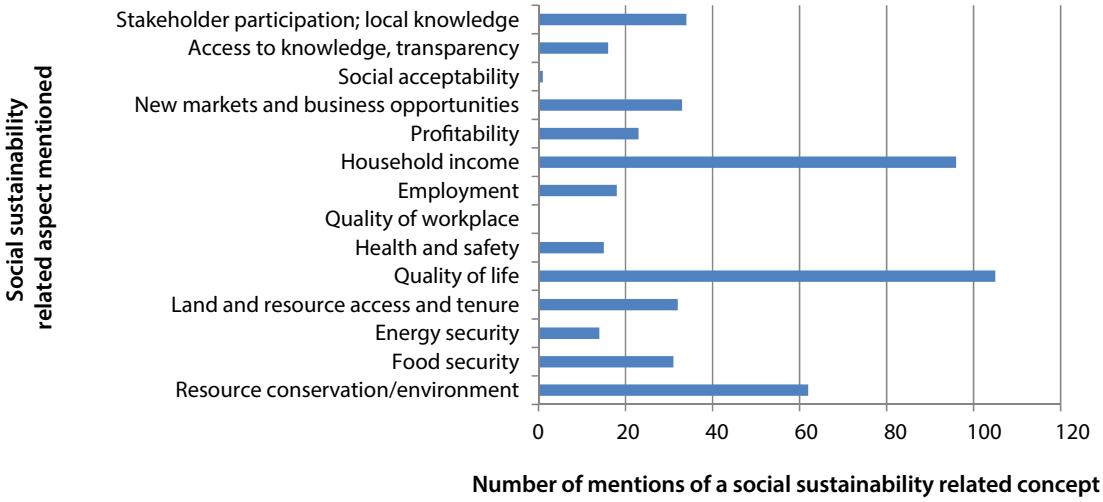

Figure 15. Occurence of social sustainability related aspects in eligible studies

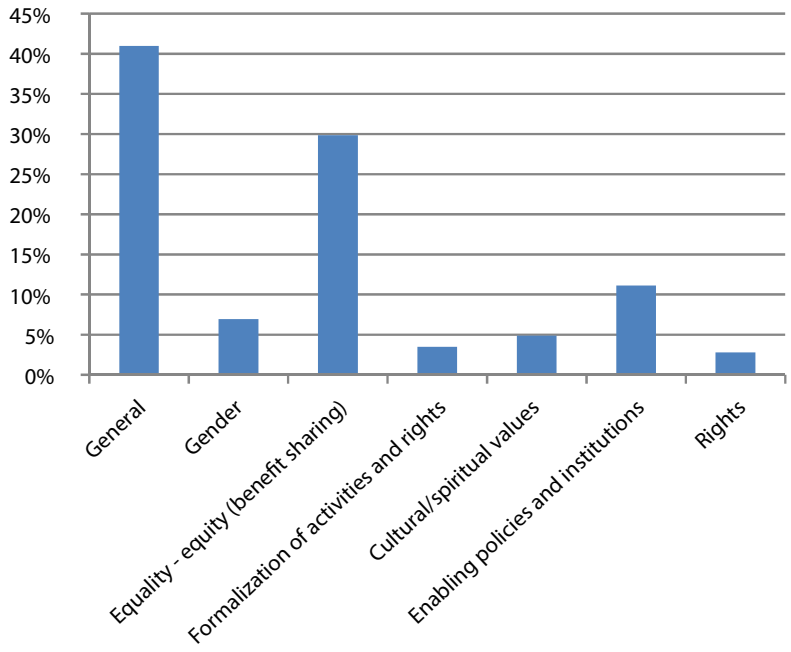

Figure 16. Breakdown of components relating to the socio-economic aspect 'Quality of life'

differences were found across categories; elements of socio-economic sustainability were given similar importance (Figure 17).

Information about the outcomes of FBBE exposure was detectable in 66% of the abstracts (Figure 18). These outcomes were positive in 30% of the cases, negative in 11%, and mixed in 25% of the cases, i.e. there was potential for either positive or negative outcomes to arise, depending on the context. These positive outcomes were associated with: improved livelihoods in the form of higher income; higher profitability; improved inter and intra-generational benefit capture; better access to markets; access to education and training; conservation of natural resources so that use is sustainable; and land tenure rights. Negative outcomes were associated with: loss of natural resources needed for subsistence due to overexploitation; dispossession and displacement (often referred to as green or land grabbing); inequalities in benefit sharing; gender issues; and elite capture.

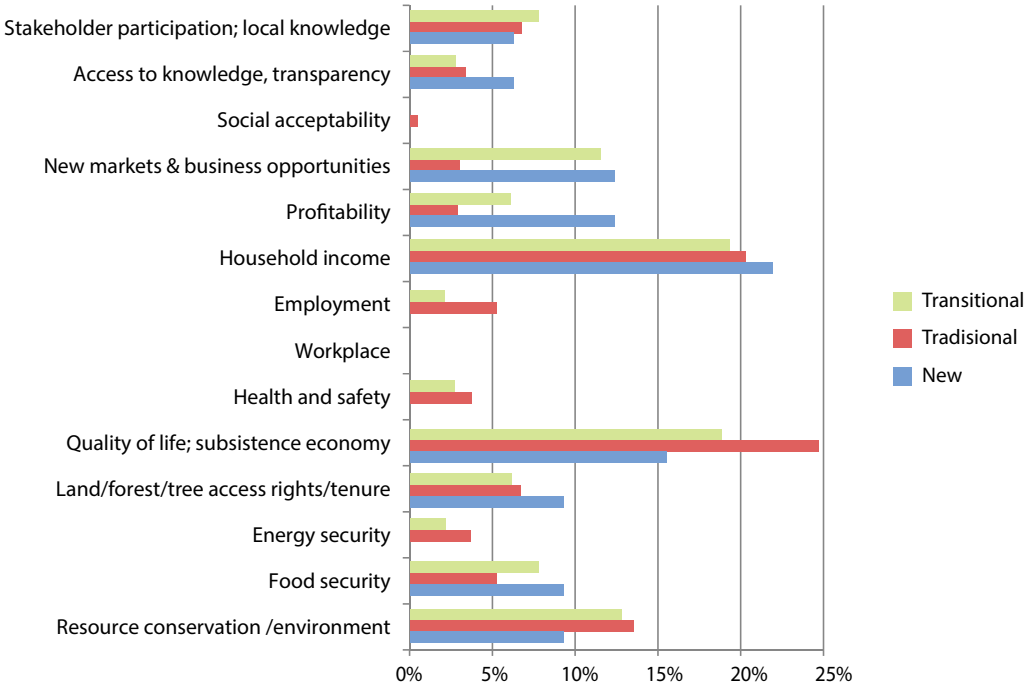

Figure 17. Occurence of social sustainability related aspects across transitional, traditional and new forest-based bioeconomies

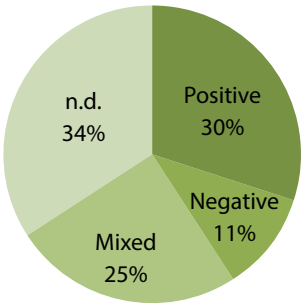

Figure 18. Socio-economic consequences of forest-based bioeconomy activities, as identified in eligible abstracts.

Note: n.d. = not determinable based on abstract

Identified obstacles to forest bioeconomy-driven socio-economic sustainability are listed in Table 7 for each socio-economic indicator in our framework. These mainly include: lack of appropriate policies and governance to enable benefits deriving from forest activities to be captured in an equitable fashion; the overlap of legal and informal systems; the development of markets for forest products and gaining access to these markets; and negotiating forest conservation and poverty alleviation goals. Indeed, conflict between resource conservation and quality of life or income was a recurring theme in the selected abstracts, which sought solutions for decoupling livelihoods from resource degradation . Other underlying obstacles cited include: lack of political will or interest; lack of funding; investment opportunities for smallholders; training technical assistance and education; and the lack of scientific foundations underpinning cultivation techniques or plant properties to be exploited.

4.3 Forest-based bioeconomy sectors: Opportunities, burdens and challenges

4.3.1 Traditional forestry (management for extractive resources)

While the reviewed abstracts established the important contribution of forests to livelihoods, economy and wellbeing through the provision of ecosystem services, tradable forest products, food or medicinal products (Oyono et al. 2005; Mamo et al. 2007; Winter et al. 2015; Chagumaira et al. 2016; Duboz et al. 2019), they also emphasize the unresolved dilemma of reconciling poverty alleviation and forest conservation goals (Wunder 2001; Asongu and Jingwa 2012; Chavarria et al. 2018; Kimengsi et al. 2019). Indeed, forests

Table 7. Potential socio-economic burdens and challenges preventing forest-based bioeconomy from improving rural livelihoods

#	Socio-economic category leading to improved livelihoods	Challenges to forest-based bioeconomy and potential socio-economic burdens
1	Resource conservation/ environment	• Loss of subsistence economy • Land use balance between conservation and development goals
2	Food/water security	• Unsustainable use of resources driven by poverty • Competition for land use with agriculture
3	Energy security	• Unsustainable use of resources driven by poverty • Competition for land use with agriculture
4	Land/resource access and property rights	• Need to resolve land/resource access and tenure rights • Loss of local rights over resources, need to resolve resource conflicts • Exploitation by large entrepreneurs • Dispossession and displacement (land grabbing, spatial injustice) • Unintended consequences from granting rights and tenure, and from legalization of informal forest activities
5	Quality of life (incl. human rights, gender issues, equity, corruption, beneficial environment, social protection)	• Historically hindering political economy and sticky institutions • Lack of enabling institutions • Lack of law enforcement • Unclear institutional arrangements and superposition of conflicting legal and customary/informal systems) • Corruption • Elite capture • Appropriation of labor and financial resources of smallholders by forest investors • Need to resolve benefit sharing issues • Disempowerment • Lack of social protection laws • Complex bureaucracy • Inter and intra-generational inequities in access to resources and ecosystem services • Gender inequalities in access and benefits from FBBE activities
6	Health and safety	• Lack of scientific knowledge on plant characteristics • Need to resolve rights over genetic resource benefit sharing
7	Quality of workplace	n/a
8	Employment	• Lack of forest enterprise development, notably in small enterprises, and enabling institutions
9	Household income	• Frequent failure of financial benefit capture • Loss of rural income due to large-scale land acquisition • Inequalities across value chains
10	Profitability	• Resolve benefit sharing • Superposition of formal and informal economy • Illegality (ensuing corruption and control of market access) • Need to improve value chain and added value of forest products (products currently sold with little value added) • Need to make FBBE more lucrative than illegal activities • Lack of data on economic value of forest products • Lack of seeds and seedlings supply

continued on next page

Table 7. Continued

#	Socio-economic category leading to improved livelihoods	Challenges to forest-based bioeconomy and potential socio-economic burdens
11	New markets and business opportunities	• Value chains underperforming • Absence of stimuli/policies for new markets/products/value chain improvement • Inappropriate technology, inadequate electricity supply • High interest rates, and limited access to banks and other financial institutions for smallholders • Lack of benefit capture • Commercialization usually resulting in overexploitation of the resource by outsiders • Inequalities in market access
12	Social acceptability	• Sustainable practices seen as costly (need to resolve compensatory measures) • Need to reach rural populations and have innovative sustainable practices/ markets adopted
13	Access to knowledge	• Lack of skills (organization, marketing, business management, entrepreneurship) • Lack of knowledge (e.g. medicinal properties) • Lack of capacity development, technology transfer and educational opportunities • Rural populations' lack of awareness around forest legislations or initiatives
14	Stakeholder participation, indigenous knowledge	• Lack of citizen empowerment and transparent information, inhibiting local communities from effectively managing resources • Governments' determination to hold control over forest resources while transferring only part of property rights to local communities • Lack of confidence from communities in managing forests • Exclusion of forest-dependent communities from decisions and benefits

Note: n/a = not detected in reviewed abstracts

are a safety net for dependent communities, contributing to over 30% of total household revenue (Mamo et al. 2007; Mutandwa and Kanyarukiga 2016; Endamana et al. 2019), and restricting access to these resources would only foster more poverty. Poverty conditions however drive unsustainable and illegal use of resources, which in turn lead to forest degradation and loss, thereby annihilating the very source of income and subsistence of these communities. Wunder (2001) stresses the ambiguous role of poverty in forest conservation, highlighting that higher income can also lead to forest loss as agricultural (land) needs increase. Poverty, development and sustainable forest management are thus interrelated and finding the right balance is crucial if forest-based development is to be considered. One solution can be found in maximizing the value of forest products so that they can compete with agricultural products and with the profits of illegal activities (Sutcliffe et al. 2012; Roques et al. 2019). This could happen if forest products became more valuable through bio-based economies.

The plantation and cultivation of wild forest plants are suggested as a way to relieve pressure on natural forests (Jamnadass et al. 2009; Malkamäki et al. 2018; Arvola et al. 2019). Large-scale commercial plantations and smallholder plantations are considered in publications, and studies show both negative and positive implications for socio-economic sustainability. Large-scale plantations, while offering additional livelihood activities (e.g. employment), benefit forestry actors more than local populations, and may result in displacement of populations with impacts on their customary land use, as well as resulting in land grabbing if the tenure system is not formalized. Plantations of species such as pine and eucalyptus, which should have improved livelihoods, have done more harm than good due to forest conversion and the detrimental consequences for soil resources

(Mwanukuzi 2009). The increasing need for timber may, on the other hand, open new opportunities for small-scale tree farmers, as Arvola et al. (2019) showed in Tanzania, even though the farmers' capacity to market their wood and negotiate prices was unclear. While unhealthy competition can occur in informal markets, formalization risks less powerful actors being excluded for performing an activity that has become illegal or for being financially unable to legalize their activity (e.g. abiding by a permit system). As for the cultivation of plant and tree species for NTFPs, some studies argue that knowledge about cultivation techniques must be built (e.g. Komayire 2017; Sanou et al. 2019) and efforts to make seeds and seedlings accessible to farmers must be made (Odoi et al. 2019). The cultivation of species like bamboo (Endalamaw et al. 2013; Ingram and Tieguhong 2013; Lin et al. 2019) is common, but efforts also visibly expand to lesser-known plants like allanblackia, a tree species whose seeds produce edible oil (Jamnadass et al. 2009; Leakey and Damme 2014; Mpanda et al. 2014), indigenous and exotic fruits (Jamnadass et al. 2011; Rankoana 2016), medicinal trees and plants (Geldenhuys 2004; van Niekerk and Wynberg 2012; Cunningham et al. 2014; Kulak 2018), trees and plants supporting the production of spices (Meaton et al. 2015), snails (Ndoye et al. 2016) and edible larvae (Meutchieye and Niassy 2016; Bomolo et al. 2019).

Afforestation and reforestation initiatives with the aims of income generation and ecosystem restoration to improve population resilience and poverty conditions, as well as initiatives focused on carbon markets, have also yielded context-dependent results in terms of socio-economic sustainability. Cases of green grabbing and spatial injustice are reported (Cormier-Salem and Panfili 2016), but there is also evidence of opportunities to improve livelihoods, ecosystem services and economy (Brown et al. 2011; Pistorius et al. 2017; Duboz et al. 2019), as well as create business opportunities in seed and seedling markets (Odoi et al. 2019). Unclear land use rights and tenure, poor silvicultural practices and lack of government initiatives are listed as obstacles to sustainability, while the importance of local involvement has been underlined (Roba and Oba 2013).

As with large-scale plantations, the concessionary forestry business model in SSA, largely responsible for the production of timber for export from natural forests, has been associated with a lack of inter- and intra-generational equity. Little attention is paid to environmental sustainability, which risks leaving future generations with scarce resources. Benefits from forest exploitation are also more profitable for the forestry elite than for local communities with customary rights, who are excluded or marginalized. For example, the taxes collected by the states from concessionaires are not equitably redistributed, and promises of social investment are also not fulfilled. Local communities are likewise not recognized as important stakeholders or sufficiently engaged in the decision-making process. By focusing on short-term profit rather than creating value added products and neglecting sustainable management, the concessionary model limits the development potential of the forestry industry. Factors slowing down such a transition include, for example, the lack of technology development in SSA (including the lack of electricity) and a weak political economy characterized by corruption and rent-seeking (Oyono et al. 2005; Atewamba and Boimah 2017).

The superposition of legal and informal (customary) tenure systems and economies is an unavoidable and wicked issue that is reflected in any activity involving the use or trade of forest resources. Changes in tenure have been used as a tool to counter forest degradation arising from open access (Namaalwa and Hofstad 2007), but ill-defined property rights can lead to displacement, exclusion from resources on which communities have always depended, or marginalization; and tenure does not necessarily help improve sustainability practices, because conservation is still perceived as a cost (Owubah et al. 2001). Granting property rights has been associated with a mix of context-specific positive and adverse outcomes for both social and environmental sustainability (German et al. 2014; Lambini and Nguyen 2014).

Finally, even though reforms have aimed in some cases for better land use and forest management, and taken into consideration logging concessions, protected areas, plantations and community forests (e.g. Jum et al. 2007), conflicting or inappropriate policies, weak governance and the absence of functional links between the various forest management units, have not yet allowed sustainability goals to be achieved (Chirwa et al.

2008; Feka 2015; Atewamba and Boimah 2017). Likewise, lack of compliance with (Ramcilovic-Suominen and Hansen 2012) and enforcement and awareness (Soto et al. 2001; Kayode 2011) of the existence of forest laws in forest-dependent communities represents another obstacle to sustainability.

4.3.2 Community forestry

Community forestry is addressed in about 5% of the selected publications. Evidence suggests that the concept has not yet fulfilled its promises. While it can promote sustainable management, foster social innovation, enable diversification and attract investment (Gnych et al. 2020), community forestry initiatives remain fragile and over 20 years after the launch of community-based forest management, local communities are still not enjoying the expected benefits (Scheba and Mustalahti 2015). Gilmour (2015) describes community forestry as underperforming, particularly in terms of delivering financial benefits to the local community. In particular, the commercialization of forest products from community forestry is proving problematic, and state-imposed bureaucratic procedures are preventing communities from successfully exploiting the economic potential of their forests. Other barriers include lack of entrepreneurial and business management skills in rural communities, and a range of legal and market-related issues (Molnar et al. 2008; Gilmour 2015).

4.3.3 Agroforestry systems

In total, 11% of the abstracts referred to agroforestry, farm forestry or home garden practices. Tree planting is promoted as an alternative livelihood source, relying on the production of food and non-food products (e.g. medicinal plants) (Holden et al. 2005; Ndayambaje et al. 2013; Leakey and Damme 2014; Sanou et al. 2019) and, alongside community forestry, is put forward as a way to maintain family farming (Meunier et al. 2014). Kiptot et al. (2012) showed that women's participation in agroforestry is still limited to enterprises that have little or no commercial value, like the collection of indigenous fruits and vegetables. Challenges associated with the adoption and profitability of agroforestry include the development of relevant tree crops and silvicultural practices, as well as reaching smallholders in rural areas (Lilleso et al. 2018). Farmers were found to be more likely to adopt agroforestry if they had adequate silvicultural knowledge and technical support, and if the economic benefits were perceived to be sufficient (Sanou et al. 2019). Agroforestry plantation systems (e.g. cocoa, coffee), besides improving productivity (Pinard et al. 2014), are also found to contribute to farmers' livelihoods by providing NTFPs (Beyene et al. 2019). Some studies reminded of the potential benefits that value chain improvements (Deans et al. 2018), greening (Nhantumbo and Camargo 2016) and certification (Millard 2011; Mitiku et al. 2018) of agroforestry plantations could bring for local communities, such as price premiums or improved benefit sharing. Certifications schemes were, however, documented as having mixed outcomes (see Section 4.3.5).

4.3.4 Construction industry

No reference to timber construction was found using our search strings. Instead, the topic was embedded in studies concerning the availability and access of forest resources, and NTFPs providing building materials (Roba 2000; de Neergaard et al. 2005; Zegeye et al. 2011; Kimaro and Lulandala 2013).

4.3.5 Subsistence and income diversification through forest-based products

By far the most popular topic, subsistence economy and income diversification through forest-based products, were identified in 36% of the abstracts. This theme can be subdivided into different categories, as shown in Figure 19; of which the subject of NTFPs as a means for income diversification is the largest.

Identified NTFPs are extremely varied; these can be the object of wild harvesting, plantation and cultivation, agroforestry or home gardens. Examples of NTFPs include the medicinal pelargonium, spices (e.g. korerima), bush mango, bayere (yam), the multi-purpose miracle berry, baobab products, snails, crabs, caterpillars, mushrooms, shea products, the uapaca fruit tree, gum, resin, coconut wine, honey, oil seeds, fodder, wild tuber and construction material.

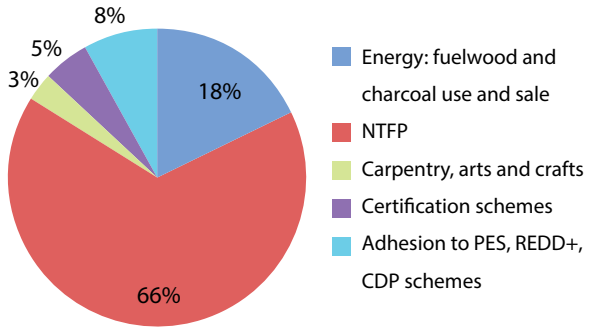

Figure 19. Forest-based activities contributing to subsistence and income diversification

As with traditional forestry, evidence shows that overexploitation of natural resources is leading to their depletion, which points to the need for sustainable management and cultivation, for the sake of both natural resources and forest-dependent communities' livelihoods (Dovie 2003; Kimaro and Lulandala 2013). Indeed, the contribution of NTFPs to household income was shown to be important, particularly for poorer and/or more remote households, who also use them to fulfill their basic needs (Heubach et al. 2011; Malleson et al. 2014; Schaafsma et al. 2014; Beyene et al. 2019). They represent an income equalizer and an opportunity for poverty alleviation in rural areas, as well as contributing to food security and resilience in time of crisis. Despite NTFP resources being threatened by overexploitation, it has been argued that the significant contribution they make to local communities' income, livelihoods and resilience could represent an incentive for sustainable forest management (Kimaro and Lulandala 2013; Kefa et al. 2018). Asides from the issue of sustainable management, the contribution of NTFPs is also suboptimal due to the many challenges faced during their processing and marketing, including the informal economy, disorganization and a lack of marketing skills among farmers and smallholders (Ahenkan and Boon 2010).

A lot of attention is thus given in the publications to analysis of the value chains of these NTFPs, as seen in Figure 12. Developing new markets, ensuring the integration of all actors across the value chains, and adding value to forest products can all improve forest-dependent communities' livelihoods, by increasing the profitability of their activities, or creating alternative income and employment. For example, considering plant-based drugs, health products, pharmaceuticals, food additives and cosmetics alongside traditional uses of forest products, or considering neglected and underutilized species, may contribute to rural incomes (Pitalounani et al. 2017; Kulak 2018). Value chains were analyzed for products like bamboo (Ingram and Tieguhong 2013; Mekonnen et al. 2014), gums and resins (Mekonnen et al. 2013), miracle berries (Arowosoge and Popoola 2006), snails (Ndoye et al. 2016), oily NTFPs (Roques et al. 2019), frankincense (Abtew et al. 2012), baobab (Jäckering et al. 2019), coconut wine (Njugu 2013) and rubber trees (Iyayi et al. 2008), among others. Overall, these studies show that, although income is being generated, value chains are underperforming and inefficient. Little attention has been paid to the exploitation of seeds produced by the rubber tree, for example, which in fact contain valuable oil with potential for industrial applications. Likewise, bamboo value chains have untapped potential despite huge demand and possibilities for product diversification and innovation. Factors hindering the development of value chains include: resource access rights; lack of technical, financial and institutional support; lack of sustainability; lack of skills and training leading to poor handling and losses of products; difficult access to markets; legality issues due to the lack of recognition of informal markets; informal markets fostering corruption and control of market access; and limited self-organization among value chain actors, with subsequent reliance on middle men. From a social sustainability perspective, value chains often display an upward skewed distribution of benefits among the value chain actors, with those actors involved in marketing products accruing higher benefits than those who collect or produce. Poorer producers generally have less access to markets and, in the case of informal markets, risk exclusion for illegal trade. The latter has also been linked to child labor, as children are less likely to be arrested (Kefa et al. 2018). However, attempts at legalizing activities have also borne economic and social costs for communities (Wynberg et al. 2015; Acheampong and Maryudi 2020). Gender issues are also noted: women dominate particular activities, like mushroom or edible larvae collection, but overall, their role is limited to the less lucrative activities in the value chain, like informal sales.

Woodfuel collection and charcoal production, which often represent the only source of energy

in SSA, are critical for both subsistence economy and income diversification for rural populations. These value chains have been relatively well studied, and their adverse environmental and social impacts have been highlighted repeatedly (Sola et al. 2017). Indeed, these activities are a driving force of forest degradation, responsible for sizeable carbon emissions, as well as reducing household air quality, thereby affecting the health of communities. Mostly illegal and unsustainable (Smith et al. 2019), these activities are tolerated due to lack of better energy alternatives. As noted above, illegality is also synonymous with unequal and unfair trade practices, as well as with the uncontrolled exploitation of forests, contributing to their decline. The informal sector is nonetheless organized, notably in the case of commercial charcoal production, and evidence suggests that local communities pay attention to protecting useful trees (Salami and Brieger 2010). However, most of the financial benefits do not reach the local communities, in part due to punitive tax rates and the bureaucratic burdens of obtaining charcoal commercialization licenses (Baumert et al. 2016). Attempts at formalizing markets for forest products have led to further inequalities, including power abuses as well as financial and physical corruption (Wynberg et al. 2015). It is also noteworthy from a social sustainability perspective, that woodfuel collection is particularly burdening for women, and sometimes children, who are the ones dedicating a large amount of their time to gathering wood and exposing themselves to the risks associated with this activity. Agroforestry has been suggested as a solution to fuelwood collection and shortages, and some households have resorted to planting trees on their own farms (Sikei et al. 2010; Peltier 2019). Fuelwood farming has also been proposed, to produce energy from biomass in a sustainable way and contribute to smallholders' livelihoods (Omer 2005). These activities could be entry points for a 'new' FBBE approach.

Other sources of income diversification from forest resources were much less represented than NTFPs and fuelwood. The informal carpentry sector was investigated by Adam et al. (2013) who identified its potential to contribute to rural economic development, but with the caveat that operators face many constraints including funding shortages, lack of raw materials, an insecure market, lack of technology and disorganization.

Certification schemes were shown to have positive impact on the adoption of sustainable land use practices, quality of products and the income of adhering landholders (Girma and Gardebroek 2015; Kalonga and Kulindwa 2017; Mengesha et al. 2019). However, such schemes depend on tenure security and can be costly for smallholders to adopt, thereby limiting access to 'green' businesses (Damme 2018). Claims that benefits are skewed towards retailers have also been made (Araki 2007). There are few examples of adhesion to PES schemes, perhaps because the establishment of PES schemes in Africa is more challenging than elsewhere, due to the lack of buyers and high poverty in both rural and urban populations (Lopa et al. 2012). Additional obstacles lie in high transaction costs, land tenure and insufficient enabling policy. However, studies suggest that agroforestry PES schemes, for example, can be cost-effective and efficient in some farming systems in SSA (Benjamin and Sauer 2018), and that a certain willingness to pay for forests' ecosystem services exists. Benin residents, for example, were willing to pay for ecosystem services provided by peri-urban and urban trees (Arabomen et al. 2019), while in Tanzania urban water users were willing to pay for watershed ecosystem services (Lopa et al. 2012). In the latter case, interventions were mostly in the agroforestry sector; farmers adopted the practices primarily because of the monetary incentives and agricultural extension advice that is not available otherwise. The PES payments had positive livelihood impacts as farmers purchased better seeds and animals, improved their homes, and enjoyed non-income benefits like the development of a business network and potential for learning.

4.3.6 Modern/emerging forest industry markets

Elements of modern or emerging forest industry markets were detected in 12% of the eligible abstracts, but these are rather subtle for the most part. Generally, these elements consist of improving (or attempting to improve) value chains and identifying value added products, like domesticating trees for new tree crops for food, cosmetic and pharmaceutical industries (Leakey and Damme 2014; Aworh 2015; Damme 2018). Roques et al. (2019), for example, investigated the sustainable production of oily NTFPs. Crops

like cocoa would be grown to produce vegetable oil rather than cocoa beans, as oil represents an added value product. A similar approach was described for the rubber tree, the seeds of which can produce valuable oil (Iyayi et al. 2008). A few bioprospecting and biotrading activities (e.g. for pelargonium, medicinal plants) are also mentioned (Bodeker et al. 2001; Chinsembu et al. 2011; van Niekerk and Wynberg 2012; Wynberg and Van Niekerk 2014), but bioenterprise development remains limited, and knowledge about plants efficacy and safety is still scarce. While this type of activity generates business and employment, the issues of benefit sharing, rights over genetic resources and intellectual rights, and risks of monopolistic exploitation by ruthless entrepreneurs persist. An additional example of a modern/emerging forest industry market is seen in Lestari et al. (2015), who performed an economic valuation of potential products originating from Jatropha, notably press cakes, the by-product of biodiesel production.

The bioenergy industry is also classified as a modern forest industry activity. Various bioenergy systems have been pursued based on their potential to meet domestic energy demands, reduce fuel importation, diversify the rural economy and create employment; this would not only reduce poverty but also provide net energy gains while reducing environmental impacts (Mangoyana 2009). Bioenergy production from primary and secondary forest residues constitutes a step up from direct use of forest resources for energy (e.g. charcoal) and would also offer a solution to the energy issues that SSA faces. With this in mind, Dasappa (2011) investigated the production of electricity from forest residues, identifying technological and economic barriers to the undertaking of this approach. With the abundance of natural resources and high interest of international stakeholders, biofuels are high on the agenda in SSA; however the development of markets has been slow, and there have been concerns about competition for land that could be utilized for food and water security and biodiversity protection (Faaij and Domac 2006; Mangoyana 2009). Jatropha, portrayed as the silver bullet crop for biofuel production, has not held its promises (Hunsberger 2016) and, according to Kalinda (2015), farmers who decided to cultivate Jatropha experienced worsening economic conditions, notably due to unclear policies on biofuel production.

4.3.7 Forest services (management for non-extractive resources)

Identified forest services consisted mainly of evaluating the provision of forests' ecosystem services by analyzing their economic value and perceptions of them (Krause et al. 2017), as well as the extent to which local populations depend on the ecosystem services that forest landscapes provide, including water, shade, food, fodder and flood regulation (Ashagre et al. 2018). Willingness to pay for forest ecosystem services, and factors influencing smallholders' participation in ecosystem service-related schemes, are also investigated (Lopa et al. 2012; Benjamin and Sauer 2018), as well as the potential to balance the goals of conservation and improved livelihoods of forest-dependent communities through PES schemes (Syampungani et al. 2009). Interestingly, Krause et al. (2017) identified that rural communities in Ethiopia valued forests the most for their intangible ecosystem services and felt that forests' contribution to their livelihoods was declining.

Only two mentions of ecotourism were found. One addressed the importance of preserving ecosystems to maintain revenues from nature-based tourism (Turpie et al. 2003), while the second analyzed two different ecotourism business models, one based on land sharing with local communities and villages, the other on the appropriation of large parts of village land for exclusive access and control (Bluwstein 2017). The latter showed that ecotourism through land sharing reinforces village land rights, while ecotourism through land appropriation undermines the land rights of an entire village or ethnic minority.

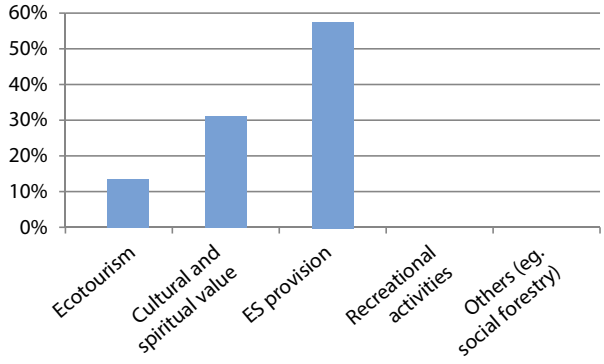

Figure 20. Categories of forest services identified in selected abstracts

Cultural and spiritual values were addressed in the context of conservation of church forests (Wassie et al. 2005; Amare et al. 2016) and NTFP harvesting, including the harvesting of wild plants for health care, the value of home gardens, and foraging (Gbedomon et al. 2015; Towns and van Andel 2016; Garekae and Shackleton 2020). Some studies also stress the fact that cultural diversities are not addressed when implementing reforestation or conservation efforts (Cormier-Salem and Panfili 2016).

4.3.8 Forest-based bioeconomy governance elements

Abstracts with mentions of the governance of forest activities concerned carbon forestry, namely REDD+ initiatives (Cavanagh and Benjaminsen 2014; Cavanagh et al. 2015; Kansanga and Luginaah 2019), forest reforms, tenure rights, taxation systems and the legalization of informal markets (e.g. Gautier et al. 2013), as well as initiatives like the 'Model Forest' (Jum et al. 2007). All highlight challenges and depict direct and indirect burdens resulting from governance attempts: extensive legal and institutional gaps, including lack of stable and equitable forest tenure (leading to spatial injustice and green grabbing); lack of stakeholder participation in forest management and benefit-sharing schemes; facilitation of elite capture; weak law enforcement; contradictory or uncoordinated policies and regulations disincentivizing sustainable development; displacement; and conflation of illegal with informal trade. For example, Gautier et al. (2013) warn about the unexpected outcomes of green neoliberalism in their study on Malian forest reforms. These reforms, establishing fuelwood markets and rights to harvest and sell wood, were deemed successful but in fact led to increased confusion about forest rights, reduced state forest revenues and the facilitation of elite capture. Others warn about the risks of green grabbing and the appropriation of labor and financial resources of smallholders by forest investors, notably in the context of carbon forestry and carbon offsetting, and argue for local rather than centralized control of carbon and land rights, to allow the coexistence of smallholder agriculture and carbon forestry (Kansanga and Luginaah 2019).

5 Conclusions

This abstract-based literature review examined information from 360 abstracts so as to identify the aspects of forest-based bioeconomy that were most represented, and how these might contribute or hinder social sustainability in rural populations in sub-Saharan Africa.

5.1 Forest-based activities in sub-Saharan Africa are mostly traditional

Aiming to identify the benefits and burdens of a forest-based bioeconomy in sub-Saharan Africa from the perspective of social sustainability, this review highlighted a prevalence of more traditional forestry activities, as hinted by the initial literature scoping. Indeed, there was little evidence of modern forest industry as seen in the Northern hemisphere, nor of evidence of innovative products, value chains and new markets. Despite this, forest-related activities are important for both subsistence and income for rural populations, notably through the NTFP trade. Yet the overexploitation of these natural resources – due to poverty and growing populations – is degrading forests, to the point that rural populations' livelihoods have become threatened. These findings illustrate the importance of assessing trade-offs between environmental (e.g. SDG 15 Life on land) and socio-economic (e.g. SDG 12 Responsible production and consumption) goals (Pradhan et al. 2017). Sustainable management of forests, as well as solutions like plantations, are pushed forward as win-win solutions for both the conservation of natural resources and the wellbeing of forest-dependent communities. Poverty, development and sustainable forest management are interrelated; finding the right balance is therefore crucial, if forest-based development is to be considered.

5.2 Social sustainability issues in forest-based activities are clearly evident

The review identified that improvements could be made in all 14 of the socio-economic elements considered within the framework (Figure 5). Rural populations' wellbeing, for example, is not thoroughly addressed or directly measured, but is very often used to legitimize the research and reinforce conclusions that sustainable development must be achieved. Social sustainability is often referred to loosely as 'improved livelihoods' or 'poverty reduction' and, when addressed, tends to focus on household income. Nevertheless, household income does encompass various activities – like monetary income from sales of forest products, wage labor, or value addition to forest products – and is therefore particularly indicative of any potential improvements to forest activities' value chains. It is also closely linked to the matter of benefit sharing, another recurrent theme in the abstracts reviewed, and perhaps one of the most important challenges to a successful forest-based bioeconomy. The 14 elements analyzed are embedded in the four dimensions of poverty defined in the Sida poverty framework: power over material and non-material resources; access to services and opportunities to use the resources and move out of poverty; voice to express rights and concerns; and human security (Sida 2017), reaffirming the potential of FBBE to contribute to poverty reduction. Indeed, the role that bioeconomy can play in addressing UN SDG1 (poverty reduction) has been recognized (Figure 2).

5.3 Forest-based bioeconomy opportunities and challenges

Noticeable efforts to transition towards a modern forest-based bioeconomy are seen in the studies examining value chain improvement, bioenergy options and the cultivation potential of wild species. By improving value chain performance and adding value to forest products, opportunities for new markets, enterprises, employment and income can significantly increase. If combined with approaches to sustainably manage resources, bioeconomy could become a solution to help disentangle the poverty-development nexus, notably in rural areas. By fostering the development of forest-based solutions to bioenergy production (e.g. from primary and secondary forest residues), bioeconomy would, for example, constitute an invaluable asset for a rural SSA that is currently facing insufficient energy supply, limiting the region's further development. Bioenergy solutions, rather than exclusively serving global biofuel needs which often negatively impacts social outcomes, could be developed with national or regional energy security in mind, as exemplified in some SSA bioenergy or biofuel strategies (Table 1). Transitioning to a modern forest-based bioeconomy will also require certain skills and technology to be developed; financing opportunities are thus also required.

The prevailing areas of study uncovered in this review – namely NTFPs as income generators and value chain improvement – align with rural development goals, revealing the potential of a forest-based bioeconomy to contribute to the wellbeing of forest-dependent communities, notably through diversification of rural economies, new employment and income possibilities, as well as through improvements in the sustainable management of natural resources. More often than not, forest activities were associated, whether hypothetically or not, with positive outcomes for the rural population (Figure 18). However, gaps in the range of forest sectors covered in the literature exist, and there are serious obstacles to reaching social sustainability. The overall lack of explicit links between bioeconomy and forests in the retrieved publications, is also indicative of the fact that bioeconomy is still mostly associated with agriculture.

The sectors of forest- and forestry-related services are not explored in the literature, and studies on forest services are limited to provisioning ecosystem services (e.g. NTFPs), leaving aside recreational activities or ecotourism, which may both boost international tourism and also strengthen links with urban communities. Examples of novel business models and social innovations were equally scarce in this sample of peer-reviewed literature. These gaps indicate that existing forest activities are still entrenched in traditional forestry, and that several missed development opportunities could be reversed. That said, the existence of innovative bioeconomy approaches cannot be excluded; this warrants exploring grey literature and on-the-ground development projects. The review did not expose a significant number of studies on the management of forests for extractive resources, pulp and paper activities or biorefinery. This might be due to the use of a search string focused on social sustainability elements, which thus excluded from our selection technology-oriented studies that did not consider social impacts . However, considering the potential role of SSA in responding to the foreseen increase in global biomass demand – resulting from a more generalized transition towards bioeconomy – the sustainability of the traditional forestry sector should be addressed with extreme caution.

As for FBBE social sustainability, the research evidenced here indicates that it is mostly lacking, even in traditional forest activities: benefit sharing is skewed, practices of elite capture and land grabbing are common, tenure rights are often undefined, and access to markets, which remain largely informal, is unequal. A lack of governmental interest in rural populations, conflicting and inappropriate policies and forest reforms, and scarcity of local involvement in decision-making have also emerged as factors hindering development (see Table 7 for summary). While encouraging evidence regarding efforts to better include stakeholders in forest management and forest value chains emerges in the review, the road to equal benefit sharing and equal opportunities still appears long and rocky, particularly since these efforts are not matched with parallel efforts to equip communities with the physical and financial means to manage forest sustainably.

5.4 Conclusion

Two prerequisites emerge when it comes to untapping the potential of the FBBE and leaving behind the unsustainable, resource-depleting 'business-as-usual' approach, while empowering rural communities in SSA: (i) adopting a 'strong' sustainability approach; and (ii) integrating innovations in forest activities, leading to biomass valorization and value-added products and services. In other words, there needs to be a transition to sustainability *combined with* a transition towards 'new' FBBE activities. While failing to adopt such a strong sustainability approach will limit the potential for social inclusion and disregard local realities, failing to transition to an innovative bioeconomy and to challenge traditional forest activities will lead to missed socio-economic development opportunities, and suboptimal utilization of resources. To maximize the environmental, economic and social benefits that forest bioeconomy strategies can foster, the sustainability and valorization of natural resources must go hand-in-hand with sustainability across the full spectrum of forest-related activities – beyond the usual bioeconomy focus on biotechnology and biomass production and processing. In light of this literature review, a deeper analysis of the state of current novel FBBE approaches in SSA, and of the type of sustainability they reflect and foster, is needed. In particular, this review highlights the need for more focused analyses of how specific FBBE activities impact social sustainability so lessons can be drawn, in order to work towards improved social outcomes.

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Populations in sub-Saharan Africa (SSA) living on the fringes of forests indubitably rely on them for income and subsistence. But unsustainable practices can lead to resource degradation and depletion, threatening the very basis of their livelihoods. A forest-based 'circular' bioeconomy approach could stabilize sustainable natural resource use, yet bioeconomy strategies so far have focused mostly on technology and economics, rather than on matters of social sustainability. This study reviews literature published between 2000 and 2020, with the aim of identifying whether socio-economic impacts were taken into account in the forest sectors and bioeconomy elements covered in this SSA-focused literature. Many studies investigate forest-related value chain development across a forest sector that remains mostly traditional and largely informal. Non-timber forest products (NTFPs) play a significant role and could represent an entry point for bioeconomy development. Energy security could also benefit from taking a bioeconomy perspective. Forest activities resulted in positive social outcomes in just a third of the studied cases. Challenges to bioeconomy development include uncoordinated and often bureaucratic forest policies and regulations, as well as overlaps and clashes between formal and informal economic activities and land tenure regimes. Lack of knowledge and skills – around entrepreneurship, investment and finance – further hampers development. In conclusion, while forest-based bioeconomy could enrich the forest sector and contribute to poverty reduction and natural resource conservation, strategies must adopt a strong social sustainability approach, or this transition risks reproducing patterns of land grabbing, elite capture, spatial injustice and the displacement and disempowerment of rural populations.

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