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Towards a Global Framework for Analysing the Forest-Based Bioeconomy

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Abstract: The bioeconomy approach offers potential solutions to global challenges, including sustainable forest management. The body of literature on the forest-based bioeconomy is rapidly expanding, and the diversity of approaches is bewildering. In this paper, we (1) discuss and clarify terminology related to the forest-based bioeconomy as a basis for (2) developing a general framework for analysing the forest-based bioeconomy, which is then (3) applied to two bioeconomy cases. The point of departure is a structured literature review; through qualitative content analysis, we identified the key questions characterizing current approaches to the forest-based bioeconomy; subsequently, the two cases were investigated through analysis of nominal and functional national bioeconomy policy documents and case-specific literature. Answering the key questions allowed the identification of five distinct schools of thought that make up the global framework: the biotechnology, techno-bioresource, socio-bioresource, eco-efficiency, and eco-society schools. These provide a systematic tool to analyse key paradigms, public policy goals, product or service sold, stakeholders, strength of environmental sustainability, and likely transition pathways. We illustrate the application of the framework through analysis of two cases (medicinal plants in Nepal and timber in Finland). We end by discussing how to operationalize the framework further.

Keywords: Finland; forests; Nepal; non-timber forest products; schools; sustainable development; timber

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1. Introduction

The bioeconomy, the green economy, and the circular economy are concepts that have grown strong roots since the early 2000s [1]. However, they are often vaguely defined, used interchangeably, and overlap. An enquiry into the bioeconomy must start with terminological clarification. A recent comprehensive study of nearly two thousand papers reviewed the three concepts and found substantial differences [1]. The concept of the circular economy originated during the 1970s and 1980s as an evolution of industrial ecology and industrial metabolism [1,2] and aims to replace the “take, make, and dispose” model of the currently dominant linear economy [3]. It has been defined “as minimizing the generation of waste and maintaining the value of products, materials and resources for as long as possible” [4] and is embedded in five decades of optimising efficiency and recycling capacity of the existing production-consumption system through reduction of inputs, eco-design principles, improved practices, reprocessing and re-use of waste [5–7]. The green economy was coined in the late 1980s [8] and gained momentum after the 2012 UN Conference on Sustainable Development in Rio de Janeiro (Rio+20) [1]. The aim is to reconcile environmental preservation with poverty reduction [9]. In its simplest form, the green economy emphasizes low carbon, resource efficiency, and social inclusiveness [10]. It consists of landscape-based (or nature-based) solutions, biodiversity preservation, and ecosystem service clusters that endeavour to account for nature’s fundamental benefits that

are often disregarded [1]. Figure 1 illustrates the relationships between the two concepts and the bioeconomy. The substantial circular economy literature emphasizes technological interventions and some degree of decoupling (of economic growth and natural resources use), while the green economy also encompasses green growth through use of natural resources. In the literature, the bioeconomy is found in both the territory covered by the circular and green economies as well as on old land, namely the business-as-usual approach with weak sustainability in the market economy. The bioeconomy concept is thus the widest, with the circular/green/bioeconomy overlaps leading to hybrid-terminology, such as the circular bioeconomy [11]. This calls for a more structured understanding; here we proceed to (1) discuss and clarify terminology related to the forest-based bioeconomy as a basis for (2) developing a general framework for analysing the forest-based bioeconomy, which is then (3) applied to two bioeconomy cases.

Figure 1. The positioning and overlaps between the standard market economy (ME), circular economy (CE), green economy (GE), and bioeconomy (BE) in relation to economic growth and means of change, with shaded areas reflecting the number of published studies (derived from [1,12]).

1.1. Defining the Bioeconomy

The widely quoted EU definition is: “The bioeconomy covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services” [13]. This broad and descriptive definition entrenches the use of the bioeconomy as an “umbrella concept” [14] or boundary object (like sustainability or deforestation) used by a wide range of stakeholders to pursue their specific interests [1].

This broadness of concept is also reflected in the findings of the detailed review by Bugge et al. [15] of 453 bioeconomy related publications from 2005–2014. They distilled the biotechnology, bioresource, and bioecology “ideal type visions” of the bioeconomy. The biotechnology vision emphasizes research, firms, patents, and commercialization; the bioresource vision the role of research, development, and demonstration in relation to biological raw (agriculture, marine, forest) materials and optimal land use; and the bio-ecology vision the importance of ecological processes that promote the efficient use of energy and nutrients, promotes biodiversity, and avoids monocultures and soil degradation. While the visions are only described in general terms, they promote our understanding of approaches to the bioeconomy.

