Solutions from Space?

A Dynamic Capabilities Perspective on the Growing Use of Satellite Technology for Managing Sustainability in Multi-tier Supply Chains

Heldt, Lisa; Beske-Janssen, Philip

Document Version
Final published version

Published in:
International Journal of Production Economics

DOI:
10.1016/j.ijpe.2023.108864

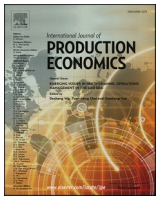
Publication date:
2023

Int. J. Production Economics 260 (2023) 108864

Contents lists available at ScienceDirect

International Journal of Production Economics

journal homepage: www.elsevier.com/locate/ijpe



Solutions from space? A dynamic capabilities perspective on the growing use of satellite technology for managing sustainability in multi-tier supply chains

Lisa Heldt [a,*], Philip Beske-Janssen [b]

[a] International Institute for Industrial Environmental Economics (IIIEE), Lund University, Lund, Sweden
[b] Department of Operations Management, Copenhagen Business School, Frederiksberg, Denmark

ARTICLE INFO

Keywords:
Sustainable supply chain management
Multi-tier supply chains
Sustainability risks
Dynamic capabilities
Satellite technology
Deforestation
Due diligence

ABSTRACT

Distant upstream tiers in supply chains are hotspots for sustainability issues that expose focal firms to growing reputational, financial, operational and legal risks – yet sustainable supply chain management (SSCM) practice and research still focus on dyadic buyer-supplier relationships due to poor upstream transparency. Recently, however, focal firms have started adopting satellite technology as a tool for gaining systematic, continuous and direct oversight of issues like deforestation occurring far upstream to complement standards and certifications. This could transform multi-tier SSCM dynamics but, being a novel phenomenon, it remains unclear which organizational capabilities and collaborations focal firms apply to leverage remote sensing's potential. Combining dynamic capabilities theory and a multi-tier SSCM framework, our paper analyzes the current use of satellite technology in forest-risk commodity supply chains. Triangulating insights from interviews, documents and observations in a qualitative content analysis, the study finds that effective multi-tier SSCM relies on (a) internal resources providing four functions (traceability; monitoring; follow-up; stakeholder accountability), (b) complemented with external resources accessed through strategically selected collaborations that (c) take the form of working along supply chains, across supply chains and across sectors. The results show that technology-driven multi-tier SSCM can hold strategic benefits beyond risk reduction. Further research is needed to assess these relations.

1. Introduction

Sustainability in supply chain management has become an important topic in academia, practice, politics and wider society in recent years. Upstream tiers in complex supply chains can be hotspots for environmental, labor and human rights issues and 'the further upstream an organization is the more impact it is likely to have' (Mena et al., 2013, p. 72). Yet, upstream visibility is decreasing with every tier (Choi et al., 2001). This translates into less control, accountability and incentives for focal firms to act on these issues. Accordingly, focal firms' sustainable supply chain management (SSCM) continues to focus on visible dyadic relationships mostly with first tier suppliers (Carter et al., 2015).

In recent years, however, focal firms face growing regulatory, operational, financial and reputational risk from sustainability issues hidden deep in their supply chains (Hajmohammad and Vachon, 2016). This leads to increasing and diverse stakeholder pressure holding focal firms accountable for their entire supply chain, creating 'chain liability' (Hartmann and Moeller, 2014, p. 281). An increased risk of repercussions related to upstream issues strengthens the case for increased transparency and action. In SSCM research, this has sparked interest in studies focusing explicitly on multi-tiered SSCM (Jamalnia et al., 2023), visibility (Taghizadeh et al., 2021) and transparency (Montecchi et al., 2021). It has also led to growing legislation on these issues, such as the German Supply Chain Due Diligence Act coming into force in 2023 (Federal Ministry for Economic Cooperation and Development, 2021). In practice, however, poor upstream visibility remains a limitation and focal firms' SSCM still focuses mostly on establishing and monitoring sustainability at first-tier suppliers instead and shifts responsibility for upstream supply chain activities to those suppliers. However, drowning direct suppliers with relatively mature sustainability standards in

* Corresponding author. International Institute for Industrial Environmental Economics (IIIEE), Lund University, P. O. Box 196, Tegnersplatsen 4, 221 00, Lund, Sweden.
E-mail address: lisa.heldt@iiiee.lu.se (L. Heldt).

https://doi.org/10.1016/j.ijpe.2023.108864
Received 27 December 2021; Received in revised form 19 December 2022; Accepted 30 March 2023
Available online 8 April 2023

requirements and audits seems misguided (Schmidt et al., 2017) and overemphasizing the direct tier can be inefficient in terms of resource use and ineffective in terms of reducing buyers' sustainability risk exposure.

To give a concrete example: For focal firms with palm oil and cocoa supply chains, deforestation is a central sustainability issue. Deforestation occurs far upstream – beyond focal firms' premises, visibility and influence (Lambin et al., 2018). At the same time, stakeholder pressure to mitigate deforestation, has historically been driven by NGOs (Wolf, 2014), but is becoming more important to wider society and is diversifying and intensifying with growing pressure from investors (Reuters, 2019) and regulators (COWI, 2018). However, targeting first-tier suppliers with sustainability audits and capacity-building does little to mitigate deforestation risk on the ground and may even divert budget, staff and attention from more critical topics and tiers. To ensure sustainable practices on the ground, multinational buyers rely on voluntary standards of industry roundtables and certification schemes for external assurance. Such schemes, like the Forest Stewardship Council (FSC) or the Roundtable on Sustainable Palm Oil (RSPO), face recurring criticism concerning their legitimacy, audit quality and ability to effect lasting improvements (Marin-Burgos et al., 2015; Schepers, 2010), thus providing limited assurance against aforementioned risks. Further, certification rarely covers focal firms' total sourcing volume and – as companies move towards 'doing no harm' (Pagell and Shevchenko, 2014, p. 45) approaches – companies are increasingly looking to complement certification standards with more tailored, direct ways of monitoring specific issues like deforestation for the entire supply base.

For soft commodity supply chains where deforestation and land conversion, i.e. visually explicit changes, are key sustainability issues, remote sensing and satellite technology emerge as relevant tools for technology-enhanced auditing and continuous monitoring of on-the-ground issues (Castka et al., 2020; Werner et al., 2019). While satellite technology is not new, it is becoming more practical and economic through recent advances regarding higher resolutions, lower costs and better analytics with advanced algorithms and artificial intelligence (Guo et al., 2017). It could enable timelier identification of high-risk suppliers across tiers, more targeted auditing or capacity-building and more effective advancement of sustainability standards. However, adoption of satellite technology in SSCM remains an emerging phenomenon. It is unclear how focal companies tap the technology's full potential, i.e. which organizational capabilities they need to leverage this new technical resource and which external collaborations they engage in to drive multi-tier sustainability. Further, the dynamics of complex supply chains, associated sustainability risks and stakeholder actions create a rapidly changing context for focal firms to navigate and adapt to.[1]

This paper takes a dynamic capabilities view to investigate the phenomenon of how buyers use satellite technology to complement certification standards and build sustainability in multi-tier, complex forest-risk commodity supply chains. Specifically, our paper addresses the following research questions.

(1) Which capabilities do focal firms require to use satellite technology as a new strategic resource in multi-tier SSCM?
(2) Why do focal firms choose to collaborate with external actors for satellite-technology-based multi-tier SSCM?
(3) What forms of collaboration exist in multi-tier supply chains?

For this purpose, the study draws on the concept of dynamic capabilities (Teece, 2007; Teece et al., 1997) and on Tachizawa and Wong's (2014, p. 657) multi-tier SSCM framework and applies them to satellite-based deforestation monitoring. The contributions of our research are fourfold: First, we provides nuanced empirical insights into the emerging phenomenon of focal firms using satellite technology to navigate the complexity of forest-risk commodity supply chains. Second, our paper extends existing knowledge of forms of collaboration in multi-tier SSCM by elaborating how focal firms engage in them. Third, drawing in dynamic capabilities, we contrast and expand the existing focus on risks as potential negative consequences in SSCM research and practice with an emerging opportunity focus found in practice. Fourth, we derive managerial recommendations for focal firms seeking to strengthen their multi-tier SSCM with recent technology.

The remainder of this paper is organized as follows: Section 2 reviews prior research on multi-tier SSCM and supplier sustainability risk to position the paper in its disciplinary context and links it to dynamic capabilities. Section 3 outlines the research design and methods for data collection and analysis. Section 4 presents the main findings and analysis, followed by their discussion in Section 5. Section 6 then provides a conclusion and future research directions.

2. Literature review and theoretical background

2.1. From dyadic to multi-tier SSCM

SSCM research has extensively investigated dyadic buyer-supplier relationships, reflecting prevalent industry practice, but sees an emerging explicit focus on triadic (Choi and Wu, 2009) and multi-tier SSCM (Sarkis et al., 2019; Sauer and Seuring, 2018). The dyad-focus has been criticized for poorly reflecting the complex supply networks found in reality (Mena et al., 2013) and for limited transferability to multi-tier relations (Sauer and Seuring, 2018). Yet, research on multi-tier SSCM has itself focused primarily on triadic buyer-supplier-supplier relationships (Grimm et al., 2016; Mena et al., 2013). A recent multi-tier SSCM review finds substantial room for improvement with '[o]nly 12% of the identified publications focused on joint sustainability efforts that included partners across more than two tiers' (Jabbour et al., 2019, p. 17). Apart from a few recent articles (Hofmann et al., 2018; Jia et al., 2019; Sancha et al., 2019; Sauer and Seuring, 2018), there has been limited – but strongly growing (Jamalnia et al., 2023) – focus on relationships with operationally and geographically distant upstream suppliers.

Poor transparency, limited influence and the involvement of various supply-chain-internal and external actors complicate the process (Wilhelm et al., 2016), yet buyers are under growing pressure to act as they face 'chain liability' (Hartmann and Moeller, 2014, p. 281) for upstream issues. Focal firms' approaches can be structured in different ways like Mena et al.'s (2013) model of distinct supply chain structures, differentiated by how close the relation between buyer and second-tier supplier is and Tachizawa and Wong's (2014) multi-tier framework that proposes four forms of governance or collaboration (direct – indirect – work with third party – don't bother). Working directly with lower-tier suppliers gives focal companies access to better, timelier information and promises more effective sustainability improvement and reduced operational and reputational risks than relying on trickle-down effects via pressure on intermediary suppliers. However, this approach requires comparatively more resources, efforts and capability from the focal company, meaning it is more costly, particularly with increasing distance to the tier and number of suppliers to be managed. Working

[1] While developing this article, this paragraph provided an 'educated guess' of how we expected satellite technology's role in SSCM to develop. Since then, much has happened. In December 2022, the EU agreed on its new 'regulation on deforestation-free products'. The regulation will require provision of geolocation data for all plots of land and satellite data as evidence that forest-risk commodities (including palm oil, cocoa, timber, cattle, soy, coffee and rubber) have not been linked to deforestation (https://environment.ec.europa.eu/topics/forests/deforestation/regulation-deforestation-free-products_en). In April 2023, as this article is published, companies are facing the imminent entry into force of the regulation, expected for early summer 2023, and will subsequently have 18 months for implementation https://www2.deloitte.com/dl/en/pages/legal/articles/entwaldungsfreie-lieferketten.html.

indirectly with lower-tier suppliers via first-tier suppliers is more efficient but in practice commonly entails the passing-on of codes of conduct and certification requirements rather than active engagement. The third mechanism of working with third party actors, such as NGOs, certification schemes or competitors and industry associations serves to develop joint standards, increase leverage over lower-tier suppliers or get external assurance (Tachizawa and Wong, 2014). While widely applied (Jia et al., 2019; Meinlschmidt et al., 2018; Villena and Gioia, 2018), this framework provides limited insights into the managerial perspective of how buyers choose to engage in these collaborations and advance sustainability across tiers. The fourth mechanism that Tachizawa and Wong (2014) identify is termed 'don't bother' in which focal firms do not engage with lower-tier suppliers but keep a focus on first-tier suppliers or their internal operations.

Even in these classifications, prior research on multi-tier collaboration remains largely descriptive – except for Meinlschmidt et al. (2018) – and provides limited insights into why firms select specific collaboration forms and how they engage in them to address a particular issue. By linking Tachizawa and Wong's (2014) framework with dynamic capabilities, we aim to understand the capabilities focal firms need, internally and from potential partners, for multi-tier SSCM. Other multi-tier SSCM frameworks like Sauer & Seuring's cascaded approach (2018) and three-dimensional framework (2019) similarly build on Tachizawa and Wong (2014) but emphasize external contextual factors like suppliers' business environment and chain complexity.

2.2. Upstream sustainability risks as a driver of multi-tier SSCM

In the multi-tier SSCM context, research on supplier sustainability risk is growing (Hajmohammad and Vachon, 2016; Hofmann et al., 2014), but still scarce. Supplier sustainability risk in this context can be defined as 'potential negative impacts on a buyer from its suppliers' ecological or social misconducts' (Hajmohammad and Vachon, 2016, p. 48). Supplier misconduct turns into potential negative impacts for buyers when mediated by stakeholder reaction (Hofmann et al., 2014). Historically, NGOs have been key stakeholders exerting pressure via campaigns (Wolf, 2014) but recently this is diversifying as scrutiny and access to information is growing among investors, regulators, consumers and business customers. Accordingly, supplier sustainability risks are diversifying. Regulatory risk increases with recent due diligence legislation on illegal logging (Partzsch and Vlaskamp, 2016), conflict minerals and modern slavery (Hofmann et al., 2018) and the supply chain due diligence regulations which are under discussion, e.g. the EU Directive on Due Diligence (European Commission, 2022). Financial risk related to increased cost of capital grows as investors and banks recognize that supplier issues threaten business performance and remove these risks from their portfolios. Beyond this, operational risks result from worker strikes (Hofmann et al., 2014) or environmental causes like extreme weather leading to disruptions. Stakeholder accountability, i.e. 'the extent to which a firm justifies behaviors and actions across its extended supply chain to stakeholders' (Gualandris et al., 2015, pp. 1–2), is thus gaining relevance for mitigating upstream risks.

Much SSCM research focuses on the management of direct suppliers. Managing issues at distant lower-tier suppliers is harder since visibility and influence tend to be low (Meinlschmidt et al., 2018), although paradoxically the attributed responsibility for misconduct and resulting repercussions on focal firms have been found to be high (Hartmann and Moeller, 2014). To bridge this, focal firms traditionally rely on standards and collaboration partners, including certification schemes (Roberts, 2003), voluntary industry coalitions (Orsato et al., 2013), or multi-stakeholder initiatives (Pagell and Wu, 2009) for the indirect management of upstream risks. Alongside this, companies are increasingly engaging in supply chain mapping in different forms and functions (MacCarthy et al., 2022). Considering the spectrum of options, buyers benefit from consciously prioritizing and tailoring their approach.

Certification schemes have long been the primary tool for buyers seeking to ensure sustainable practices at raw material suppliers. However, certification schemes are facing recurring criticism concerning their stringency and legitimacy. This includes variations in enforcement (Smit et al., 2015) or reliance on field audits as 'snapshot' evaluations while entailing considerable cost, time and staff requirements for the auditing and audited organizations (Marin-Burgos et al., 2015; Schepers, 2010). This has sparked interest in emerging technologies as an additional 'line of defense' (Lopatin et al., 2016).

2.3. Technology for transparency and traceability in SSCM

Information technology helps improve visibility and traceability across the supply chain (Chen, 2022; Scholz et al., 2018). Following Sodhi and Tang's (2019, p. 2946) definition, we understand visibility as 'efforts to gather information about operations upstream and downstream in their supply chains. (…) Traceability is a particular aspect of visibility, being the capability of a company for ascertaining provenance'. With growing stakeholder pressure and verification requirements, technologies like radio-frequency identification, Internet of Things, GPS tracking devices and more recently blockchain gain attention (Francisco and Swanson, 2018; Montecchi et al., 2021; Saberi et al., 2019). However, a core challenge is reliably linking the physical and digital world, the 'garbage in, garbage out' (Blossey et al., 2019, p. 6891) problem: While establishing traceability provides data on actors along the chain, it provides limited transparency and assurance concerning on-the-ground conditions.

This is where transparency-oriented technology like remote sensing, i.e. 'use of aerial or satellite imagery to study features on Earth's surface' (Werner et al., 2019, p. 994), add more direct, continuous insights. Recent advances in data processing and analytics (Sisodiya et al., 2020) enable accurate and timely monitoring (Aguiar et al., 2011) of environmental changes like deforestation (Hansen et al., 2013) at falling costs. More efficient processes for turning raw satellite data into actionable insights like maps and automatic alerts have triggered interest among firms monitoring deforestation in remote regions.

The adoption of satellite technology in multi-tier SSCM remains a largely practical phenomenon though. SSCM research has not addressed this beyond satellite technology's potential to contribute to technology-enhanced auditing (Castka et al., 2020). In contrast, it has been studied in sustainable commodity production and governance, but only focusing on users like NGOs or environmental authorities (Gardner et al., 2019; Godar et al., 2016). Lacking research from a managerial or buyers' perspective is significant considering the growing uptake in practice. This suggests that satellite technology's potential value to SSCM is not sufficiently understood as research is lagging practice.

2.4. Understanding technology-based multi-tier SSCM through dynamic capabilities

Based on the above research gaps, this study links literature on dynamic capabilities and multi-tier SSCM to investigate the phenomenon at hand.

As practical uptake of satellite technology for multi-tier monitoring is growing, its effective use demands new capabilities from focal firms. However, considering the complexity and dynamics of global supply chains, shifting stakeholder pressure and sustainability risks, the application context and purpose of satellite technology is under constant development and focal firms thus require adapting skills to use it effectively.

The concept of dynamic capabilities emerged as an extension of the resource-based view of the firm (Barney, 1991). Resources are 'those (tangible and intangible) assets which are tied semipermanently to the firm' (Wernerfelt, 1984, p. 172). The dynamic capabilities view questions the assumption that resources are stable and continuously valuable. Instead, it argues companies need a different approach when operating in complex, unstable contexts where organizations, their roles

and interrelations are rapidly and unpredictably changing (Eisenhardt and Martin, 2000)– such as global supply chains and stakeholder sustainability expectations.

Teece et al. (1997, p. 516) define dynamic capabilities as 'the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments'. Teece (2007) further introduces microfoundations of dynamic capabilities: (1) sensing opportunities and threats (for example by identifying a new technological innovation), (2) shaping/seizing opportunities (for example implementing the technology into a set of new sustainable business processes), and (3) maintaining competitiveness by the reconfiguration and transformation of the resource base (for example by institutionalizing the new processes throughout the organization). We use these microfoundations to structure the analysis and the results accordingly. Dynamic capabilities have been applied in SSCM research to understand how focal firms transition to green supply chain management (Bowen et al., 2001), respond to customer demand for traceability (Beske et al., 2014), or manage supplier sustainability risks (Reuter et al., 2010). Prior research has identified internal resources, technical knowledge and environmental proactivity (Beske, 2012; Bowen et al., 2001) alongside external resources like collaboration with suppliers (Bowen et al., 2001), stakeholders (Reuter et al., 2010) and competitors (Beske et al., 2014) as critical for enabling early detection, effective management and continuous adaptation to emerging environmental issues and stakeholder expectations. They have also been put forward as a means to successfully and cooperatively implement innovative projects in rapidly developing areas such as the circular economy (Köhler et al., 2022). We argue that such capabilities become even more relevant for focal firms exposed to complexity from multi-tier SSCM and sustainability issues, amplified by dynamic stakeholder demands – yet that they may need collaborations to build these capabilities.

3. Research method

The research design takes a qualitative explorative approach to account for the characteristics of the research topic, conducting 'empirical research that primarily uses contextually rich data from bounded real-world settings to investigate a focused phenomenon' (Barratt et al., 2011, p. 329). Case-based research is considered useful for novel, complex subjects where opportunities to study the phenomenon in the real world exist but prior research is limited (Verschuren, 2003). Since SSCM and supply chain risk are inherently complex topics, especially in the emerging multi-tier SSCM field, qualitative research has been highlighted as valuable (Pagell and Shevchenko, 2014; Sarkis et al., 2019) to generate a more nuanced, in-depth understanding (Sauer and Seuring, 2019) and as the basis for quantitative or modeling approaches (Sarkis and Zhu, 2018). Further, qualitative research is considered suitable for studying dynamic capabilities since other methods may face difficulties capturing nuances and contextual factors (Barratt et al., 2011).

Case selection in qualitative studies serves to provide rich, differentiated insights into the phenomenon studied (Verschuren, 2003). For this purpose, strategic sampling of extreme, novel or contrasting cases is considered more valuable than statistical sampling from a defined population (Barratt et al., 2011). For this paper, since the use of satellite technology in multi-tier SSCM is currently limited to a handful of technology providers and pioneering buyers, we selected these early adopters for our strategic sampling to gain insights into this emerging phenomenon. Technology providers were linked to focal firms through commercial relations as service providers, often entailing collaborations to co-develop, pilot or refine tools due to their novelty. Palm oil supply chains represent the primary and oldest use case of satellite-based deforestation monitoring in the supply chain context due to its links to severe deforestation, intense stakeholder pressure and the relative ease of satellite-based detection of clear-cut deforestation (Welsh and Wielaard, 2020). Palm oil supply chains move from large plantations or smallholder plots to mills, to refineries, to traders, to consumer-facing brands. Deforestation has long been driven by large-scale clearing events for industrial palm oil plantations. To date, these events have come under better control while small-scale deforestation by smallholders for palm oil or for subsistence activities like farming or firewood persists (Earthworm et al., 2020). Cocoa is the second major use case of satellite tools. Compared to palm oil, smallholder farming plays a larger role in cocoa. From farmers, often organized in cooperatives, the supply chain flows via traders, domestic exporters, grinders and other intermediaries to consumer brands (Kroeger et al., 2017). From a supply chain context, this further complicates upstream visibility and traceability of cocoa to specific cooperatives or farms which have an average size of only 2–5ha in West Africa where most cocoa is grown (GFW, 2019).

We conducted a web search and spoke to technology providers to identify those early-adopting companies using satellite technology for deforestation monitoring in their SSCM approach already, beyond a planning or pilot stage. This limited the sample size to a total of six firms with a distinct focus on the forest-risk commodities of palm oil and cocoa where the implementation of satellite technology for SSCM is most advanced. Within these early adopters, we then identified the person(s) who were specifically in charge of and/or working directly with satellite monitoring to ensure their answers were based on in-depth, first-hand experience rather than expectations or hearsay. Out of the initial six firms, four agreed to participate. Due to the relative novelty and therefore limited number of users, we complemented our search through snowballing to include technology providers, certification schemes and NGOs that were actively involved in such projects. The network turned out to be densely interconnected around a few key technology providers, buyers, larger intermediary suppliers, certification bodies and NGOs that were linked through supply relations, co-developed tools and/or industry-level or landscape initiatives linked to satellite technology and anti-deforestation. Since several of these organizations work with multiple focal firms, we decided against a multi-case setting since boundaries between cases are blurred and would not allow meaningful within-case and cross-case analysis.

Data collection was based primarily on thirteen interviews conducted with multinational brands and traders as well as technology providers, certification schemes and NGOs, i.e. the ecosystem of organizations that are involved in the development, provision and use of satellite technology in SSCM (see Table 1). A semi-structured interview protocol was used to allow for flexibility and emerging questions while ensuring reliability (Barratt et al., 2011). Interviews lasted 50–90min and were conducted online between January and April 2020. They were recorded when interviewees consented and transcribed. To increase validity and reduce bias through triangulation of data sources (Barratt

Table 1
Interviewees.

	Organization type (in article context)	Interviewee Title
1	Focal firm	Project Manager
2	Focal firm	Environmental Sourcing Coordinator
3	Focal firm	Global Responsible Sourcing Leader
4	Focal firm	Global Head Sustainable Sourcing
5	Supplier	Forest Advisor
6	Certification scheme	GIS & Earth Observation Officer
7	Certification scheme	Chief Innovation & Technology Officer (former)
8	NGO	Program Officer, Soy, Palm Oil & Tropical Timber
9	Technology provider	Program Manager, Sustainability & Corporate Responsibility
10	Technology provider	Director of Forest Programs
11	Technology provider	CEO
12	Technology provider	Head of Sales, Agriculture & Forest Solutions
13	Technology provider	CEO

et al., 2011; Mayring, 2014), the interviews were combined with a review of public documents (21 reports, 11 articles and 28 websites or press releases) and 8 h of audio/visual material produced by or featuring representatives of the selected organizations (6 industry podcasts recorded as expert interviews during the Sustainable Landscapes and Commodities Forum and 6 webinars on satellite technology and deforestation; transcribed for analysis). These data sources were identified through a web search of material on satellite technology use in SSCM with explicit reference to the organizations and supply chains we focus on. The documents were used as background preparation for the interviews, as well as to capture additional information, and viewpoints to compare and contrast with the interview data.

For data analysis, we conducted a qualitative content analysis following the process suggested by Mayring (2014), see Fig. 1, applied in SSCM research before (Beske et al., 2014; Seuring and Müller, 2008). The coding framework evolved in iterative rounds. Initially, coding categories were identified deductively based on concepts from prior literature on sustainability risks and multi-tier SSCM (e.g. Tachizawa and Wong, 2014). During coding in NVivo, it quickly emerged from the data that adoption of satellite technology was viewed as more than a means for risk management and that the initial coding framework did not capture the full picture of more proactive and strategic reasons behind adoption, highlighting the applicability of the dynamic capabilities theory for further analysis. We thus created additional categories inductively and then went back to the literature to identify a suitable theory to capture these emerging elements. We adopted elements from dynamic capabilities (Teece, 2007) to extend the framework and refine the codes before returning to the data. During coding, the framework was refined to reduce overlaps and redundancies or add inductively emerging codes in relation to the deductive codes. The adjusted framework was then reapplied to capture all information and ensure consistency in coding and analysis.

4. Results

The application of satellite technology in multi-tier SSCM is developing rapidly and currently most prevalent in palm oil and cocoa supply chains. Adoption is particularly driven by an intensification and diversification of stakeholder pressure which makes focal firms perceive risks as higher and less predictable. Within this complex and dynamic context, firms increasingly consider solutions like certification schemes as too slow in terms of technological innovation and as less able to meet firms' needs for assurance and impact on the ground. As technological progress continues alongside costs, focal firms increasingly adopt their own approaches to data-driven multi-tier SSCM. The remaining section presents empirical findings (see also Appendix B) concerning capabilities and collaboration forms characterizing current practice.

4.1. Internal and external resources in multi-tier SSCM

The analysis found clear evidence that satellite technology, when leveraged effectively, represents a novel technical resource that can help focal firms navigate dynamics of multi-tier SSCM: The pattern emerging is that satellite technology relies on buyers' existing organizational resources, but that these internal resources vary between buyers. Across the board, these resources essentially serve four functions: Traceability; Monitoring; Follow-up; Stakeholder accountability (see Fig. 2) which correspond to Teece's (2007) microfoundations of dynamic capabilities.

Traceability refers to 'the capability of a company for ascertaining provenance' based on their 'efforts to gather information about operations upstream and downstream in their supply chain' (Sodhi and Tang, 2019, p. 2946). Traceability was highlighted in interviews as a critical precondition for effectively linking satellite data and suspected deforestation to specific suppliers, thus depicted as the foundational layer in Fig. 2. '*Without these reference points, further investigation, intervention or action related to deforestation alerts or data received from satellite monitoring platforms (…) cannot be carried out, regardless how precise the satellite imagery is*' (Ng, 2019, p. 2) The more details on supplier locations, concession or plantation boundaries are available, the more actionable the insights. However, the analysis reflects that focal firms struggle to gain full upstream visibility on their own, suggesting that supportive resources are not sufficiently developed yet. This applies particularly for sourcing from smallholders and for visibility beyond nexus suppliers like palm oil mills or domestic cocoa exporters. '*One challenge is getting data on where your material is from, who your sub-suppliers are. That's particularly difficult with smallholders. Once things get mixed at the mill, you can't tell. So we are using multiple approaches and datasets to monitor our trade flows and establish traceability. The maybe coarsest layer is to draw a circle around a mill. But that does not provide any granularity. And then we add in other datasets to get a better understanding … concession maps, high conservation value areas, high carbon stock areas.*' (Global Head Sustainable Sourcing, Focal Firm 4). Raw material like fresh palm fruit can only be transported a certain distance before it needs to be processed or before transport becomes uneconomical. Thus, based on the maximum transportation radius, it is possible to draw a circle around mills to get a rough estimate of deforestation alerts in the sourcing region that should be prioritized for gaining more upstream traceability. Here, satellite information systems can replace or markedly supplement traditional

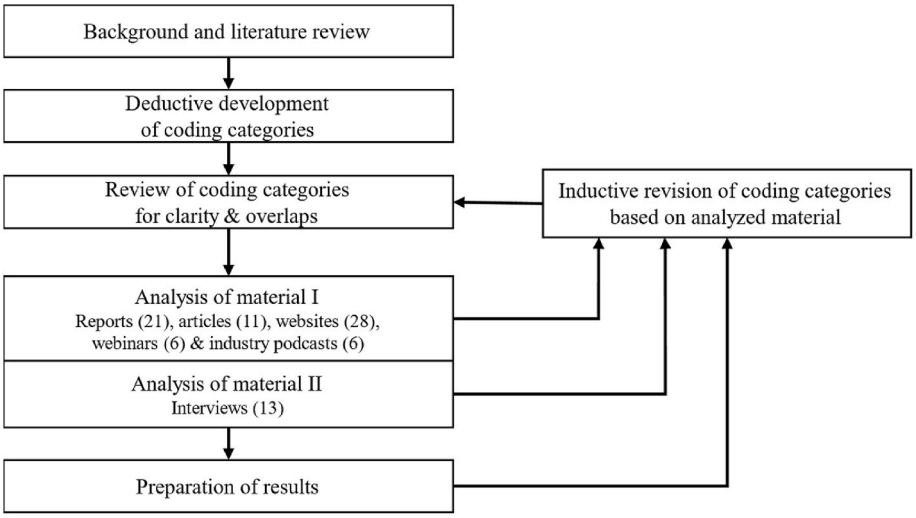


Fig. 1. Process of qualitative content analysis (adapted from Mayring (2014, p. 378)).

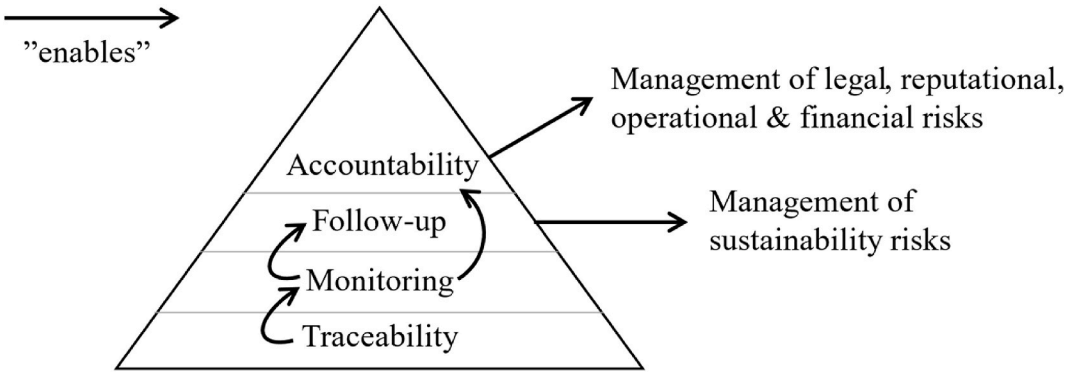


Fig. 2. Key functions of satellite technology in SSCM.

approaches like audits for detecting issues and third-party certification. In that context, applying satellite technology for traceability is a precondition for firms to sense threats and thereby reducing reputational, but also economic risks. Potentially they can also see the value of specific regions to empower smallholders.

Monitoring refers to activities linked to the recurrent assessment of suppliers' compliance and performance, e.g. conducted through satellite-based approaches. Monitoring deforestation remotely from space in near-real time can drastically cut involved effort, time, staff and budget while providing a more robust informational resource. *'We learned from our clients that the information they were using [previously] did not really help them in responding on the ground fast enough. Often deforestation was detected too late or not at all. And we are using radar satellite imagery because it can penetrate clouds and that way we are able to provide faster and more consistent data to clients. And this helps our clients to respond faster'* (CEO, Technology Provider 11). Yet, raw satellite imagery needs to be processed and interpreted through geospatial analytics and algorithms. The data suggests that consumer-facing buyers rarely possess the necessary technical and knowledge resources and see little value for developing these internally. Instead, they rely on comprehensive solutions from technology providers or collaboration with direct suppliers, i.e. multinational traders and producers. *' … you could of course say that a company should have a hundred people and should have their own GIS experts, but that's probably not where most companies are going. But it's definitely good to have some of that internally in the company and then you need a good partner that complements and supplements your skills'* (Global Responsible Sourcing Leader, Focal Firm 3). Such actors are often experienced using satellite technology to monitor yields and harvesting and thus have corresponding technology, analytical expertise and on-the-ground staff which can be employed more efficiently than focal a company's own resources, thereby setting those free for other tasks, such as supplier development. Together with traceability, this application exemplifies the microfoundation of sensing threats, but also identifying opportunities. These resources are vital for enabling for higher functions (see Fig. 2) such as follow-up and accountability which contribute to seizing of opportunities or reshaping for competitiveness.

Follow-up covers activities aimed at enforcing or improving sustainability standards of suppliers. Follow-up capacities are critical for acting on deforestation alerts and addressing issues on the ground. '*Receiving information about high-risk deforestation areas (…) alone, is not stopping deforestation from happening. How the information is used is what makes the difference*' (Dekker, 2020, p. 2). *'In the past, often our partners would follow up because we didn't have the capacity. But it's significantly more effective for us to do it directly. Our sustainability and procurement teams reach out jointly to our suppliers. We usually just share the information, say this is what we found, restate our policies, initiate verification and if needed suspend the supplier.'* (Global Responsible Sourcing Leader, Focal Firm 3). Again, satellite-based systems are not used separately but integrated with existing approaches like audits and procurement data. Yet, effective follow-up in complex multi-tier supply chains requires a broader range of skills. '[Sometimes] *governments or smallholders who live on the land there have the right to convert it, so (…) this can create social and political issues. And these situations and interest conflicts you need to take into account when thinking about remote sensing*' (Program Officer, NGO, 8). Therefore companies have to find solutions how to distinguish between legal and illegal deforestation and how to follow-up on this, e.g. in the form of suspending a supplier or not. Interviewees pointed out personnel (e.g. a local office and staff for on-site visits), organizational resources (e.g. aligned and concerted action across procurement and sustainability functions), knowledge (e.g. understanding of local context, deforestation drivers and suppliers' incentive structures) as critical to make a difference and effectively manage deforestation risk (Fig. 2). *'It's been less easy to apply suspend-and-exclude principles to this [cocoa] context. Suspending farmers from the supply chain, imposing programs and then to decide whether to let them back in or exclude them permanently is not really feasible … Cocoa always finds its way back in and is bought by someone else. And it does not help the farmer either'* (Forest Adviser, Supplier 5). These often need to be combined and complemented through collaborations (e.g. with direct suppliers as enforcement partners or NGOs in landscape-level projects) to build effective capability for supplier development: '*You need to be able to engage with [suppliers and smallholders], you need to understand what is going on in their lives, what their incentive structure is, how you can make them change their behavior if necessary to actually stop deforestation'* (CEO, Technology Provider 13). This possibility linked to satellite technology falls into both the shaping and seizing of opportunities, e.g. if an incentive scheme is introduced, and of course also into the maintaining competitiveness through the implementation of processes to manage the supply chain in accordance with the latest information. This can be in the form of training the suppliers in line with the companies' overall due diligence agenda, or eventually by ending the business partnership to avoid future risks and liabilities.

Stakeholder accountability is defined as 'the extent to which a firm justifies behaviors and actions across its extended supply chain to stakeholders' (Gualandris et al., 2015, pp. 1–2) and is a critical element for buying companies to manage reputational, legal and financial risks. While structured and actionable follow-up, as outlined above, is important, it is not sufficient to eliminate business risk if buyers' stakeholders remain unconvinced. *'Certification only covers part of their supply chain and … they want [selected issues] out of their supply chain. That was the case with [Consumer goods multinational]. It was not about certification, but they wanted to ensure [no deforestation] for their whole palm oil supply chain. Because that's where they were vulnerable to the NGOs.'* (Chief Innovation & Technology Officer, Certification 7). Hence stakeholder accountability through communication and providing transparent data is a necessary step to show the impact and intentions of the follow-up actions. The analysis indicates that stakeholder perceptions can diverge from actual impact on the ground when it comes to supplier

(de-)selection vs. supplier development: Terminating deforesting suppliers or exclusively sourcing certified material to begin with can be perceived as more resolute. However, if buyers '*simply divest from problematic areas, less scrupulous actors may continue to invest in deforestation and agricultural expansion into forests*' (SCTN, 2017, p. 21), thus risking 'leakage', i.e. deforestation-associated produce entering the market via other buyers or deforestation pressure shifting between commodities within the same landscape, which might lead to stakeholder criticism. Simultaneously, engaging with suppliers to stop deforesting practices promises lasting change yet exposes buyers to stakeholder scrutiny and greenwashing accusations. In Fig. 2, this is depicted as follow-up enabling the management of factual deforestation risk, while accountability allows firms to manage secondary risks that build on the perception of stakeholders. The data suggests that satellite data can support more transparent communication as stakeholders perceive it as more reliable than traditional tools like audits.

To summarize these findings, the analysis is synthesized into essential functions (see Fig. 2) that SSCM needs to provide to build a dynamic capability to make effective use of satellite technology. Traceability provides vital information for sensing of threats and opportunities and to make data actionable to react to threats in a timely manner and enable the shaping and seizing of opportunities. Traceability thereby enables the monitoring function and continues oversight, e.g. based on satellite data. The follow-up function provides the capacity to act on satellite-based insights and manage on-the-ground issues. The three functions together form the base for technology-based multi-tier SSCM – knowing where to look, detecting issues and taking action to remove them. Yet, supplier sustainability risks extend beyond on-the-ground deforestation risk and entail secondary risks that emerge from stakeholder pressure. Consequently, the three basic functions are complemented by an accountability function that draws on satellite data to respond to stakeholder expectations in a transparent way. This way, firms can maintain their competitiveness by showing compliance with stakeholder demands or legal regulations and support internal congruence of sustainability vision and actions taken, thereby employing the third of the microfoundations. The findings suggest focal firms do not fully meet these functions internally but complement them with external resources.

4.2. Collaboration types in technology-based multi-tier SSCM

Prior research suggests that collaboration is important in multi-tier SSCM, yet it remains unclear how focal firms choose partners. The data suggests that focal firms strategically select collaborators that allow them to access complementary external resources.

We find ample evidence of focal firms **w**orking along the supply chain, which Tachizawa and Wong (2014) differentiate into working 'directly' or 'indirectly' with lower-tier suppliers. Due to our study's focus on identifying the raw materials suppliers, this distinction is not as relevant since focal companies' work with direct suppliers was always also targeted at working with or getting closer to the raw material suppliers. We thus decided to subsume both categories into the inductive theme of **working along the supply chain**. Practitioners outlined that in palm oil where supply is concentrated through a few large producers and traders, gaining traceability and acting on suspected issues at plantation or mill-level is often a joint exercise by consumer brands and their direct suppliers. '*It's a challenge to get information on our suppliers without breaching any directives or stepping on anyone's tail. (…) We've got data coverage of 80 percent of our suppliers, where we can confidently say what concessions they own and where they are*' (Ng, 2019, p. 2). This applies particularly when focal firms face (geographically or operationally) distant and fragmented (e.g. consisting of many smallholders) raw material tiers. Accordingly, they draw on direct suppliers who help bridge information and action gaps and often already have internal experience and systems for geospatial analytics from productivity monitoring. Similarly, early adopters explained how satellite technology has fostered alignment of sustainability and procurement or operations teams within the focal firm but also with their suppliers. '… *we have quite a lot of factories that have a digital twin which is connected to real-time data. So you can manage your stock, your production, everything through your datasets that you get on a real-time basis. And we want to do that also for our supply chain. So that … you are able to see [supply chain] performance in real-time, also in the areas of deforestation and natural capital*' (Global Head Sustainable Sourcing, Focal Firm 4). Through integration of satellite insights with operational data and processes, like digital twins, buyers gained deeper understanding of production flows, and on-the-ground parameters like smallholder agricultural yields or vulnerability to droughts. '*I realized that we have so much information on our supply chain, nowadays we have digital farm polygon maps that represent almost 90% of our direct sourcing network in Ivory Coast. And this information was not yet used optimally to also understand environmental risks such as deforestation risk*' (Forest Adviser, Supplier 5). This creates a tighter connection with suppliers, also more distant raw material suppliers which helps uncover unused potential or opportunities. Addressing optimization potentials identified along the chain in turn frees up resources for driving sustainability standards or for internalizing resources accessed through partners. '*In the past, our partners would follow up because we didn't have the capacity. But it's significantly more effective for us to do it directly*' (Global Responsible Sourcing Leader, Focal Firm 3).

Still, 'working with third parties', as Tachizawa and Wong (2014) term it, plays a key role as deforestation is difficult to address unilaterally due to leakage of deforestation-associated produce onto the market through other buyers. However, in our data, we observe marked differences between focal firms working across supply chains with competitors and peers in contrast to them working across sectors with NGOs, certification schemes, technology providers or local governments. We, thus, differentiate Tachizawa and Wong's (2014) category of working with third parties into **working across supply chains** and **working across sectors** to capture more granularity.

The results show that pre-competitive collaboration with competitors or peers across e.g. food and beverages or personal care industries, see growing uptake especially in palm oil supply chains. '*We are technology-agnostic, but we had hoped that all companies in the palm oil supply chain at least need to be using some kind of satellite monitoring to verify no deforestation. (…) Therefore, we are very supportive of a joint monitoring system … and it seems that companies in our supply chain and a lot of peers are excited too*' (Global Responsible Sourcing Leader, Focal Firm 3). Industry alliances like RADD aims to establish a joint satellite-based monitoring system to foster efficiency, data sharing and streamlined follow-up: Since stakeholder scrutiny is often generalized across an industry, vocal transparent companies can be affected comparatively harder than actual industry laggards. Joining forces with competitors strengthens the commitment and increases external accountability. '*What is special about this one [RADD] … is that it also brings these companies together on the landscape level when it is about acting on the data. For instance, it may be that in one region, [consumer goods company] is stronger in presence and in the neighboring part [food and beverages company] may be stronger in presence and the idea is that they can then complement each other's actions*' (CEO, Technology Provider 11). In the cocoa context, by contrast, focal firms see anti-deforestation measures as competitive differentiation for, e.g., their chocolate brands, creating more emphasis on collaboration at cross-sectoral level. This variation between supply chains is interesting as several studied buyers in the food-and-beverage industry source both commodities.

Working across sectors involves organizations like NGOs, technology providers, governmental or certification bodies in contrast to between businesses along the same or similar supply chains. Companies initially adopt satellite technology to gain assurance against growing risks (e.g. stakeholder pressure and perceived limitations of certification. '*I don't think it's a full replacement [of certification]. But … certification only covers part of their supply chain and … they want (…) to ensure [no deforestation] for their whole palm oil supply chain*' (Chief Innovation

& Technology Officer, Certification 7). The continuous monitoring can further deter suppliers from deforesting and complement certification-based efforts yet requires new skills. *'It's not necessary that a company has a specific skillset, but if they don't, they need a partner that has it'* (Global Responsible Sourcing Leader, Focal Firm 3). In this sense, combining skills from partners can create a shared capability. This cross-sectoral collaboration promises access to different sets of resources and increased legitimacy – but also new challenges with diverging interests and approaches. Alliances like the Cocoa & Forests Initiative help elevate issues beyond the commercial arena to a cross-sectoral level with government and NGOs. However, the more (diverse) actors, the more complex the collaboration becomes to handle. *'You can use remote sensing … but then how do you act on that. … And if it is a fragmented supply base with smallholders, …companies may need to engage with local governments or other local actors and build alliances that address [deforestation] in collaboration'* (Chief Innovation & Technology Officer, Certification 7). Particularly for follow-up, practice, however, reflects the entire spectrum of approaches as focal firms struggle with multi-tier complexity, including NGOs and local communities for solutions at landscape level. In multi-tier SSCM addressing a seemingly clear-cut issue like deforestation can be intertwined with unclear land rights, local development and smallholder livelihoods, extending into quasi-governmental responsibilities. Here, satellite imagery was perceived as a jointly accepted data source and therefore critical for facilitating dialogue with stakeholders: *' … we try to bring companies and governments and cooperatives and farmer associations together in a landscape or jurisdictional approach. … And in this process, we really need data. Because sometimes when we talk with companies or governments or stakeholders, they just don't know where the [palm] oil we're talking about even comes from … Remote sensing in this sense is valuable as a facilitation tool … '* (Program Officer, NGO 8).

In essence (see Fig. 3), focal firms draw on three collaboration types, i.e. along the supply chain, across supply chains/industries and across sectors, to complement internal weaknesses and achieve better traceability, monitoring, follow-up and accountability functions, which taken together enables them to build the corresponding microfoundations of dynamic capabilities. In our sample, we did not find evidence for Tachizawa and Wong's (2014) category of don't bother, but this is likely because we specifically focused on examples where focal firms do work with suppliers. This study provides evidence that together, buyers' internal resources and complementary external resources form a dynamic capability (see Fig. 3) that enables them to navigate the forest-risk supply chains. This shared capability enables the buyer to systematically monitor issues (sensing), anticipate emerging risks and opportunities (sensing), reactively or proactively but continuously adjust the resource base, e.g. by restructuring the listed suppliers, to maintain a competitive advantage in terms of risk-aversion, but also proactively shaping business opportunities by, for example, freeing up resources for additional direct supplier engagement.

5. Discussion

This section serves to critically review the findings, establish what they mean and answer the research questions, outlining broader implications.

5.1. Findings, significance and relevance

The results of this study support a position that effective satellite-based multi-tier SSCM is not determined by buyers' specific resources or skills but by buyers' ability to ensure specific functions described as: traceability; monitoring; follow-up; stakeholder accountability. The empirical results are consistent with theory on dynamic capabilities (Teece, 2007): Satellite technology specifically enables the sensing of opportunities and threats, allows for shaping and seizing opportunities and also supports maintaining a competitive advantage, if the technology is employed using these microfoundations of dynamic capabilities. If not, by itself it remains a simple, commonly accessible resource. This in turn is in line with research arguing resources need not be unique (Eisenhardt and Martin, 2000) but that they only become idiosyncratic through specific operationalization or integration with other resources (Gibbert, 2006). Additionally, pre-competitive collaboration through sharing of information, or even by forming alliances such as RADD, have been linked to successful development and employment of dynamic capabilities in innovative areas (Köhler et al., 2022). It is argued here that when integrated effectively in the sense of dynamic capabilities, satellite monitoring enables companies to go beyond problem-solving and risk reduction to sense and seize emerging opportunities, thus challenging or extending the risk-oriented perspective in SSCM. The focal firms we analyzed appear to expect that access to satellite insights and advanced algorithms will become more universal and that to maintain their advantage, they need to make it hard to imitate through integration and focus on their core skills (Prahalad and Hamel, 1990): This includes co-developed tools between buyers and technology providers with tailored functionalities or strong internal analytics teams

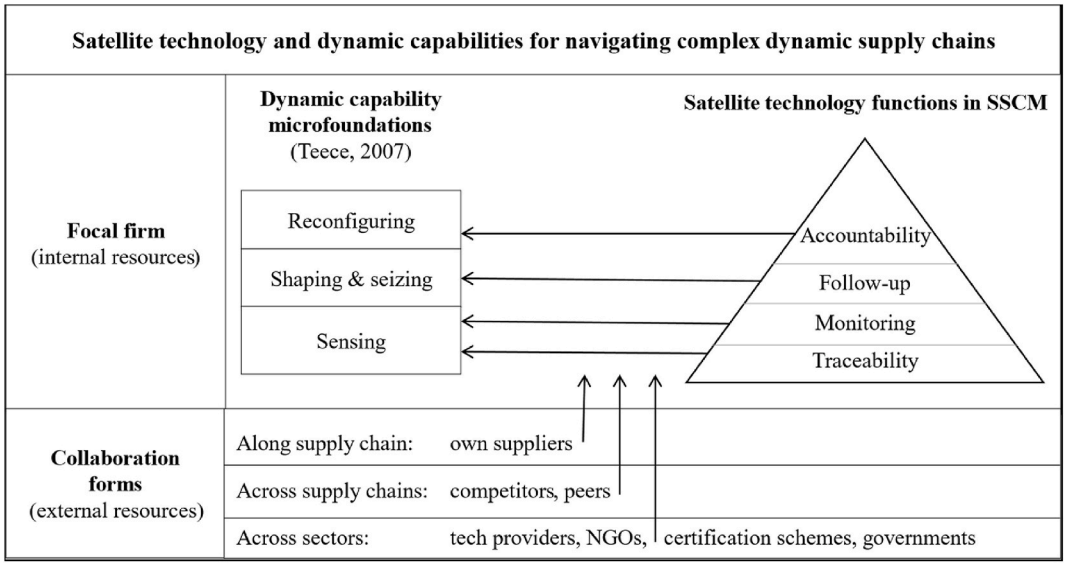


Fig. 3. Dynamic capabilities and collaboration forms for satellite technology use in SSCM.

within buyers, particularly large traders and producers that already used geospatial analytics for productivity analyses, thereby combining relationship building and collaboration with dynamic capabilities (Köhler et al., 2022).

Addressing the second research question on how buyers choose collaboration partners, our paper draws on Tachizawa and Wong's (2014) multi-tier SSCM framework which proposes four mechanisms. In line with Jia et al. (2019) who see all four approaches applied simultaneously but to varying degrees, this study finds that collaboration forms overlap. The categories of 'direct' and 'indirect' collaboration with suppliers, as Tachizawa and Wong (2014) term them, which we combine into 'working along the supply chain' is the most prevalent form. This is consistent with research finding focal firms rely on direct suppliers as gatekeepers (Grimm et al., 2016) and nexus suppliers that aggregate large numbers of upstream suppliers such as smelters in mineral supply chains (Sancha et al., 2019) as important steppingstones on their way towards working with raw material suppliers more directly. Monitoring of nexus suppliers' like palm oil mills' radius provides estimates of associated risks – as proxies for full upstream transparency – and enables focal firms to prioritize high-risk areas for traceability efforts. This trend towards risk-based prioritization in auditing is consistent with research (Hofmann et al., 2018) and suggests that increased multi-tier transparency could redistribute SSCM activities across tiers. Sauer and Seuring (2018) extend this, suggesting a two-step cascaded approach where nexus suppliers essentially function as secondary focal companies. Evidence for a similar pattern in palm oil emerges where consumer brands collaborate closely with large traders.

At the same time, satellite technology offers a new way for collaboration practices in the form of working with third parties. Focal companies can gain access to external resources and combine them with internal resources to monitor their suppliers without direct interaction. Whereas Tachizawa and Wong's (2014) framework subsumes this under the 'work with third parties' label, we find that a differentiation into working across supply chains, i.e. with competitors or peers in the same or different industries, and working across sectors, i.e. with NGOs, technology providers, certification schemes or governments, better captures the patterns in our data.

Pre-competitive alliances and working across supply chains establish higher industry standards where legal frameworks lag stakeholder demands requiring companies to create accountability and pressure on laggards themselves (Orsato et al., 2013). However, their effectiveness can be restricted when lacking sanctions and enforcement mechanisms (King and Lenox, 2000). This limitation, together with downstream buyers' lack of local knowledge concerning deforestation drivers, dynamics and needs, explains the emergence of multi-stakeholder or landscape-level approaches despite being more difficult to manage. It is interpreted as an example of buyers using their dynamic capability to gradually internalize strategically crucial resources and skills (Eisenhardt and Martin, 2000; Prahalad and Hamel, 1990). Taking this further, we argue that buyers also gradually externalize non-essential tasks to free up resources and sharpen their strategic profile. Shifting capabilities back to regulators or third-party providers and NGOs can thus be understood as externalizing governance tasks and skills that are outside of companies' scope and were only acquired out of necessity to begin with. This refers particularly to situations where deforestation is driven by smallholders due to unclear land rights or poverty and the need for subsistence farming and where mitigation needs to address larger root causes that are beyond a single company's responsibility. By selecting the right partners and building the necessary relationships, these functions can be understood as dynamic capabilities across companies or sectors (Köhler et al., 2022). Teece (2020) links the sharing of information by investing in open innovation directly to the advancement of dynamic capabilities. Additionally, identifying, i.e. sensing, the right partners in this rapidly developing field to strategically innovate and profit from the external development of ideas can also be considered part of the necessary dynamic capabilities (Teece, 2020).

Prior research on multi-tier collaboration remains descriptive – except for Meinlschmidt et al. (2018) – and provides limited managerial guidance on how to select suitable collaboration types. Our paper addresses this gap and, responding to research question 2 on why focal firms choose partners, we find that focal firms' choices reflect a gap analysis of internally available resources to identify complementary partners. Buyers' observed reliance on external partners to compensate for internal weakness appears consistent with research by Eisenhardt and Martin (2000, p. 1113) arguing that '[d]ynamic capabilities also rely more on real-time information, cross-functional relationships and intensive communication', with the latter two aspects also highlighted by other researchers (Köhler et al., 2022; Teece, 2020). Defee and Fugate (2010) argue that knowledge sharing is an essential dynamic capability for SSCM for sensing and seizing opportunities and threats (Easterby-Smith et al., 2009) as shown by our study. Similarly, Gong et al. (2018) highlight the role of knowledge resources and supply chain learning in multi-tier projects and propose that learning takes place in three stages (set up, operating and sustaining). While we did not explicitly focus on learning, knowledge resources form part of the basis for dynamic capabilities and Gong et al.'s (2018) stages mirror Teece's (2007) microfoundations. We find supporting evidence for Gong et al.'s (2018) finding that focal firms' knowledge is not a prerequisite for engaging in multi-tier projects. In our case, we see focal firms that deliberately engage in these despite a relative lack of knowledge but that seek out partners along and across supply chains and sectors to remedy possible knowledge resource gaps. It appears plausible that supply chain learning would be associated with a better ability to 'sense, seize/shape and reconfigure' and a stronger competitive advantage. It would be relevant to explore these links further to understand the learning processes underlying shared dynamic capabilities and where in the supply chain knowledge and learning is needed.

Simultaneously, while investing in strategic collaboration is considered valuable (Beske et al., 2014) and necessary to cope with the complexity of sustainability risks in global supply chains (Grimm et al., 2014), it seems less suited to accommodate their volatility. Further, it even contradicts the very nature of dynamic capabilities theory which emerged to address resource-based view's tendency to create path-dependencies by tying strategic advantage to fixed resources which hinder innovation in dynamic markets. The findings reflect these inherent trade-offs that focal firms face. Multi-stakeholder processes can slow down decision-making, innovation and create lock-in – factors that essentially created the need for buyers to adopt satellite monitoring to begin with.

Responding to research question 3 on how firms collaborate with partners, this study suggests that buyers navigate these tensions by working with partners strategically to complement internal weaknesses, while gradually internalizing these critical resources over time to reduce external dependency. Additionally, we confirm that, to create interfirm competitive advantage within a network, suitable collaborations need to guide the relationships (Beske et al., 2014) which then also allows relevant knowledge, in this case satellite data, to employ the microfoundations. The recognition and interpretation of relevant knowledge and thereby the selection of relevant partners has been put forward in a SSCM setting by previous research (Beske et al., 2014). Further the study confirms that dynamic capabilities need 'leadership qualities, skills to design organizational structures, incentives, and culture that are open to external knowledge, can rapidly absorb and apply new knowledge, can create breakthrough products and services, and can respond rapidly to changing conditions' (Teece, 2016, p. 11). Such leadership skills can be employed inside the focal company, or across supply chains and sectors, for example in the collaborations described in this study.

The possibility for multi-tier SSCM to improve both, efficiency and sustainability, supports research on the supply chain paradox (Schmidt et al., 2017) and views that supply chain integration and strategic supplier partnerships correlate with higher environmental performance of supply chain partners (Vachon and Klassen, 2007). This analysis

suggests that when focal firms go beyond using satellite imagery for sustainability means alone and integrate it with procurement data and tools like digital twins in collaboration with their suppliers, they gain efficiency and better supplier relations that, in turn, prompt further sustainability efforts. Such development towards closer supplier relations to go beyond standards to secure long-term commodity supply and quality provides further support for decommodification as discussed by Pagell and Wu (2009) and Sauer and Seuring (2018) for mineral supply chains. This study finds evidence that focal firms are leveraging closer supplier relations and shared data to jointly develop and ensure priority access to sustainable, resilient commodity production. As it underpins future access for buyers and less vulnerability for suppliers, this also reinforces the diffusion of sustainability standards.

This focus on opportunities is not explicitly discussed in SSCM research (Hajmohammad and Vachon, 2016; Villena and Gioia, 2018) where 'negative' risk and stakeholder pressure dominate definitions (Seuring and Müller, 2008). Where opportunities were addressed, they have been operationalized as 'what may be solutions to existing sustainability problems' (Schaltegger and Burritt, 2014) with potential 'positive spill over benefits' (Pagell and Wu, 2017, p. 341) rather than as what may be business opportunities arising from solving sustainability problems. In contrast, this study finds that technology adoption is not pursued by companies purely seeking to cut costs or trial novel sustainability solutions. Approaches like one buyer's digital twin of the entire supply chain inherently build on a tight integration of sustainability data into operational processes: an approach that offers strategic benefits beyond risk mitigation (e.g. ensuring resource access or benefits from improved supplier relations). This suggests that extending research and models on (supply chain) sustainability risks to also account for 'upside' risks could yield a better understanding of what firms get when pursuing SSCM that is systematically supported by technology.

5.2. Research implications

Multi-tier SSCM is receiving limited attention in research (and practice) because it is considered a complex, messy undertaking. This work, however, finds that buyers who adopt satellite-technology-based multi-tier SSCM use it to restructure their overall approach to SSCM and focus on synergies with business. This shift is interesting as it occurs in a high-stakeholder-pressure, high-risk context where focusing on risk reduction alone seems justified. However, the shift occurs over time which suggests that buyers primarily adopt technology-driven multi-tier SSCM for risk purposes and then gradually recognize untapped potential. This requires further empirical validation, but if confirmed, calls for and thereby enables two shifts in research focus: First, expanding the notion of supply chain risk as potential negative consequences to encompass positive risks, i.e. opportunities; Second, researching actual multi-tier SSCM efforts, beyond the dyad or triad, and their effects on buyers, suppliers and sustainability.

The results imply that research could benefit from broadening the current understanding and operationalization of the risk spectrum. Critically reviewing and extending frameworks and definitions that only account for negative risks, i.e. potential costs, to also encompass upside risks, i.e. potential opportunities or gains, as discussed by (Hajmohammad and Vachon, 2016), could reveal overlooked business opportunities that emerge from shared dynamic capabilities and increase the strategic relevance of supply chain transparency and sustainability. Investigating and redefining SSCM, not just concerning its ability to avoid environmental or social harm and stakeholder pressure, but also potential opportunities to ensure future resource supply, market access and differentiation are deemed relevant. As sustainability issues and supply chain complexities and demands on buyers are dynamically evolving and characterized by complex interdependencies, capturing a holistic picture of negative and positive risks seems critical for decision-making.

Similarly, the scope of multi-tier SSCM research requires broadening. While our paper explicitly focuses on SSCM to the last upstream tier, there remains a need for '[t]ruly multi-tiered supply chain research' (Jabbour et al., 2019, p. 19). As Sauer and Seuring (2018, p. 31) conclude for mineral supply chains, 'the most impactful tiers lie outside the reach of current MT-SSCM concepts'. This can only be confirmed for palm oil and cocoa and presumably extended to other forest-risk chains. Moving towards all-tier SSCM includes a more differentiated understanding of supply chain structures and their implications. As companies move towards more targeted, risk-based management within tiers, this should be expanded to prioritize the highest-risk suppliers across tiers to reflect the location of upstream issues more adequately. Investigating technology's role in data-driven risk assessment could be relevant to support practical operationalization since this research suggests they help streamline SSCM and rethink auditing and assurance practices. As Castka and Searcy (2021) point out, technological changes enabled by digitalization and automation do not just innovate assurance practice on multiple levels but may drive an overall shift in paradigm. This resonates with our findings that companies can draw competitive strength from technology-enabled SSCM if they use it to strategically sense, seize and adapt to risks and opportunities in their supply networks instead of treating it as a mere formality with an undifferentiated blanket approach. The ongoing Covid-19 pandemic and resulting supply disruptions have only reinforced this urgency (Searcy and Castka, 2020), as actionable supply chain data can make or break companies' strategy. Future research could therefore take a larger perspective, beyond the individual technology or assurance practice, and instead examine how these are integrated (or not) with focal firms' digitalization and overall strategy and how this, in turn, is synchronized with the surrounding complex adaptive system that is their supply networks.

5.3. Managerial implications

Multi-tier SSCM is a complex, messy process in a changing, volatile context. Focal firms that adopt emerging (e.g. satellite-based) technologies and build dynamic capability around them can however leverage the additional transparency to free up resources, target their risk management and access strategic opportunities. Decision-makers in industry can use the developed framework to position their company and assess SSCM's strengths and weaknesses based on current skills, programs and collaborations. For instance, the concrete company examples show that firms lacking technical skills for analyzing satellite data benefit from working with technology providers or those struggling to effectively follow-up on the ground because they lack local knowledge can strategically work with peers located in the same area, possibly drawing in local NGOs or governments depending on the issue, to ensure suitable measures and better accountability. Likewise, to fully use the dynamic capability, satellite technology should be leveraged beyond risk management and align with the broader digitalization and overall strategy. Based on this gap analysis, managers can evaluate if satellite technology is suitable for their needs and how partnering with selected technology providers, suppliers or others can provide tailored support and which skills to internalize over time.

6. Conclusion

Focal firms face growing regulatory, operational, financial and reputational risk from sustainability issues hidden deep in their global supply chains. This is particularly the case for forest-risk commodity supply chains where critical sustainability issues like deforestation typically occur at the raw material tier. Our paper helped unpack the emerging phenomenon of focal firms adopting satellite technology to gain continuous oversight over deforestation at distant upstream suppliers.

Our paper set out to identify how this novel data-driven approach changes multi-tier SSCM from the perspective of the focal firm, i.e. in terms of required organizational capabilities and selected collaboration

constellations. We conduct a qualitative content analysis of semi-structured interviews and documentation to generate empirical evidence into the emerging phenomenon.

Synthesizing the data, the paper finds that satellite technology can enable focal firms to leverage their multi-tier SSCM when integrated effectively. For this, satellite technology relies on focal firms' existing organizational resources that vary between companies but essentially serve the same four functions: First, a traceability function that connects satellite data to supplier locations and thereby enables monitoring; Second, a monitoring function, for instance provided via satellite technology; Third, a follow-up function that ensures satellite alerts are acted upon effectively to mitigate sustainability risk on the ground; Fourth, an accountability function that harnesses satellite data to provide transparent stakeholder accountability thereby mitigating reputational, financial, and legal risks.

Focal firms vary in the extent to which they can fulfill these functions internally and therefore collaborate selectively with external partners to access their resources to build shared dynamic capabilities. