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Theorising and analysing the forest-based bioeconomy through a global production network lens

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ABSTRACT

There is a multiplicity of bioeconomies and transition pathways, many of which are radically different from the biotechnological approach dominating in Western and Northern Europe. While the empirical basis for understanding this diversity is growing, also in the Global South, there is a lack of bioeconomic learning from existing allied theories. This paper applies global production network theory to the forest-based bioeconomy. Specifically, we focus on internationally traded renewable environmental products and identify an analytical framework for empirical investigation of the forest-based bioeconomy. We then apply the approach to the case of commercial medicinal plants in Nepal, using the example of the trade in air-dried bulbs of the Himalayan herbaceous plant *Fritillaria cirrhosa* in 2014–14 and 2021–22 with empirical data from structured interviews with traders ($n = 65$ and $n = 79$ for the two observation years) supplemented with interviews in the first period with harvesters ($n = 540$), central wholesalers ($n = 73$), processing industries ($n = 79$), and regional wholesalers in India and Tibet ($n = 78$). We find that global production network theory, and the associated array of analytical devices, can inform empirical investigation of the forest-based bioeconomy by operationalising the bioeconomy concept and grounding findings within an established theoretical frame and its associated emerging body of literature. The empirical application also demonstrated the possible policy outcomes from such empirical analyses.

1. Introduction

The bioeconomy concept is a boundary object that “inhabit[s] several intersecting social worlds ... [and] plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites” (Star and Griesemer, 1989: 393). The advantage of such objects is that they speak to a diversity of stakeholders, enabling their wide sectoral and spatial adoption. However, the proliferation of uses, combined with vague reporting of applied definitions, may lead to miscommunication and misunderstandings. For instance, Smith-Hall and Chamberlain (2023a) noted the sweeping range of variation in bioeconomy studies, from framing biotechnological research to providing Marxist inspired criticism of neoliberal market responses. Hence, as a first step, research must be explicit in reporting bioeconomy definitions, preferably beyond the often-cited all-encompassing EU bioeconomy description (EU, 2018). Here, we focus on the forest-based bioeconomy defined as “the set of economic activities to grow, harvest, process, reuse, recycle, and sell

forest products and associated forest ecosystem services” (Piplani and Smith-Hall, 2021: 3). Such activities may be dynamic, spatially dispersed, organizationally rich, and have a variety of outcomes. As a second step, the applied definition should be operationalised – what situations does a definition cover and how can these be systematically described and measured? Bugge et al. (2016) provided a useful overview of three general visions of the bioeconomy (bio-technology, bio-resource, and bio-ecology) while Piplani and Smith-Hall (2021) identified five schools of thinking in relation to the forest-based bioeconomy (the biotechnology, techno-bioresource, socio-bioresource, eco-efficiency, and eco-society schools). These studies provide structured analysis of approaches to the bioeconomy but do not constitute formal models enabling empirical analysis.

While the number of publications on the bioeconomy is increasing fast, particularly within the biotechnology approach in Western and Northern Europe (Smith-Hall and Chamberlain, 2023a), little of this work benefits from existing theories. A recent book on the bioeconomy and non-timber forest products (Smith-Hall and Chamberlain, 2023b)

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indicated that most research on the forest-based bioeconomy originates within the forest sector, without benefitting from explicit use of bio-economic relevant theory from outside the sector.

The purpose of this paper is to use global production network theory to develop an analytical framework allowing empirical investigation of the forest-based bioeconomy and then apply this to a case of commercial environmental products. First, we provide an overview of global production network theory and forest sector structural components. Second, we combine these to arrive at an analytical framework of the forest-based bioeconomy. Third, we apply the model to the empirical case of a medicinal plant species traded in and from Nepal. Fourth, we discuss lessons learned and point to future research.

2. Global production network theory and concepts

Focusing on the forest-based bioeconomy leads to a focus on renewable environmental products, such as timber, fuelwood, medicinal plants, bushmeat, barks, leaves, and fruits. There are few studies of the global production systems for such products even if they are commonly used and of substantial value. For instance, more than five billion people are estimated to use non-timber forest products (Shackleton and de Vos, 2022), and the global herbal medicine market has been valued at USD 166 billion in 2021 with an expected annual growth of 11.2% (FF, 2022). Following Henderson et al. (2002), we would expect firms operating in the same sector to create similar production networks as they face similar technological, product, and market constraints. Most renewable environmental products are wild-harvested, e.g. some 28,000 plant species are used for medicinal purposes (Willis, 2017) but only around 3000 are cultivated (Brinckmann et al., 2022). Hence, our focus is on wild-harvested renewable environmental products. The limited number of global production network studies on such resources have focused on Bolivia's wood product sector (Murphy, 2012), wooden furniture in Mexico (Klooster and Mercado-Celis, 2016), medicinal plants in South Asia (Pauls and Franz, 2013; Pouliot et al., 2018; Pyakurel et al., 2018; Wallrapp et al., 2019; Fold et al., 2023), shea nuts in Burkina Faso (Wardell et al., 2021), and wild flowers in South Africa (Hughes et al., 2015). These studies focus on contributing to expand thinking on global production networks or provide examples of instrumental use of the global production network toolbox; none are explicitly connected to the forest-based bioeconomy.

Production networks were defined by Henderson et al. (2002: 445) as “the nexus of interconnected functions and operations through which goods and services are produced, distributed and consumed”. The term global is not defined. Here we use it to refer to the entirety of a production network rather than its physical coverage; hence, the geographical area of a global production network can be regional, such as the Chinese caterpillar south-south network ranging from production sites in the Himalayas to end consumers in China (Pouliot et al., 2018; He et al., 2022). Henderson et al. (2002) also identified the three core categories of value, power, and embeddedness that have remained key elements in later work on global production networks. In their seminal book, Coe and Yeung (2015: 1–2) redefined global production networks as “an organizational arrangement, comprising interconnected economic and non-economic actors, coordinated by a global lead firm, and producing goods or services across multiple geographical locations for worldwide markets”. As the forest-based bioeconomy is characterised by a huge number of products whose production networks remain poorly understood (Smith-Hall and Chamberlain, 2023a), this lead firm definitional limitation risks excluding many networks in the forest-based bioeconomy. For instance, no lead firms have (yet) been documented in the trade of medicinal plants from Nepal to India and China (Fold et al., 2023). This restriction is therefore relaxed here and we maintain our above interpretation of global/worldwide; otherwise we draw on recent theoretical advances (Coe and Yeung, 2015; Coe, 2021), also known as GPN 2.0. To couple global production network theory to the forest-based bioeconomy, we first distil concepts (Table 1) and identify a

Table 1

Basic analytical devices in global production network theory: concepts, definitions, and notes. Based on Coe and Yeung (2015, 2019) and Coe (2021).

Concept	Definition ¹	Operational notes on wild-harvested renewable environmental products
Value creation	The process through which an economic surplus is generated by the transformation of materials and inputs into a new product or the provision of new services by a group of interrelated actors (p. 36–37)	Happens in the act of harvesting, typically by members of rural households. Mediated by harvester assets (such as education), access factors (e.g. social relations and legislation), and context (e.g. infrastructure), see Ellis (2000)
Value enhancement	Increasing economic surplus by adding tangible or intangible inputs to an existing good or service (p. 37)	Activities increasing product values, including quality grading, processing, and certification
Value capture	The actor-specific and territory-specific ability and capacity to retain economic surplus (p. 37)	Influenced by location-specific conditions and interventions; includes rent-seeking, royalties, and other taxes that impact actor-specific net margins
Societal embeddedness	The importance for economic action of the cultural, institutional, and historical origins of an economic actor (p. 17)	Factors tying an actor to a particular role, e.g. expectations to traders' behaviour
Territorial embeddedness	How firms and other actors are placed-anchored (p. 18)	Factors tying an actor to a particular territorial location, e.g. at a road head
Network embeddedness	The degree of functional and social connectivity, the stability of its agents' relations, and the importance of the network for its participants (p. 17)	Factors tying an actor to a particular network position, e.g. as a trader rather than a wholesaler
Bargaining power	The direct power exercised between actors in the production network (Dallas et al., 2019: 678)	Actor-to-actor relationships, such as power exercised between harvesters and traders or between regional and central wholesalers
Demonstrative power	The diffuse power operating between actors, including aspiring actors, through informal mechanisms (Dallas et al., 2019: 678)	Imitation of the successful activities of competitors or non-firm actors such as NGOs, e.g. in storage techniques, processing, or certification
Institutional power	The direct power exercised by formally organized collectives (Dallas et al., 2019: 679)	Includes the actions of government administrative bodies (e.g. the Department of Customs), trader associations, I/NGOs, standard-setting certification bodies, and international conventions
Constitutive power	The diffused power exercised by non-membership collectives (Dallas et al., 2019: 680)	Includes the influence leveraged by social movements, such as green consumers, on firm behaviour, such as increased attention to sustainable supplies
Firms	A managerial device for optimising the accumulation and deployment of its available resources underpinning its core capabilities, at the lowest possible cost (p. 84)	A huge variability, from part-time one-man units to transnational corporations, spanning local to global scales
Extra-firm actors	International and civil society organisations, the state, labour groups, and consumers influencing production networks (p. 47)	Influences wild-harvesting in many ways, including through legislation, research, political pressure, and market demand

(continued on next page)

Table 1 (continued)

Concept	Definition ¹	Operational notes on wild-harvested renewable environmental products
Intermediaries	Enabling firm or extra-firm actors connecting actors to services, e.g. finance, logistics, and standards (p. 50–51)	Limited presence in wild-harvested environmental product networks but with potential, e.g. in relation to credit or certification
Networks	The organisation of diverse manufacturing and service activities by a range of actors and institutions in multiple locations (p. 57)	Analysis of environmental product networks is rare; these are typically analysed as value chains
Territoriality	The organisation of global production network relations and development outcomes along the vertical dimension of global-local scales and the horizontal territorial interface (p. 68)	The national scale often important in regulating production and trade. Few environmental product studies
Economic development	A process that results in the improvement of economic conditions within a particular territorial unit (p. 167)	Much environmental product literature has emphasized harvester incomes; much less work on firms, markets, and value retention; focus on the local with little generalisation of findings
Value capture trajectories	Charting the evolutionary aspects of a firm's value capture position (p. 172)	Existing work limited to focusing on upgrading
Regional development	The dynamic aggregate effect of the value capture trajectories of the various firms located in a particular territory (p. 179)	Almost no work on this
Strategic coupling	A development process through which the advantages of regions interact positively with the strategic needs of actors (pp. 19–20)	No examples of use of the concept of strategic coupling in the environmental product literature
Actor strategies	How actors translate the causal power of competitive dynamics into differential value activities that produce developmental outcomes (p. 123)	Not analysed for environment product networks. Extra-firm bargaining may relate to negotiations on sustainability of environmental product trade
Cost-capability ratio	The optimisation process that allows firms to achieve greater firm-specific capabilities and value capture (pp. 85–87)	Not applied in the environmental product literature
Market imperative	The complex and negotiated outcome of the producer-customer interface through which both producers and customers are actively involved in market creation (p. 95)	The need to develop new markets; occasionally studied for environmental products
Financial discipline	When financial considerations drive choices about the boundaries and strategies of the firm (p. 104)	Not studied for environmental product firms
Customer	Corporate users and individual consumers of goods and services in the end markets (p. 97)	Customer studies for wild-harvested environmental products are rare
Risk	Conditions leading to predictable outcomes subject to probability distributions (pp. 110–111)	Seldom explicitly analysed for environmental products

¹ Paging in this column refers to [Coe and Yeung \(2015\)](#) unless otherwise noted. Note that many concepts are not explicitly defined in that book; paging refers to where each concept is discussed.

stylised structural representation of the forest sector ([Fig. 1](#)), then connect the two.

The core value of GPN 2.0 is as a theory of industrial organisation and economic development, allowing an unpacking of cross-border production networks in specific sectors and examining the economic consequences in participating localities ([Yeung, 2021](#)). [Table 1](#) illustrates the richness and potential for global production network theory to inform the forest-based bioeconomy, in particular in relation to trade, actor, and network issues. However, perhaps given the theory's origin in economic geography, it is less useful to guide analysis of resource base issues. Notably, as is also common in other parts of social science literature, the term materiality is used to denote the quantity and quality of natural resources. Here global production network theory can benefit from adopting the vast work on forest resources, e.g. [Weiskittel et al. \(2011\)](#). This enables a more structured and operational approach to resource use sustainability, and addresses the missing element of environment in GPN theory ([Coe and Yeung, 2019](#); [Yeung, 2021](#)), an element of obvious importance: the resource base of renewable environmental products has a co-constitutive role in the organisation of their production networks and value dynamics.

GPN theory and analytical devices can thus be usefully connected to studies of wild-harvested environmental products even if this has only been done to a limited degree so far. However, they are not in themselves sufficient to analyse the forest-based bioeconomy. This must include other perspectives. Now, we turn to look at the concept of the forest sector.

3. Forest sector structural components

While the terms forest sector and forest industry are widely used in the literature, this is not accompanied with definitions, reflecting the lack of a commonly accepted forest sector definition ([FAO, 2014](#)). This makes studies less transparent, as results vary with what is included/excluded. For instance, in their study to estimate the economic contribution of the world's forest sector, [Li et al. \(2019\)](#) focused on traditional mainstream subsectors (wood manufacture and products, paper, pulp) in 58 countries where data was available, thus excluding all non-timber forest products and most countries in the Global South. This study did not provide an explicit forest sector definition; the same is the case for high-profile publications, such as FAO's global forest sector outlook ([FAO, 2022](#)), and academic review papers of the forest sector (e.g. [Hurmekoski and Hetemäki, 2013](#)).

[Kallio et al. \(1987: 1\)](#) defined the forest sector as “the set of activities related to the use of wood: forest growth and harvest; the manufacture of pulp, paper, and solid-wood products; and international trade and intermediate and final consumption of these products”. This wood-focus, excluding non-wood products and services, seems persistent in current forest sector studies as exemplified above. However, the forest sector is becoming more complex as it addresses concerns spanning from degrowth to biotechnology ([Piplani and Smith-Hall, 2021](#)), is central to rural incomes in the Global South ([Angelsen et al., 2014](#)), becomes integrated into climate change ([Bonan, 2008](#)), or with the increasing importance of services ([Acharya et al., 2019](#)).

Here, to capture these wider perceptions of the forest sector, we present a stylised conceptual framework of the forest sector ([Fig. 1](#)). With point of departure in [McGinnis and Ostrom \(2014\)](#), the four principal components are: the resource base (typically a specific forest) made up of a range of resource units (e.g. logs or bark), the activities connected to move these into consumption, the actors and stakeholders involved, and the outcomes such as unsustainable harvesting that feedback into the resource base or actor components. The components interact across spatial (local, national, international) and temporal scales, and are influenced by the social, economic, and political settings relevant to particular points in space and time. The building blocks of each component are thus context dependent and contingent on industry specifics. Each of the four components are exemplified with the text in

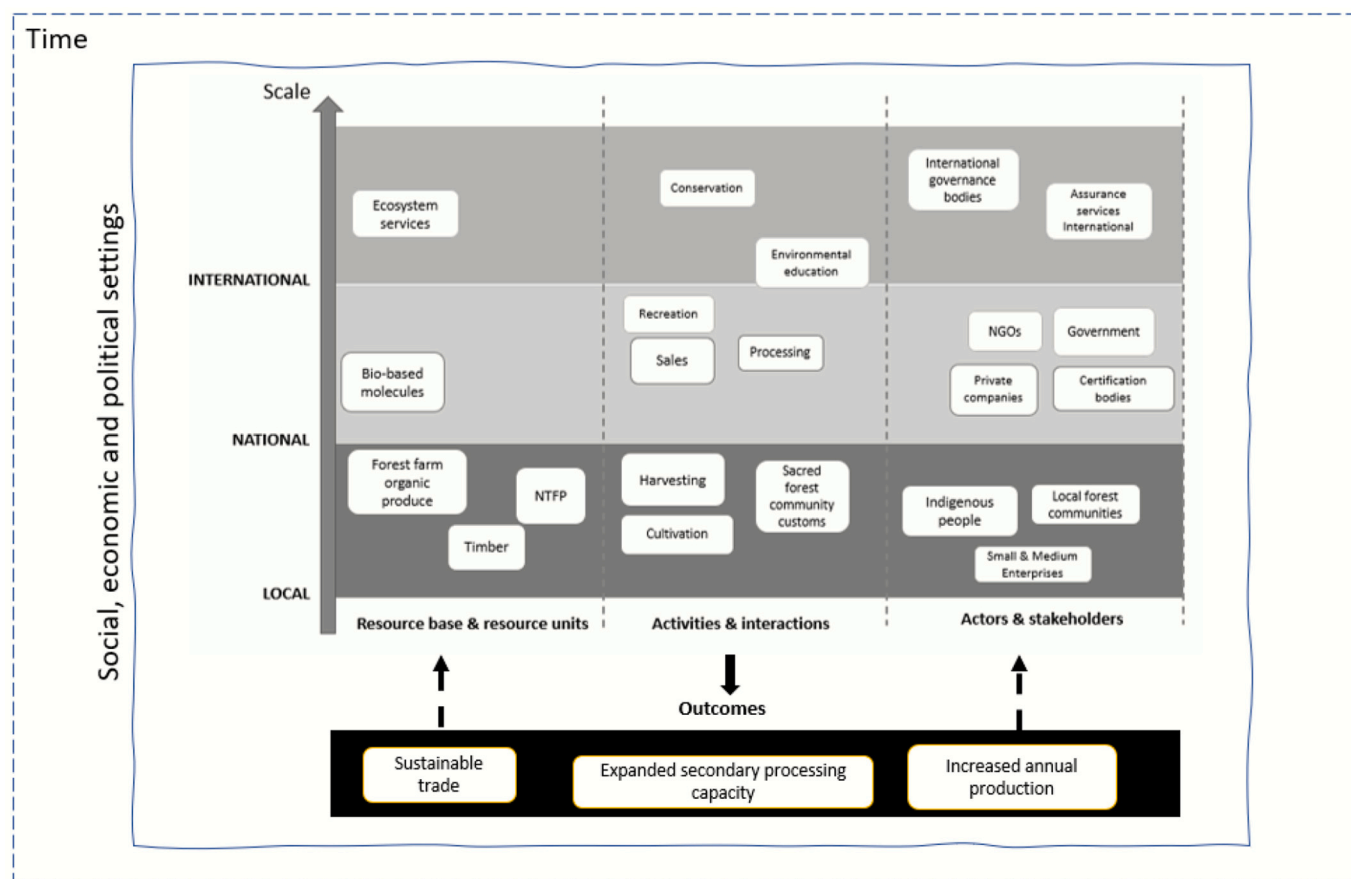


Fig. 1. A stylised conceptual framework of the forest sector with four components: resource base and resource units; activities and interactions; actors and stakeholders; and outcomes. The white boxes are examples illustrating the diversity of each component.

the white boxes. Of course, other examples could be included and some examples are relevant at different spatial scales, e.g. timber is a locally harvested resource unit but can also be considered aggregated at the national level.

As noted in Section 2, the forest sector literature can contribute to develop and operationalise analyses of resource base issues, moving beyond the vague concept of materiality. Two points stand out. First, even though absent in the GPN literature, tenure matters (e.g. Ellis, 2000; Dawson et al., 2021). Major categories are state, private, and communal ownership and the way these property rights are understood and enforced are critical for sustainable forest management and socio-economic development (Jagger et al., 2014; Miller et al., 2021). Second, while tools and data collection instruments are well-established for estimating timber stocks and sustainable harvest levels, this is not the case for most renewable environmental products (Balasso et al., 2023). For instance, knowledge on sustainable harvest levels is available for less than 1% of the commercial species harvested for environmental product trade in Nepal (Smith-Hall et al., 2020). Associated with this is a need to develop silvicultural techniques, management plans, and new technology such as cultivation techniques that are not part of conventional forest management. Recent advances include work on synergistic compatible timber and non-timber production (Baumflek et al., 2022) and a general model for understanding when environmental products enter cultivation (Madsen and Smith-Hall, 2023). For most products and locations, however, investments are required for inventories, growth and yield studies, and development of co-production methods (Chamberlain and Smith-Hall, 2023).

Lastly, the recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) review of sustainable use of wild species has emphasized the importance of noting the economic,

social, and ecological dimensions of sustainability (Fromentin et al., 2022). Hence, the dominant focus on economic development in GPN theory needs to be accompanied by focus on social development and ecological development.

4. Methods

In the Results below, we combine the conceptual framework (Fig. 1) and the associated considerations with the analytical devices (Table 1) to arrive at an operational approach to the forest-based bioeconomy (Table 2).

4.1. Study area and species

Nepal has five ecological zones (tropical, subtropical, temperate, subalpine, and alpine) and three physiographic zones (lowlands below 1000 m, mid-hills from 1000 to 3000 m, and the highlands above 3000 m), Fig. 2, resulting in rich biodiversity, including 300 commercial medicinal plant species (Pyakurel et al., 2019). *Fritillaria cirrhosa* D. Don (English: Himalayan fritillary; Nepali: kakoli, ban lasun) is a bulbous geophyte in the Liliaceae family and a high-value high-altitude Himalayan species distributed in China, Pakistan, India, Nepal, Bhutan, and Myanmar (Chen et al., 2019). Using TISC (2010) terminology, it is found in Nepal in the alpine (upper alpine meadows, dry and moist alpine scrubs) and sub-alpine zones (blue pine forest, birch-rhododendron forest, fir forest, and fir-oak-rhododendron forest) from 3000 to 4750 m across 37 districts with an estimated distribution area of 16,261 km² (Supplementary Information, Table SI 1).

The species has been assessed as vulnerable in Nepal (Bhattarai and Karki, 2002). The bulbs are widely gathered with harvester prices

Table 2

An analytical framework for empirical investigation of the forest-based bioeconomy.

Analytical devices	Indicators	Notes on using the framework for analysing the forest-based bioeconomy
Principal component 1: Resource base and units		
Value creation	- Commercial forest types - Commercial species - Growth and yield per unit - Harvest per unit - Price per unit	While value is created in the act of consuming or selling a product, other data is needed to assess wider value creation aspects, such as annual growth and yield to estimate the sustainable value creation level for a particular product
Tenure	- Ownership - Management plans - Legislation	While not central in GPN theory, tenure is a key aspect of forest-related modes of production and in regulating resource access
Principal component 2: Activities		
Value enhancement	- Primary processing - Secondary processing - Certification - Spatial arbitrage - Net value per unit per actor	Primary processing are local low-skill operations, such as air-drying, while secondary processing requires purchased inputs, technologies, and specialised skills to make consumer products (Fellows, 2011). Spatial arbitrage exist when the price of a homogenous good at any two locations differs by more than the transport cost from the lower to the higher price location
Value capture	- Taxes - Rent-seeking - Net margins - Conflicts	There is a huge number of ways to capture value in the forest-based bioeconomy, some of which may be disruptive to production and trade (e.g. Wallrapp et al., 2019)
Principal component 3: Actors		
Societal embeddedness	- Types of actors - Role of actor - History of actor	This can be important in understanding the political ecology of a forest-based economy, e.g. Basnyat et al. (2023) detail how local timber brokers operate as conveyers of unofficial payments to forestry officials
Territorial embeddedness	- Years since establishment in location - Reasons for establishment	A constitutive part of the physical configuration of a forest-based bioeconomy, e.g. Fold et al. (2023) showed how upstream actors moved with development of new road infrastructure
Network embeddedness	- Duration of inter-firm relations - Trust in inter-firm relations - Share of trade in total income - Mobility between actor types	Examples are emerging in the literature, e.g. Fold et al. (2023) found wholesalers conducting transactions based on trust rather than written agreements, and detailed the reasons behind lack of mobility between actor types
Bargaining power	- Price determination mechanism - Oligopsony, monopsony	A typical mechanism is private treaty trading (buyer and seller negotiate price). Empirical investigation of pricing efficiency can reveal inefficient markets
Demonstrative power	- Adoption of new approaches - Effect of demand-side campaigns	Few such studies. An example is Vu and Nielsen (2021) finding low demonstrative power as campaigns to reduce rhino horn consumption in Vietnam have failed
Institutional power	- Share of illegal trade	An example of low institutional power of central government is

Table 2 (continued)

Analytical devices	Indicators	Notes on using the framework for analysing the forest-based bioeconomy
	- Degree of implementation of law and policies - Membership	orchid trade in Nepal: despite 55 pieces of legislation, illegal trade is common (Bashyal et al., 2023)
Constitutive power	- No. of sustainably produced products - No. of companies reporting ESG data - Green consumer trends	Few studies. The potential to leverage influence is indicated by studies such as Kilchling et al. (2009) reporting urban consumer interest in green forest products in Switzerland
Firms	- Managerial capacity - Corporate culture - Resources and assets - Ownership mode	Environmental product studies usually focus on households, livelihoods, institutions, or governance with no or marginal attention to firms (e.g. Ellis, 2000)
Strategies	- Intra-firm coordination - Inter-firm control - Inter-firm partnership - Extra-firm bargaining	Well-developed but not applied to the study of the forest-based bioeconomy
Cost-capability ratio	- Level of costs - Level of capability	Likely that many forest product providers and processors are characterised by low costs and low capabilities, e.g. resulting in being price-takers with little or no bargaining power
Market imperative	- Time-to-market - Customer pressure - Consumer preferences	Customer and consumer surveys are rare for environmental products limiting understandings of market dynamics
Financial discipline	- Stock prices - Executive rewards	Not studied for firms in the forest-based bioeconomy
Principal component 4: Outcomes		
Territoriality	- Production network structure	Environmental product studies are gradually emerging (e.g. Murphy, 2012; Pouliot et al., 2018; Fold et al., 2023)
Economic development	- Sector employment - Sector value addition - Sector share in exports	Can be aggregated at relevant spatial scale (e.g. provincial or national). Few studies provide results beyond the local level
Social development	- Fair pricing - Income equality effect - Non-exploitative actor relationships - Share of legal trade	There is no agreement on what constitutes fair pricing. Studies indicate an income equalising effect of environmental products (Angelsen et al., 2014). Exploitative relationships and illegal trade are widespread (e.g. Nevins and Peluso, 2008)
Ecological development	- Sustainable harvest level per product per unit area - Trade level per product	There are few estimates of sustainable harvest level for any environmental product, and even fewer comparing these to trade data. Data on the sustainability of the forest-based bioeconomy are largely unavailable
Value capture trajectories	- Type of growth - Type of path - Shifts between networks	Requires panel data for individual firms. Not explicitly studied for environmental product enterprises in the forest-based bioeconomy
Regional development	- Capital flows - No. of firms - Access to new technology - Employment	The sum of trajectories in a location, and hence also not studied as above
Strategic coupling	- Modes - Types	Classified into three modes and eight types. Well-studied elsewhere (e.g. electronics) but has not been applied to the forest-based bioeconomy

(continued on next page)

Table 2 (continued)

Analytical devices	Indicators	Notes on using the framework for analysing the forest-based bioeconomy
Risk	- Economic - Product - Regulatory - Labour - Environmental	When risks are addressed in environmental product studies, the focus is typically on only a few types, e.g. product risk in relation to ginseng consumption in Korea (Park and Lee, 2023)

The indicators for the devices strategies, cost-capability ration, strategic coupling, and risk were derived from Coe and Yeung (2015, 2019) and Coe (2021).

around USD 150/kg, a unit price only surpassed by the caterpillar fungus *Ophiocordyceps sinensis*. China is the main market (Cunningham et al., 2018); the dried bulbs are used in Traditional Chinese Medicine to treat cough, bronchitis, pneumonia, lung injury and cancer (Wu et al., 2022). Around 400 Chinese companies make fritillary-based products worth USD 400 million in annual sales (IMPLAD, 2023). Demand is increasing as is harvesting in the Himalayas (Cunningham et al., 2018). However, the production network remains unknown as do key data such as the annual traded amount.

4.2. Data collection

District-level trade data was collected in 15 randomly selected districts – one in each of the 15 cells created by the three physiographic zones and the five former development regions (now replaced by the new provinces) – for the Nepalese fiscal years 2014–15 and 2021–22. In the districts, all traders were interviewed: $n = 65$ in 2014–15 and $n = 79$ in 2021–22. For the first period, to investigate the production network, this was supplemented with interviews of 540 harvesters encountered *en route*, 73 central wholesalers and 79 processing industries in Nepal, and 78 regional wholesalers in India and Tibet. The respondents were asked for their informed consent and both quantitative and qualitative

approaches were used. Full procedural details and the data collection instruments are provided in Smith-Hall et al. (2018). We adopted the Olsen and Bhattarai (2005) economic actor typology and their functions as described by Pouliot et al. (2018) and Pyakurel et al. (2018). In general, harvesters create value by harvesting and selling to sub-local traders operating from villages. The sub-local traders sell to local traders in district headquarters or major market centres. Both sub-local and local traders enhance value through primary processing. Local traders sell the products in bulk to processors and city-based central wholesalers who export to regional wholesalers. Quantitative answers were recorded using tablets and the freeware KoboCollect, and downloaded into Microsoft Excel and analysed. Qualitative questions were recorded, transcribed, and translated.

4.3. Data analysis

For each case year (2014–15 and 2021–22), the 15 district-level trade data were generalised to the national level (62 additional districts) using the recorded volumes and the ratio of suitable growing areas between case and non-case districts (Table SI 2). Specifically:

$$Q_{jy} = (a_j/a_c)Q_{cy} \quad (1)$$

where Q_{jy} is the estimated amount (kg) of air-dry bulbs traded from non-case district j ($j = 1, 2, \dots, 62$) in study year y (2014–15 or 2021–22); a_j is the adjusted suitable growing area (ha) in non-case district j ; a_c is the adjusted suitable growing area in case district c ($c = 1, 2, \dots, 15$) in the cell containing district j or the nearest neighbour; and Q_{cy} is the reported amount (kg) of air-dry bulbs purchased from harvesters (by traders, central wholesalers, and processors) in case district c in study year y . Furthermore, our trade estimates were compared with the officially registered trade.

Qualitative data was analysed using colour codes for the analytical devices in Table 2 and synthesising the findings.

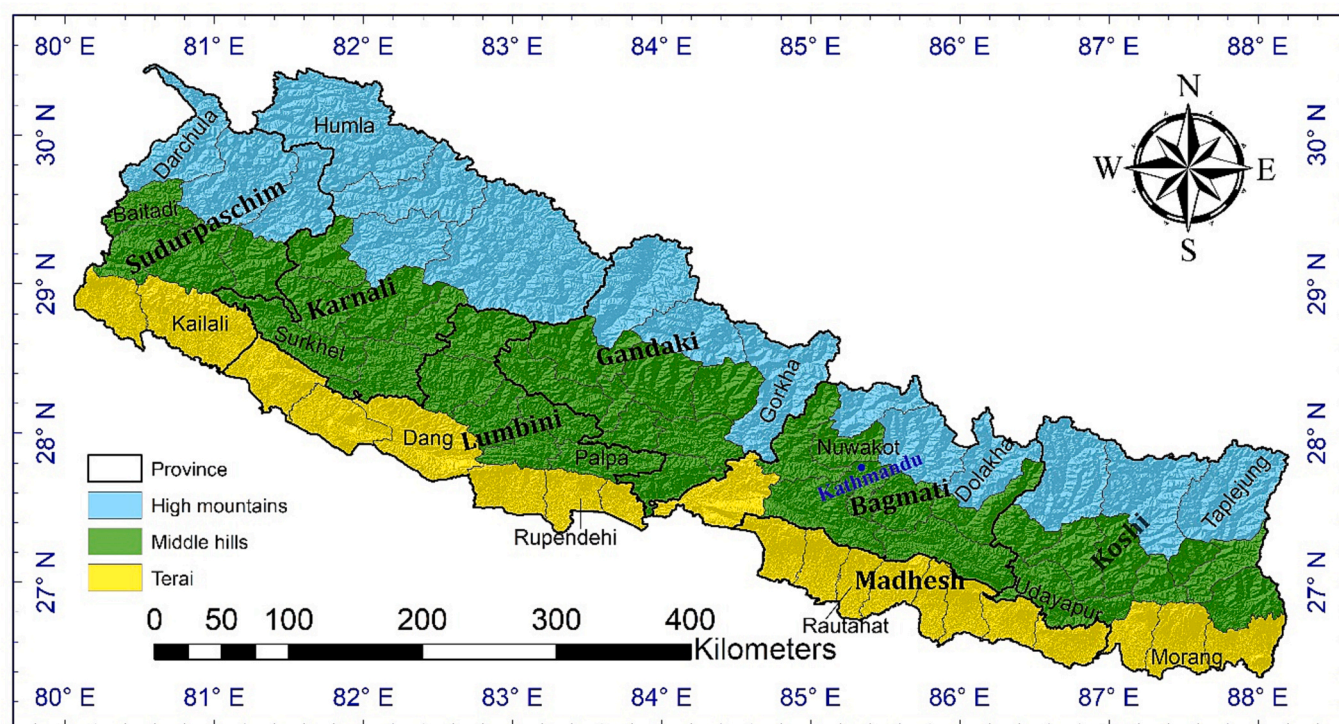


Fig. 2. Nepal's three physiographic zones (lowlands in yellow, mid-hills in green, and highlands in blue), seven provinces (bold), and the 15 named survey districts. Map by Sailesh Ranjitkar. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

5. Results

5.1. An analytical framework for empirical investigation of the forest-based bioeconomy

Here we combined the four principal components of the forest sector with the array of analytical devices of global production network theory and developed examples of indicators (Table 2). To this marriage, building on the observations in Section 3, we identified and added three missing devices: “Tenure” in relation to resource base issues and “Social development” and “Ecological development” as outcomes. The high number of actor related analytical devices reflects the actor-centric approach of global production network theory. Not all analytical devices will be relevant in all studies. The list of indicators is inspirational rather than exhaustive. The choice of indicators and their units of measurements depend on the purpose of a given study, e.g. the indicator “Secondary processing” can be measured in number of secondary processing firms or the value of outputs at industry, company, or species levels.

The emphasis in Table 2 is on providing insights and inspiration for measurable indicators in the forest-based bioeconomy rather than being prescriptive and normative, e.g. we are interested in estimating the indicator “Rent-seeking” (such as through the value extracted per kg of a particular product at different points in the production network) rather than preventing rent-seeking. While some of the analytical devices are commonly used in studies on environmental products, most are rare in existing studies of the forest-based bioeconomy indicating scope for gaining insights from explicit and structured application of global production network theory.

5.2. The model applied: *Fritillaria cirrhosa* and the forest-based bioeconomy in Nepal

The following provides examples of use of the framework's analytical devices. The purpose is to illustrate rather than to provide a comprehensive analysis for the case species.

The global production network configuration for fritillary is relatively straightforward: specialised suppliers (harvesters, traders, central wholesalers) in Nepal supply specialised suppliers (regional wholesalers) in China who supply lead and competing firms in China, Hong Kong, and Taiwan. The majority of consumption is in China, with minor amounts re-exported to countries such as Australia, Canada, and the Republic of Korea. A well-known consumer product is the Nin Jiom Pei Pa Koa syrup produced by Nin Jiom Medicine in Hong Kong, a possible lead firm. Hence, three spatial levels are noteworthy: production at the local level, regulation at the national level, and processing, demand, and consumption at the international level. These relationships are integrated and dynamic, e.g. with price signals from China leading from low harvest levels two decades ago to the current substantial annual harvest.

In relation to the resource base, the first principal component in the above framework, Table 3 presents an overview of provincial and

national level annual harvests. The harvest increased by 12% from around 18 t in 2014–15 to around 20 t in 2021–22. The main supply shifted from Karnali to Sudurpashchim Province (specifically to Bajhang, Bajura, and Darchula districts, SI 2), with harvesting in Karnali crashing between the two observation years. Based on harvester interviews, overharvesting is a main reason but this needs to be disentangled from other possible causes such as shifting to other species (most notably *O. sinensis*) and decreased gathering due to outmigration. However, these alternative explanations appear less important as they would also apply to Sudurpashchim Province. Therefore, it is reasonable to expect a similar production crash in this province soon. Hence, even if we lack detailed stock and yield studies for the case species, there is a pattern of unsustainable trade in western Nepal while the resource base is little utilised in the eastern part of the country. This indicates the importance of a sub-national attention in developing the forest-based bioeconomy.

In relation to activities, there is no secondary processing or certification. Comparing the estimated trade with the officially recorded volume (Table 3, for the period 2007–15 for which national records are available) shows that all fritillary trade is formally illegal. This strongly indicates the existence of value capture through rent-seeking.

In terms of actors, the trade in *F. cirrhosa* bulbs is done alongside a number of other commercial medicinal plant products. Inside Nepal, therefore, the situation as regards embeddedness and power is similar to that for other products, such as documented by Fold et al. (2023), e.g. in terms of horizontal cooperation among local traders, interlocked markets in the initial nodes of the production network, the physical embeddedness of harvesters and the strong cultural, social, and ethnic bonds in harvesting areas, and the exercise of institutional power in regulating trade, e.g. issuing collection and transport permits. There are simple inter-firm relationships; no evidence of any strategic partnerships or intra-firm networks; while extra-firm connections are important, e.g. in order to move the bulbs across the border.

6. Discussion

There is no formal (forest-based) bioeconomy in Nepal; however, the existing nominal and functional law indicate a situation similar to the socio-bioresource school characterised by ecopragmatic thinking, a largely informal economy, and acknowledgement of the importance of resource sustainability and poverty alleviation (Piplani and Smith-Hall, 2021, 2023). Three general development trends are important in this context. First, the past decades has seen a rapid expansion of south-south trade and particularly intra-Asia trade (Horner and Nadvi, 2018). Second, Nepal achieved an upgrading trajectory movement from commodities to limited manufacturing from 1990 to 2015 (World Bank, 2020), a change also reflected in the forest-based bioeconomy where the number of processing companies increased 20-fold in the same period (Caporale et al., 2020). Third, environmental sustainability is emerging as a key driver of production networks (Ponte, 2019) indicating increased importance of sustainable trade in future markets. This points to two important short-comings in the Nepalese forest-based bioeconomy:

1. Limited use of firms' comparative advantages. Arguably, firms in Nepal are positioning themselves to gain from being sandwiched between two of the largest markets in the world. So far, however, despite this market proximity and access to raw materials, growth in the environmental product industry has mainly come from the domestic Nepalese markets with no emergence of a large-scale export-oriented successful firm. Entrepreneurs could be deterred by risks in the forest-based economy: regulatory risk from political interference such as the India closure of the border in 2015, product risk such as the EU Negative Opinion of the sustainability of *Nardostachys jatamansi* rhizome harvesting and the associated stop to imports, and environmental risks like the 2015 earthquake. Presently, Nepal exports its entire annual production of fritillary bulbs without any form of secondary processing.

Table 3

Provincial and national overviews of the annual trade in *F. cirrhosa* air-dried bulbs (kg) in Nepal in 2014–15 and 2021–22 (SI 2), and the official annual government record (DoF, 2007–15).

Province	Total trade		Record
	2014–15	2021–22	
Koshi	0	23	0
Madhesh	0	0	0
Bagmati	991	1004	0
Gandaki	1420	1918	0
Lumbini	219	296	0
Karnali	9076	1174	0
Sudurpashchim	6274	15,791	0
Total	17,981	20,183	0

2. Limited attention to sustainable production. Prices for fritillary bulbs increased almost ten-fold from 2002 to 2017, leading to investment in developing technology for fritillary cultivation and enrichment planting in China (Cunningham et al., 2018). However, there are no reports of cultivation in Nepal, indicating that Nepalese fritillary follows the pathway of economic extinction rather than scarcity induced cultivation (Madsen and Smith-Hall, 2023). The Nepalese resource base is regulated with generic interventions, such as rules for accessing government forests or management plans for community forests, and no explicit attention to sustainable management of fritillary resources. There is concern about unsustainable harvests throughout the species distribution area (Cunningham et al., 2018; Mathela et al., 2021). Obtaining existing cultivation technology and making this available to Nepalese producers appears a straightforward option to maintain production and income from fritillary as part of a sustainable Nepalese forest-based bioeconomy, including through integration into community forestry management plans. If this is not pursued, processing companies will likely use the spatial flexibility of the resource to increase their supplies from allied fritillary species in China.

In other words, Nepalese fritillary production areas couple into the forest-based bioeconomy through structural coupling (Coe, 2021): generic raw material (the air-dried bulbs) are supplied dependent on external demand, with a resultant low level of value capture and high risk of decoupling, both through replacement by cultivated material from China and own-elimination through unsustainable wild harvesting. Maintaining and increasing provincial-level development from fritillary resources require transitions from wild harvesting to cultivation and from structural to functional coupling, establishing secondary processing in Nepal. If this is not achieved, fritillary will remain part of an agrifood production landscape (Coe, 2021) aimed at supplying raw materials for distant processing and consumption. While gathering commercial medicinal plants may be considered an arduous and low prestige activity, such income may constitute a major route out of poverty for rural households (Timmermann and Smith-Hall, 2019). Thus a sustainable forest-based bioeconomy needs ecologically sustainable gathering and/or cultivation of high-demand species and an economically sustainable processing industry to increase value capture. From a social sustainability perspective, increasing harvester skills and value capture is important to facilitate asset growth and poverty exit.

The main actors in the medicinal plant trade are well-known and well-described (Olsen and Bhattarai, 2005). Generalising this actor terminology, traders and central wholesalers in Nepal and regional wholesalers in India and China are industry-specific specialised suppliers of primary processed raw materials. They are difficult to replace. The recently reported commission agent (Fold et al., 2023) is a facilitating intermediary enabling smooth cross-border trade. While no lead firms have been identified, and in consequence no strategic partners, these may well exist. Customers are individual end consumers; there are no consumer surveys, except for He et al. (2022) investigating consumption of the caterpillar fungus *O. sinensis* in the main market of China, making specific product-level demand predictions difficult. Downstream linkages between consumer product manufacturers, distributors, and retailers remain unknown. The state is the main non-firm actor influencing the forest-based bioeconomy through nominal (e.g. the Forest Act 2019) and functional (e.g. Custom Regulations 2019) policies. Its main role is in facilitating production through encouraging community-based resource management and regulating trade using a centralised control system of permits, including collection and transport permits, royalties and custom duties. However, the state also arguably serves the opposite function, hindering trade and development of the forest-based bioeconomy through a 'hidden' agenda of increasing value capture by providing rent-seeking opportunities for public employees such as forest and police officers (Basnyat et al., 2023). Labour is also important to the forest-based bioeconomy. While collective forms of labour, in the form of community forestry groups, has served to increase value creation (through improved forest quality and supplies, Baniya

et al., 2019), substantial challenges are emerging. High altitude production areas are becoming depopulated as people move south and to the cities (Childs et al., 2014) and all production areas are affected by the huge number of migrants looking for employment in India, the Middle East, and Malaysia (Wagle and Devkota, 2018). With continued economic growth, high levels of supplies can likely only be maintained through cultivation. Lastly, civil society organisations also facilitate or regulate the forest-based bioeconomy, either through organising producers, such as the Federation of Community Forestry Users in Nepal, or working to transform production systems, such as introducing certification.

The forest-based bioeconomy is characterised by simple firm strategies. Intra-firm coordination is limited to enhanced value capture by expanding into adjacent markets, such as generalist traders also trading agricultural products, and providing services, for instance the advancement of credit to harvesters before the collection season. Prices are used by regional wholesalers to exercise inter-firm control, a pressure that central wholesalers pass on to traders. Olsen and Helles (1997) argued the existence of an oligopsony, that Pyakurel et al. (2018) found to be dismantling as improved infrastructure (notably mobile phones) makes price control more difficult. There appear to be substantial scope for additional upstream value capture in the forest-based bioeconomy by reconfiguring the production network, ultimately by establishing direct connections between large producers and processors. Extra-firm negotiations could support such a reconfiguration by focusing government resources on supportive interventions such as access to cultivation technology, simplified rules for production and trade in community forestry, and structured collection and dissemination of prices. There is also an important current task of ensuring a supportive regulatory landscape: how can the downscaling of resource management responsibility from the central to the new provincial governments be designed to support the forest-based bioeconomy? How can supra-national agreements be used, including duty-free export of medicinal plant products as part of the Nepal-People's Republic of China Free Trade Agreement 2016? There is potential for the Nepalese forest-based bioeconomy to benefit from the country's geopolitical position. Lastly, there seems to be potential in using multi-stakeholder initiatives, such as FairWild (there is presently no certified fritillary production in Nepal), to access markets with environmentally conscious consumers. A further unexplored avenue for the Nepalese forest-based bioeconomy is the emerging platform economy, for instance using e-commerce to connect producers to companies making consumer products.

7. Conclusion

With point of departure in international trade in renewable environmental products in the Global South, we identified and presented a suite of analytical devices from global production network theory and combined these with a four-component stylised representation of the forest sector to arrive at an analytical framework for empirical investigation of the forest-based bioeconomy. Using the example of the herbaceous Himalayan fritillary that is commercially gathered in Nepal and traded as air-dried bulbs mainly to China, we demonstrated the application of the analytical framework. We conclude that global production network theory, and the associated array of analytical devices, can inform empirical investigation of the forest-based bioeconomy, through making the often vague concept of the bioeconomy operational and through grounding findings within an established theoretical frame and its associated emerging body of literature. The empirical application also demonstrated the possible policy outcomes. The Nepalese harvest is undertaken without investments in maintaining or enhancing production, despite consistent high prices, with the air-dried bulbs exported without any secondary processing. This reduces Nepal to a production landscape supplying China with raw materials for value addition. When the resources are exhausted, supplies will likely shift to allied and cultivated species in China. Therefore, as part of a transition toward a

sustainable forest-based bioeconomy in Nepal, interventions should acknowledge the comparative production and geopolitical advantages of the country (its specific natural assets, such as fritillary, and proximity to the largest markets in the world) and be oriented toward establishment of cultivation, supporting the development of a secondary processing industry. The positive economic development outcomes would be increased rural household incomes in low-income production sites, the development of new jobs, skills, social upgrading, and increasing provincial and national incomes. Lastly, there are two promising avenues for further research: (i) to identify principles and criteria for assessing the sustainability of trade in a forest-based bioeconomy, and (ii) to develop and provide an example of a theory of change for sustainable management of environmental resources in a forest-based bioeconomy.

Declaration of Competing Interest

The authors declare no competing interests.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

- Acharya, R.P., Maraseni, T., Cockfield, G., 2019. Global trend of forest ecosystem services valuation – an analysis of publications. *Ecosyst. Serv.* 39, 100979.
- Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N., Bauch, S., Börner, B., Smith-Hall, C., Wunder, S., 2014. Environmental income and rural livelihoods: a global-comparative analysis. *World Dev.* 64, S12–S28.
- Balasso, M., Mutke, S., Sheppard, J.P., Chamberlain, J., 2023. Forest management for sustainable sourcing of non-timber forest products in a bioeconomy. In: Smith-Hall, C., Chamberlain, J. (Eds.), *The Bioeconomy and Non-timber Forest Products*. Routledge, London, pp. 199–214.
- Baniya, B., Tang, Q., Pokhrel, Y., Xu, X., 2019. Vegetation dynamics and ecosystem service values changes at national and provincial scales in Nepal from 2000 to 2017. *Environ. Develop.* 32, 100464.
- Bashyal, R., Paudel, K., Hinsley, A., Phelps, J., 2023. Making sense of domestic wildlife and CITES legislation: the example of Nepal's orchids. *Biol. Conserv.* 280, 109951.
- Basnyat, B., Treue, T., Pokharel, R.K., Kayastha, P.K., Shrestha, G.K., 2023. Conservation by corruption: the hidden yet regulated economy in Nepal's community forest timber sector. *Forest Policy Econ.* 149, 102917.
- Baumflek, M., Cabe, T., Schelhas, J., Dunlavy, M., 2022. Managing forests for culturally significant plants in traditional Cherokee homelands: emerging platforms. *Int. For. Rev.* 24 (3), 298–314.
- Bhattarai, N.K., Karki, M. (Eds.), 2002. *Sharing Local and National Experience in Conservation of Medicinal and Aromatic Plants in South Asia*. International Development Research Centre, Delhi.
- Bonan, G.B., 2008. Forests and climate change: forcings, feedbacks, and the climate benefits of forests. *Science* 320, 1444–1449.
- Brinckmann, J.A., Kathe, W., Berkhoudt, K., Harter, D.E.V., Schippmann, U., 2022. A new global estimation of medicinal and aromatic plant species in commercial cultivation and their conservation status. *Econ. Bot.* 76, 319–333.
- Bugge, M., Hansen, T., Klitkou, A., 2016. What is the bioeconomy? A review of the literature. *Sustainability* 8, 691.
- Caporale, F., Mateo-Martín, J., Usman, F., Smith-Hall, C., 2020. Plant-based sustainable development – the expansion and anatomy of the medicinal plant secondary processing sector in Nepal. *Sustainability* 12, 5575.
- Chamberlain, J., Smith-Hall, C., 2023. The keys to unlocking the bioeconomy with non-timber forest products. In: Smith-Hall, C., Chamberlain, J. (Eds.), *The Bioeconomy and Non-timber Forest Products*. Routledge, London, pp. 251–265.
- Chen, Q., Wu, X., Zhang, D., 2019. Phylogenetic analysis of *Fritillaria cirrhosa* D. Don and its closely related species based on complete chloroplast genomes. *PeerJ* 7, e7480.
- Childs, G., Craig, S., Beall, C.M., Basnyat, B., 2014. Depopulating the Himalayan highlands: education and outmigration from ethnically Tibetan communities of Nepal. *Mt. Res. Dev.* 34 (2), 85–94.
- Coe, N.M., 2021. *Advanced Introduction to Global Production Networks*. Edward Elgar Publishing Limited, Cheltenham.
- Coe, N.M., Yeung, H.W.-C., 2015. *Global Production Networks: Theorizing Economic Development in an Interconnected World*. Oxford University Press, Oxford.
- Coe, N.M., Yeung, H.W.-C., 2019. Global production networks: mapping recent conceptual developments. *J. Econ. Geogr.* 19, 775–801.
- Cunningham, A.B., Brinckmann, J.A., Pei, S.-J., Luo, P., Schippmann, U., Long, X., Bi, Y.-F., 2018. High altitude species, high profits: can the trade in wild harvested *Fritillaria cirrhosa* (Liliaceae) be sustained? *J. Ethnopharmacol.* 223, 142–151.
- Dallas, M.P., Ponte, S., Sturgeon, T.J., 2019. Power in global value chains. *Rev. Int. Polit. Econ.* 26 (4), 666–694.
- Dawson, N.M., Coolsaet, B., Sterling, E.J., Loveridge, R., Gross-Camp, N.D., Wongsuvarakum, S., Sangha, K.K., Scherl, L.M., Phuong Phan, H., Zafra-Calvo, N., Lavey, W.G., Byakagaba, P., Idrobo, C.J., Chenet, A., Bennett, N.J., Mansourian, S., Rosado-May, F.J., 2021. The role of Indigenous peoples and local communities in effective and equitable conservation. *Ecol. Soc.* 26 (3), 19.
- DoF, 2007–15. *Hamro Ban* (a Yearly Publication of the Department of Forests). Department of Forests, Kathmandu.
- Ellis, F., 2000. *Rural Livelihoods and Diversity in Developing Countries*. Oxford University Press, Oxford.
- EU, 2018. *A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment*. European Commission, Brussels.
- FAO, 2014. *Contribution of the Forestry Sector to National Economies, 1990–2011*. Forest Finance Working Paper FSFM/ACC/09. FAO, Rome.
- FAO, 2022. *Global forest sector outlook 2050: Assessing future demand and sources of timber for a sustainable economy*. FAO Forestry Working Paper No. 31. FAO, Rome.
- Fellows, P., 2011. *Processing for prosperity*. In: FAO Diversification Booklet 5, 2nd ed. FAO, Rome.
- FF, 2022. *Herbal Medicine Market Size, Share Global Analysis Report, 2022–2028*. Facts and Factors, Pune.
- Fold, N., Pyakurel, D., Pouliot, M., Smith-Hall, C., 2023. Global production networks and medicinal plants: upstream actors in Nepal. *Geogr. J.* <https://doi.org/10.1111/geoj.12508>.
- Fromentin, J.M., Emery, M.R., Donaldson, J., Hallosserie, A., Michaud-Lopez, C.E., Parma, A., Martin, K.St., Stockland, H., 2022. Chapter 1: Setting the scene. In: Fromentin, J.M., Emery, M.R., Donaldson, J., Danner, M.C., Hallosserie, A., Kielling, D. (Eds.), *Thematic Assessment Report on the Sustainable Use of Wild Species of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES Secretariat, Bonn, pp. 1–76.
- He, J., Smith-Hall, C., Zhou, W., Zhou, W., Wang, Y., Fan, B., 2022. Uncovering caterpillar fungus (*Ophiocordyceps sinensis*) consumption patterns and linking them to conservation interventions. *Conserv. Sci. Practice* 4 (8), e12759.
- Henderson, J., Dicken, P., Hess, M., Coe, N., Yeung, H.W.-C., 2002. Global production networks and the analysis of economic development. *Rev. Int. Polit. Econ.* 9 (3), 436–464.
- Hornor, R., Nadvi, K., 2018. Global value chains and the rise of the global south: unpacking twenty-first century polycentric trade. *Global Netw.* 18 (2), 207–237.
- Hughes, A., McEwan, C., Bek, D., 2015. Postcolonial perspectives on global production networks: insights from Flower Valley in South Africa. *Environ. Plan. A* 47, 249–266.
- Hurmekoski, E., Hetemäki, L., 2013. Studying the future of the forest sector: review and implications for long-term outlook studies. *Forest Policy Econ.* 34, 17–29.
- IMPLAD, 2023. *Trieste: The Academy of Sciences for the Developing World*. Institute of Medicinal Plant Development, Beijing, China.
- Jagger, P., Luckert, M.K., Duchelle, A.E., Lund, J.F., Sunderlin, W.D., 2014. *Tenure and forest income: observations from a global study on forests and poverty*. World Dev. 64, S43–S55.
- Kallio, M., Dykstra, D.P., Binkley, C.S., Dykstra, D.P., 1987. Introduction. In: Kallio, M., Binkley, C.S. (Eds.), *The Global Forest Sector: An Analytical Perspective*. Wiley, Chichester, pp. 1–4.
- Kilchling, P., Hansmann, R., Seeland, K., 2009. Demand for non-timber forest products: surveys of urban consumers and sellers in Switzerland. *Forest Policy Econ.* 11 (4), 294–300.
- Klooster, D., Mercado-Celis, A., 2016. Sustainable production networks: capturing value for labour and nature in a furniture production network in Oaxaca, Mexico. *Reg. Stud.* 50 (11), 1889–1902.
- Li, Y., Mei, B., Linhares-Juvenal, T., 2019. The economic contribution of the world's forest sector. *Forest Policy Econ.* 100, 236–253.
- Madsen, S.T., Smith-Hall, C., 2023. Wild harvesting or cultivation of commercial environmental products: a theoretical model and its application to medicinal plants. *Ecol. Econ.* 205, 107701.
- Mathela, M., Kumar, A., Sharma, M., Goraya, G.S., 2021. Hue and cry for *Fritillaria cirrhosa* D. Don, a threatened medicinal plant in the Western Himalaya. *Discover Sustain.* 2, 38.

- McGinnis, M.D., Ostrom, E., 2014. Social-ecological system framework: initial changes and continuing challenges. *Ecol. Soc.* 19 (2), 30.
- Miller, D.C., Rana, P., Nakamura, K., Irwin, S., Cheng, S.H., Ahlroth, S., Perge, E., 2021. A global review of the impact of forest property rights interventions on poverty. *Glob. Environ. Chang.* 66, 102218.
- Murphy, J.T., 2012. Global production networks, relational proximity, and the socio-spatial dynamics of market internationalization in Bolivia's wood products sector. *Ann. Assoc. Am. Geogr.* 102 (1), 208–233.
- Nevens, J., Peluso, N.L. (Eds.), 2008. *Taking Southeast Asia to Market*. Cornell University Press, Ithaca.
- Olsen, C.S., Bhattarai, N., 2005. A typology of economic agents in the Himalayan plant trade. *Mt. Res. Dev.* 25, 37–44.
- Olsen, C.S., Helles, F., 1997. Medicinal plants, markets and margins in Nepal Himalaya: trouble in paradise. *Mt. Res. Dev.* 17, 363–374.
- Park, M.S., Lee, H., 2023. An operational transition pathway to a forest-based bioeconomy: Lessons from the wild-simulated ginseng industry. In: Smith-Hall, C., Chamberlain, J. (Eds.), *The Bioeconomy and Non-timber Forest Products*. Routledge, London, pp. 131–147.
- Pauls, T., Franz, M., 2013. Trading in the dark: the medicinal plants production network in Uttarakhand. *Singap. J. Trop. Geogr.* 34, 229–243.
- Piplani, M., Smith-Hall, C., 2021. Towards a global framework for analysing the forest-based bioeconomy. *Forests* 12, 1673.
- Piplani, M., Smith-Hall, C., 2023. A framework supporting the transition to a forest-based bioeconomy and its application to Nepal. In: Smith-Hall, C., Chamberlain, J. (Eds.), *The Bioeconomy and Non-timber Forest Products*. Routledge, London, pp. 164–178.
- Ponte, S., 2019. *Business, Power and Sustainability in a World of Global Value Chains*. Zed Books, London.
- Pouliot, M., Pyakurel, D., Smith-Hall, C., 2018. High altitude organic gold: the production network for *Ophiocordyceps sinensis* from far-western Nepal. *J. Ethnopharmacol.* 218, 59–68.
- Pyakurel, D., Bhattarai Sharma, I., Smith-Hall, C., 2018. Patterns of change: the dynamics of medicinal plant trade in far-western Nepal. *J. Ethnopharmacol.* 224, 323–334.
- Pyakurel, D., Smith-Hall, C., Bhattarai-Sharma, I., Ghimire, S.K., 2019. Trade and conservation of Nepalese medicinal plants, fungi, and lichen. *Econ. Bot.* 73 (4), 505–521.
- Shackleton, C.M., de Vos, A., 2022. How many people globally actually use non-timber forest products? *Forest Policy Econ.* 135, 102659.
- Smith-Hall, C., Chamberlain, J., 2023a. Why focus on non-timber forest products in the bioeconomy? In: Smith-Hall, C., Chamberlain, J. (Eds.), *The Bioeconomy and Non-timber Forest Products*. Routledge, London, pp. 3–14.
- Smith-Hall, C., Chamberlain, J. (Eds.), 2023b. *The Bioeconomy and Non-timber Forest Products*. Routledge, London.
- Smith-Hall, C., Pouliot, M., Pyakurel, D., Fold, N., Chapagain, A., Ghimire, S.K., Meilby, H., Kmoch, L., Chapagain, D.J., Das, A.K., He, J., Nepal, K., Poudeyal, M.R., Kafle, G., Larsen, H.O., 2018. *Data Collection Instruments and Procedures for Investigating National-Level Trade in Medicinal and Aromatic Plants—The Case of Nepal*. Department of Food and Resource Economics, IFRO Documentation Series, Copenhagen.
- Smith-Hall, C., Chapagain, A., Das, A.K., Ghimire, S.K., Pyakurel, D., Treue, T., Pouliot, M., 2020. *Trade and Conservation of Medicinal and Aromatic Plants – An Annotated Bibliography for Nepal*. Sopan Press, Kathmandu.
- Star, S.L., Griesemer, J.R., 1989. Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. *Soc. Stud. Sci.* 19 (3), 387–420.
- Timmermann, L., Smith-Hall, C., 2019. Commercial medicinal plant collection is transforming high-altitude livelihoods in the Himalayas. *Mt. Res. Dev.* 39 (3), R13–R21.
- TISC, 2010. *Forest and Vegetation Types of Nepal*. Tree Improvement and Silviculture Component, Ministry of Forests and Soil Conservation, Kathmandu.
- Vu, H.N.D., Nielsen, M.R., 2021. Evidence or delusion: a critique of contemporary rhino horn demand reduction strategies. *Hum. Dimens. Wildl.* 26 (4), 390–400.
- Wagle, U.R., Devkota, S., 2018. The impact of foreign remittances on poverty in Nepal: a panel study of household survey data, 1996–2011. *World Dev.* 110, 38–50.
- Wallrapp, C., Faust, H., Keck, M., 2019. Production networks and borderlands: cross-border yarsagumba trade in the Kailash landscape. *J. Rural. Stud.* 66, 67–76.
- Wardell, D.A., Tapsoba, A., Lovett, P.N., Zida, M., Rousseau, K., Gautier, D., Elias, M., Bama, T., 2021. *Shea (Vitellaria paradoxa C.F. Gaertn.) – the emergence of global production networks in Burkina Faso, 1960–2021*. *Int. For. Rev.* 23 (4), 534–561.
- Weiskittel, A.R., Hann, D.W., Kershaw, J.A., Vancley, J.K., 2011. *Forest Growth and Yield Modeling*. Wiley-Blackwell, London.
- Willis, K.J., 2017. Useful plants—medicines. In: Willis, K.J. (Ed.), *State of the world's Plants*. Kew, Royal Botanic Gardens, pp. 22–29.
- World Bank, 2020. *World Development Report: Trading for Development in the Age of Global Value Chains*. World Bank, Washington DC.
- Wu, F., Tian, M., Sun, Y., Wu, C., Liu, X., 2022. Efficacy, chemical composition, and pharmacological effects of herbal drugs derived from *Fritillaria cirrhosa* D. Don and *Fritillaria thunbergii* Miq. *Front. Pharmacol.* 13, 985935.
- Yeung, H.W.-C., 2021. The trouble with global production networks. *EPA: Econ. Space* 53 (2), 428–438.