Another important study providing structural insights into the broad concept of the bioeconomy is Vivian et al. [16], describing and characterizing three ideal-types of bio-

economy visions based on combinations of: (1) definitions, (2) nature-economy relations, (3) socio-technical relations, (4) governance, (5) sustainability, and (6) tensions and paradoxes. The type 1 vision is derived from Georgescu-Roegen's [17] interpretation of the term "bioeconomics" and recognises limits to economic growth due to nature's biophysical boundaries. This supports degrowth and expands the bioeconomy even beyond the borders in Figure 1. The type 2 vision is science-based and focused on biotechnological innovations and the commoditization of knowledge. The type 3 vision advocates a transformation of the economy from fossil fuels to biological raw materials.

Here, with our focus on forests, we want to move from the broad and inclusive definition of the bioeconomy to a narrower and more operational definition of the forest-based bioeconomy.

1.2. Defining the Forest-Based Bioeconomy

The forest-based bioeconomy takes its point of departure in the forest sector. However, there is no internationally accepted universal definition of the forest sector [18]. As noted by Kleinschmit et al. [19], the broadness of the bioeconomy concept makes delineation of the forest sector ambiguous as it cuts across myriad activities. This makes it challenging to apply narrow forest sector definitions to a definition of the forest-based bioeconomy. This includes the (1) International Standard Industrial Classification of All Economic Activities definition used by the UN, limiting the forest sector to primary forest activities such as logging, whereas the processing of roundwood is assigned to the manufacturing sector [20,21], and (2) Statistical Classification of Economic Activities in the European Community, limiting forestry to the growing and harvesting of tree crops [22]. In relation to the bioeconomy, we need a forest sector definition ranging from subsistence use of forest products to forest product value chains and forest services. This includes the growing, harvesting, and processing of wood (e.g., industrial roundwood, fuelwood, pulp and paper, furniture) and non-wood (e.g., medicinal plants and bushmeat) products. Indeed, all products obtained from primary (e.g., roundwood), secondary (e.g., pulp), and tertiary processing (e.g., bioenergy) of wood and non-wood products form a part of the bioeconomy [23].

Here, to increase shared understanding of the concept, we combine the need for a broad forest sector perspective with the need for a narrower approach to the bioeconomy. We define the forest-based bioeconomy as the set of economic activities to grow, harvest, process, reuse, recycle, and sell forest products and associated forest ecosystem services. The forest-based bioeconomy thus includes—from both natural forests and plantations—the production, manufacturing, and trade of timber and non-timber derived commodities and services as well as the economic activities required to market these. We acknowledge the low levels of operationality and functionality of this definition. It does, however, point towards (i) the need to consistently operationalize key variables (e.g., forest, non-timber forest products, and income) and (ii) gaps in how past studies have collected and presented data. For instance, the recent string of publications quantifying forest income (e.g., [24,25]) is limited to income at the producer (typically household) level, ignoring income generated in the wider sector, such as through industry employment and secondary processing. There is no study providing an overview of the forest-based bioeconomy anywhere. Below we proceed to further conceptualize and operationalize the definition by enumerating a general framework that allows for systematic examination of approaches within the forest-based bioeconomy.

2. Materials and Methods

First, to gain an overview of current approaches to the forest-based bioeconomy, we conducted a structured literature search. The included papers were subjected to inductive qualitative content analysis to arrive at the key features of approaches. The resultant framework was then applied to two case studies.

2.1. Data Collection

The literature search was conducted to acquire recent studies to identify the key dimensions of the forest-based bioeconomy. Acknowledging the efforts of Bugge et al. [15], to review literature up to 2014 and the recent rapid expansion of related literature, we focused on the period 2015–2020. Using the Core Collection of Web of Science in August 2020, we applied the keyword **bioeconomy**, resulting in more than 500 publications. Narrowing the search to the forest-based bioeconomy using **bioeconomy and forest** OR **bio-economy and forest** OR **biobased economy** OR **bio-based economy and forest** OR **bio-based knowledge economy and forest** produced 59 publications. Using the abstracts, we removed duplicates (three) and outside the scope papers (seven), resulting in the final inclusion of 49 publications that included journal papers, conference papers, and editorials (list provided in Supplementary Materials 1).

In our subsequent case selection, aimed at illustrating the use of the framework, we were guided by a two-stage case selection process: (i) country selection, emphasising a high economic contribution of forest to GDP and contrasts among cases in average national GNI per capita (high vs. low) and the nature of the national bioeconomy approach (nominal vs. functional; the former is based on policies and legislation specifically addressing the bioeconomy, the latter on non-bioeconomic policies and legislation whose provisions have some relevance for the bioeconomy), and (ii) a high number of published product-level studies and contrast in the level of technology in the product value chain (high vs. low). The selected cases were then further investigated using case-specific additional literature searches.

2.2. Data Analysis

The included 49 papers were first coded then subjected to inductive qualitative content analysis [26]. The inductive approach was chosen as we looked for patterns to use in developing explanations (the key dimensions of the framework). Consequently, the coding was open-ended, creating categories and abstraction in an iterative process (going back to the same document repeatedly) where defining elements of the forest-based bio-economy were noted in the document margins. This allowed identification of characteristics that were developed into key questions, whose answers led to the formulation of distinct forest-based bioeconomy schools.

The open coding took point of departure in anchor words identified on the basis of the existing classifications of the bioeconomy [15], focusing on forest-based dimensions. Thus, anchor words included forest specific terms (e.g., NTFPs/NWFPs, timber, ecosystem, deadwood, soil fertility) as well as broader bioeconomy terms (e.g., transition, degrowth, sustainable consumption). All codes were ranked in each publication from 0 to 3 (0: code not applied, 3: mentioned in the title/main objectives/abstract and important in the paper).

After coding completion, the themes were grouped into categories, allowing an explicit description of the key dimensions of the forest-based bioeconomy. Specifically, we ended with seven distinct key questions. Answering these questions led to the identification of distinct bioeconomy schools (with the number of schools determined by the answers drawn from the literature).

Lastly, we applied the resulting general framework of forest-based bioeconomy schools to the selected two cases using the relevant case literature.

3. Results

First, we present the key questions coming out of the literature content analysis, then answer the questions to generate the general framework of forest-based bioeconomy schools. All these results are derived from the qualitative content analysis. In addition, we link our findings to references where they are exemplified. Lastly, we apply the framework to two cases.

3.1. Key Questions Characterising the Forest-Based Bioeconomy

The qualitative content analysis resulted in 19 questions; combining questions with similar focus and removing questions with only one answer (and hence no differentiating variation), the qualitative content analysis resulted in seven key questions that distinguished approaches to the forest-based bioeconomy: (1) what is the paradigmatic belief system, (2) what are the public policy goals, (3) what final product or service is sold, (4) who are the key stakeholders, (5) which are the likely transition pathways, (6) is the informal economy included, and (7) what is the strength of the link to environmental sustainability.

3.2. The Bioeconomy Schools—Their Identification and General Characteristics

Table 1 presents an overview of the literature-derived answers to the seven key questions characterizing the forest-based bioeconomy. The distribution of the answers leads to the identification of five distinct bioeconomy schools named biotechnology, techno-bioresource, socio-bioresource, eco-efficiency, and eco-society.

Table 1. Five forest-based bioeconomy schools.

QUESTIONS	BIOTECHNOLOGY	BIORESOURCE		BIOECOLOGY	
		Techno-Bioresource	Socio-Bioresource	Eco-Efficiency	Eco-Society
What is the paradigmatic belief system?	Technocratic	Neo-industrialisation	Eco-modernist	Sustainable environmentalism	Degrowth
What are the public policy goals?	Economic growth, resource efficiency, food security	Fossil fuel substitution, climate change mitigation, competitiveness, resource efficiency	Poverty alleviation, employment, resource sustainability, territorial resilience	Biodiversity conservation, high quality of water, air, soil; recreational services	Food sovereignty, socio-economic sufficiency, sustainable consumption
What product or service is sold?	Molecular biology patents, GMOs, nanomaterials, allopathic medicine	Biorefinery products (e.g., bio-textiles), bio-composites	Timber and non-timber raw materials, secondary processed products	Quality air, water, soil experiences, spiritual recreation	Organic foods, produce from small scale farms
Who are the key stakeholders?	Large private companies, public research institutes	Governments, large private companies, public research institutes	Small and medium enterprises, local communities, NGOs	(I)NGOs, civil society organizations, landowners	Farmers, civil society organizations, NGOs, consumers
Is the informal economy included?	No	No	Yes	No	Yes
What are the likely transition pathways?	Novel products, low bulk and high value	Fossil fuel substitution, new and efficient biomass uses	Boosting primary sector productivity and secondary processing	Payments for ecosystem services	Decentralized governance and decision making
What is the strength of the link to environmental sustainability?	Weak	Weak-Medium	Medium	Strong	Strong

The identified forest-based bioeconomy schools can be related to the broader bioeconomic visions enumerated by Bugge et al. [15]. Thus, the biotechnology school is closely related to their biotechnology vision. The techno-bioresource and socio-bioresource schools can be seen as sector-specific versions of the bioresource vision, while the eco-efficiency and eco-society schools have a similar relationship to the bioecology vision. In general terms, the techno-bioresource school emerged from a neo-industrialist paradigm focused on using existing forest-related industries to produce higher-value-added bio-based products to enhance economic competitiveness while promoting sustainable development. The socio-bioresource school emerged from studies around an eco-modernist paradigm emphasizing socio-economic development driven by small and medium-sized enterprises focused on adding value to non-timber forest products. The eco-efficiency school has ecosystem services at its core, focusing on biodiversity protection, recreational services, and promoting optimal nutrient use and prevention of soil degradation. The eco-society school emerged

from degrowth studies rooted in the sufficiency principle and the promotion of greater local sovereignty (e.g., over food).

3.3. The Bioeconomy Schools—A Description

The distribution of publications is highly unequal across the schools (Figure 2). The large biotechnology circle includes the substantial body of technological literature (e.g., see [15,27]) published in fields such as molecular biology, pharmacology, and applied microbiology (all with molecular level points of departure); the relatively narrow biotechnology school is here mainly based on Bugge et al. [15], Hausknost et al. [28], and Vivien et al. [16]. The techno-bioresource school has received attention (26 out of 49 papers) in the forest-based bioeconomy (mainly due to the focus on timber as a bioresource for higher-value-added bioproducts with 12 papers on the Finnish forest industry). The remaining schools are found in fewer papers. Important papers where the socio-bioresource school is found are Falcone et al. [29] and Purwestri et al. [30]; the eco-efficiency school is seen in Eyvindson et al. [31], D’Amato et al. [32], and Linser and Lier [33]; and the eco-society school in Hurmekoski et al. [34] and Fischer et al. [27].

Figure 2. The relative location of the five forest-based bioeconomy schools according to their emphasis on ecological, economic, and social issues (based on Supplementary Materials 1). Scale: from 0 (no attention to issue) to 4 (central to school). Circle size displays coverage in the published literature.

There is no standard definition of the informal economy. Here we apply the concept to encompass all firms, workers, activities, and outputs outside the legal regulatory framework of society [35], e.g., the non-registered trade in raw medicinal products from Nepal to India [36,37].

Figure 2 also shows an overview of the relative position of the five schools according to their emphasis on ecological, economic, and social issues. In the following, we detail each of the five forest-based bioeconomy schools.

3.3.1. Biotechnology School

This school is focused on using biotech tools at the molecular level (e.g., in applied microbiology and chemistry) to make innovative consumer products across diverse sectors. It focuses on economic growth and resource efficiency, with little attention paid to social issues, and the main actors are large private companies and public research institutions. This technocratic approach is promoted by the OECD and dominates the general bioeconomy literature—in many publications, the biotechnological approach is assumed equivalent to the bioeconomy. Much research and work in this approach fall outside the forest sector (indeed, the link to sustainability is weak).

3.3.2. Techno-Bioresource School

This neo-industrialized approach emphasises economic growth through new and more efficient use of renewable natural resources, including reducing greenhouse gas emissions and lowering fossil fuel dependence (for instance, this school can be found in [34,38,39]). The focus is on increased productivity and a revival of industries in various sectors, e.g., chemical and forest industries (e.g., [27,40]). In the forest-based bioeconomy, the focus is likewise on fossil fuel substitution, climate change mitigation, economic competitiveness and resource efficiency. Ecosystem services and NTFPs are not included in this school. The focus is on moving from bulk products (e.g., laminated wood) to higher-value-added products (e.g., the pharmaceutical application of wood derivatives); raw materials should be refined to the greatest extent possible before use as energy. Another approach emphasises using bio-based alternatives to crude oil-based chemicals. The school is found in the national bioeconomy strategies of key players in the EU, such as Finland, Sweden, Germany, and Austria (e.g., [41]). For instance, the Swedish National Forest Program emphasized increased production through new industrialization to revive Swedish forestry and create employment and economic growth. The key players are governments, large private companies, and public research institutes (e.g., [42]). The exclusion of environmental protection or conservation NGOs and lack of citizen participation has been noted. The forest-based bioeconomy transition is to take place through innovations to aid fossil fuel substitution and new and efficient woody biomass uses. The school has little social focus and a weak to medium link to environmental sustainability.

3.3.3. Socio-Bioresource School

This school emphasises sustainable development with the point of departure in the ecological modernisation paradigm, simultaneously aiming at poverty alleviation, regional development (employment and territorial resilience), and resource sustainability using renewable forest resources, including non-timber products. This includes technological solutions to environmental problems within the existing economic model (for instance, in [27,40]). The focus is on value-added non-timber forest products and the social aspects of innovation. Falcone et al. [29] illustrated this for the Italian forest-based bio-economy that emphasises traditional craft enterprises based on mushrooms, chestnuts, berries, pine kernels, acorns, cork, medicinal plants, and essential oils. They also mentioned the need for social sustainability certification schemes (e.g., working conditions) along the value chain to enhance socio-economic opportunities in the Italian rural economy. There appears to be a potential for technological innovation in low-income countries e.g., [43]. This school is found in the southern EU and in the functional policies of low-income countries though explicit analyses of the latter are absent in the literature. Ludvig et al. [44] demonstrated the relevance of non-timber forest products to foster employment and local development in Europe. In the study of the forest-based bioeconomy in Italy, Falcone et al. [29] also mentioned the role of non-timber forest products in benefitting rural areas by identifying business opportunities and unlocking the associated value chains. The key players are small and medium-sized enterprises, local communities (primary producers), and non-governmental organisations. The transition pathways are boosting primary sector productivity and secondary processing, including for products in the informal non-timber sector (e.g., farmers' markets in Europe or periodic markets for wild-harvested products in low-income countries). Given the importance of sustaining resource availability, this school arguably has a medium-strength link to environmental sustainability.

3.3.4. Eco-Efficiency School

This school focuses on sustainable environmentalism (as opposed to sustainable development) and aims at biodiversity conservation, the high quality of water, air, soil, and recreational services. Natural resources should be used with caution, and there is a strong emphasis on sustainability; economic growth is secondary to holistic ecological well-being. For instance, chemical supplements should not be used in the production of tree crops or

non-timber forest products. The key players are NGOs, civil society organizations, and landowners. The transition pathways are the internalization of externalities to compensate for market failures using instruments such as Payment for Ecosystem Services, e.g., to pay for avoided deforestation or watershed protection in forests, and ecological accounting tools. Interventions include climate mitigation, sustainable forest management policies, and awareness-raising, e.g., [45], as well as accounting for any social and ecological impacts (e.g., on regulating forest ecosystem services) along forest product value chains using Life Cycle Assessment tools, e.g., [32].

3.3.5. Eco-Society School

This school is firmly situated in the degrowth paradigm aiming for local sovereignty, e.g., of food resources, resulting in socio-economic sufficiency, sustainable consumption, and societal participation and awareness. Here continued economic growth is incompatible with environmental sustainability. The key players are farmers, civil society organizations, NGOs, and consumers, including those promoting an organic food culture. These actors arguably play an important role when assessing the impact of increasingly intensive production-oriented forestry on biodiversity and ecosystem services (e.g., [31]). The transition pathway is decentralized governance and decision-making.

3.4. Forest-Based Bioeconomy Case Studies

We selected Finland and Nepal as case countries. The difference in GNI per capita is more than 12-fold (USD PPP 51,650 in Finland in 2020, 4060 in Nepal, [46]), and the bioeconomic approach is different (nominal in Finland as per this review, functional in Nepal [47]). In both countries, the contribution of forest to GDP is substantial, with Finland having the highest contribution to GDP among all high income countries at around 4.3%, [18] and Nepal around 3.5% [48]. As case products, we selected timber in Finland and commercial medicinal plants in Nepal. These contrasted in the level of value chain technology (advanced vs. simple). While other combinations of countries and cases are possible, this selection ensured case variation as well as published studies to draw on. Future selection of additional countries and cases will allow further applications of the framework.

3.4.1. Timber in Finland

The production, trade, and processing of timber in Finland are, as the wider Finnish forest-based bioeconomy, rooted in the ecological modernization paradigm with an overt neoliberal influence [49,50]—the emphasis is on economic growth, increased competitiveness, and higher employment. The Finnish Forest Act is the key guiding legal document for forest operators and owners to ensure resource sustainability [51]. However, the recent reformation of the Forest Act limited the inclusion of environmental viewpoints and is focused on “more of everything” (timber harvesting and expansion of the voluntary protection program), implicitly assuming that ecological and social sustainability will automatically happen [40]. The annual bioeconomy output in 2020 was €60 billion with harvests of 69 billion m³ of roundwood, slated to grow into a €100 billion economy by 2025 (the Finnish Bioeconomy Strategy [51]) indicating a sharp increase in timber to be harvested while combating the effects of climate change. Although their annual production value exceeds €51 billion [52], non-timber forest products are not part of the National Forest Program [40]. The general stakeholder groups are the government, research institutes, industry, environmental NGOs, non-industrialized special interests, and other networking organizations such as consultancy companies; the dominant specific actors are the National Research Institute (LUKE), Ministry of Economic Affairs and Employment (TEM), and the chemical industry group [42]. Contemporary discussion is focused on economic sustainability, resource efficiency, and innovation, including the move from low-value bulk products to higher-value-added products, such as the improved resource efficiency when refining raw material to its highest possible quality before conversion to energy [50].

For the case of timber in Finland, Table 2 summarizes the answers to the seven key questions distinguishing approaches to the forest-based bioeconomy. The resulting profile is close to the techno-bioresource school line of thinking as (i) the point of departure is eco-modernist, (ii) the public policy goals are oriented towards economic growth and increased competitiveness, (iii) there is an industrial product focus, (iv) key stakeholders are large private companies, the government, and public research institutions (and no informal economy), with (v) a transition focus biased towards new and more efficient biomass use.

Table 2. Answering the framework key questions for the case of timber in Finland.

QUESTIONS	CASE: TIMBER IN FINLAND
What is the paradigmatic belief system?	Ecological modernisation with overt neoliberal influence [40,53]
What are the public policy goals?	Steady economic growth, improved economic competitiveness, higher employment, and combating climate change with fossil fuel substitution [40,50,51]
What product or service is sold?	Wood products (composites, carpentry, match sticks, spools); panels (cross-laminated timber, laminated veneer, lumber, low-density fibreboard, glulam); sawn goods; energy (firewood, wood pellets, biofuels); chemicals (tar, turpentine, tall oil, spirit substitutes, lignin); pulp (pulp, black liquor, dissolving pulp (rayon), nanocellulose); paper (primitive paper products, cardboard, paper and carton grades) [54]
Who are the key stakeholders?	Research institutes; ministries; industry (forest, chemical, and energy); special interest groups (e.g., WWF Finland, Central Union of Agricultural Producers and Forest owners, Finnish Sawmills association), other types of organisations such as consultancies [42]
Is the informal economy included?	N/A (no informal timber economy in Finland)
What are the likely transition pathways?	More inclusive coordinated market economy (government, industry, and forest owner partnership, [55,56]); industrial symbiosis (innovation for higher-value-added bioproducts [54]); higher quality education in the forestry sector (human resources [56]); active dialogue with the public (transparent perception of the bioeconomy [49]); reform conservation (protect unique ecosystems and biodiversity [40,57])
What is the strength of the link to environmental sustainability?	Weak-medium link to sustainability [40,50,53]

3.4.2. Commercial Medicinal Plants in Nepal

There is no formal bioeconomy for Nepal. However, the existing nominal forest legislation and policy documents related to the production, trade, and conservation of non-timber forest products [47], including medicinal plants, make up a functional bioeconomic framework. The approach to commercial medicinal plants in Nepal is firmly situated in the ecological modernisation paradigm, with its explicit dual aims of simultaneously achieving poverty alleviation and species conservation (e.g., [36,58,59]). There appears to be substantial scope for development, e.g., with medicinal plants being one of the country's top export items [60] characterized by unprocessed air-dried raw materials and low levels of secondary processing [37], yet relatively high net margins for harvesters [61]. Government policy goals include supporting enterprises and facilitating sustainable resource management with a further expansion of community forestry [58]. The key stakeholders are local producers (rural households and communities, including community forestry user groups), traders and wholesalers, small and medium scale processing enterprises, development-oriented NGOs like the Asia Network for Sustainable Agriculture and Biore-sources (ANSAB) that engage in resource management and value chain interventions, associations like the Jadibuti Association of Nepal (JABAN) that lobby for wholesaler interests and the Federation of Community Forest User Groups Nepal (FECOFUN) that lobby for its members, and government agencies such as the Department of Plant Resources and the Department of Forests in the Ministry of Forests and Environment [61]. In terms of transition pathways, the literature abounds with recommendations, including for improved

resource management (e.g., establishing species-specific sustainable rates for wild harvesting [62]), increased secondary processing [37], and improved policy implementation [47]. While this trade is centuries old, rising demands in India and China attributed to rising middle-class incomes has increased sustainability concerns [61].

For the case of commercial medicinal plants in Nepal, Table 3 summarizes the answers to the seven key questions distinguishing approaches to the forest-based bioeconomy. The case closely resembles the socio-bioresource school as it (i) has an eco-modernist point of departure, (ii) prioritises explicit and particular attention to issues of poverty alleviation and resource sustainability, (iii) is highly focused on secondary processing of non-timber forest products in small and medium enterprises, with (iv) local producers and NGOs also being key stakeholders, in (v) a largely informal economy, with (vi) a national focus on boosting primary sector productivity and secondary processing. Arguably, there are traces of the eco-efficiency school in terms of voices promoting biodiversity conservation as a public policy goal.

Table 3. Answering the framework key questions for the case of commercial medicinal plants in Nepal.

QUESTIONS	CASE: COMMERCIAL MEDICINAL PLANTS IN NEPAL
What is the paradigmatic belief system?	Ecological modernization: medicinal plants are a resource to use to improve livelihoods and biodiversity conservation simultaneously [37,63]
What are the public policy goals?	Using medicinal plant resources for poverty alleviation (rural households) and economic development (secondary processing in small and medium-sized enterprises) while ensuring improvement of biodiversity conservation via sustainable management [58]
What product or service is sold?	300 medicinal plant species are traded, mainly exported as air-dried raw materials, limited secondary processing [62]
Who are the key stakeholders?	Local producers (rural households and community forest user groups); traders and wholesalers; processing enterprises; development-oriented NGOs; associations; government agencies [62]
Is the informal economy included?	Most of the trade is informal [61]
What are the likely transition pathways?	Establishing sustainable wild harvest rates, increased cultivation [62]; increased local resource management and capacity building [62]; enhancing raw material quality, improved processing technology, product innovation [37]; improved policy implementation [47]; increased transboundary species conservation and regional trade collaboration [36,64]
What is the strength of the link to environmental sustainability?	Trade has taken place for centuries. Increasing focus on sustainability as many product prices are rising [61]

4. Discussion

More and more countries are formulating explicit bioeconomic strategies, and the volume of scientific literature is increasing rapidly [65]. This reflects the promises of the bioeconomy, e.g., as a way to decoupling environmental degradation from economic growth by creating an economy sustained on renewable and efficiently managed resources [15].

The framework constituted by the five forest-based bioeconomy schools provides a tool for structured analysis of cases and countries worldwide. The schools are not mutually exclusive—there are different explanations and patterns within a country or a case. There will be regional differences in their relevance and applicability, with some schools being more common in certain geographical regions depending on location-specific variables such as the available renewable natural resources and per capita income levels. Some of these differences have already been demonstrated in the aforementioned Finland and Nepal cases, e.g., with differences in public policy goals (including general economic growth vs. poverty alleviation) and the natural resource base focus (timber vs. medicinal plants). In consequence, some schools will be more relevant than others given prevailing specific circumstances. For instance, (i) the socio-bioresource school will be more prevalent in situations where poverty alleviation concerns dominate and substantial parts of the

economy are informal; or (ii) the eco-society school is placed definitively in the degrowth paradigm that also prioritises sustainable consumption. In general, the schools should not be seen as rigid distinctions; they may overlap and should be applied in an eclectic manner. Two examples of overlaps are: (i) the biotechnology school and the bioresource schools are conceptually intertwined through their focus on technology and natural capital based growth, and (ii) product overlap, e.g., wild mushrooms can both be a resource used to pursue poverty alleviation in the socio-bioresource school and an organic food that contributes to the achieving of local food sovereignty in the eco-society school.

The dominant paradigms in the forest-based bioeconomy literature (outside the biotechnology approach) are eco-modernism [19,27,40,66] and neo-industrialisation [27,40,53]. It is also widely acknowledged that the transition to a bioeconomy is only possible in an optimum policy environment [34,45,67,68], preventing lock-in, i.e., the situation where the forest-based bioeconomy stagnates due to a lead firm's dominant market position, the advantage of economy of scale, and the pseudo-irreversibility of investments [54], blocking innovation and freezing actor coalitions [45]. In addition, individual policies seldom expose the existing regime [69] to enough transformation for systemic changes to occur, in this case towards a bioeconomy [45]. Therefore, a combination of coherent policy instruments and mixes is required to facilitate transition [45,70,71], which in turn requires collaboration in networks of participating actors.

The approach to characterize and categorise the existing literature into distinct schools of thought is not new. An excellent example is provided by Wunder [72], who distinguished three schools of deforestation used to disentangle deforestation causes, predictions, and solutions. Here, our forest-based bioeconomy schools are compatible with earlier work and can be considered as the next version of existing characterisations, including the Bugge et al. [15] three visions, the three types proposed by Vivien et al. [16], and the four visions of Hausknost et al. [28]. The relationship to Bugge et al. [15] is directly reflected in Table 1 (distribution of the schools across the biotechnology, bioresource, and bioecology visions). The Vivien et al. [16] Type I is similar to the eco-society school, Type II to biotechnology, and the biomass-oriented Type III related to the techno-bioresource school. In the four quadrants used by Hausknost et al. [28] to distinguish bioeconomy thinking, quadrant A covers the biotechnology and techno-bioresource schools, quadrant B the eco-growth, C the eco-society, while D is included in our school framework as and when the techno-bioresource (and/or the biotechnology) and the eco-society schools coexist. As Hausknost et al. [28] emphasized, this is only possible in a state-centred “planned-transition” approach wherein large-scale advanced technologies are used alongside the objective to contract resource consumption, which does not often empirically exist (e.g., biorefineries converting biomass into products—techno-bioresource—but with the aim of public welfare). The robustness of the five forest-based bioeconomy schools (their ability to explain approaches to the forest-based bioeconomy across spatial scales and a diversity of cases) remains an unanswered empirical question.

While we have moved beyond the more general bioeconomy visions identified by Bugge et al. [15], Hausknost et al. [28], and Vivien et al. [16], through our formulation of the seven key questions and the associated five schools, there is further scope for operationalising the analysis of forest-based bioeconomies. For instance, the concept of sustainability needs to be further developed, operationalised, and standardised, whether the emphasis is on plot-based inventories or proxies derived from structured household surveys [73]. The next step could be to identify the core units of any forest-based bioeconomy system and start to identify the set of variables needed to analyse each core unit. Such work could be inspired by advances in other fields, such as the Ostrom [74] general framework for analysing the sustainability of socio-ecological systems.

5. Conclusions

This paper discussed and clarified the terminology related to the bioeconomy, including defining the forest-based bioeconomy as the set of economic activities to grow,

harvest, process, reuse, recycle, and sell forest products and associated forest ecosystem services. Using a targeted literature review and qualitative content analysis, we identified seven key questions characterizing different approaches to the forest-based bioeconomy. Answering the key questions allowed identification of five distinct schools of thought: the biotechnology, techno-bioresource, socio-bioresource, eco-efficiency, and eco-society schools. These provide a systematic tool to analyse key paradigms, public policy goals, product or service sold, stakeholders, the informal economy, likely transition pathways, and the strength of environmental sustainability. The schools are not mutually exclusive and may thus co-exist spatially and at the product level. There are likely distinct geographical patterns, with some schools more common in specific regions of the world. The schools are compatible with earlier bioeconomic characterizations and offer a starting point for further operational thinking about the characteristics of the forest-based bio-economy. The key policy takeaway is that the forest-based bioeconomy is much more than minimising waste, substituting resources, or biotechnological innovation—the schools provide a range of transition pathways that can also contribute to achieve goals like poverty reduction, biodiversity conservation, and sustainable consumption.

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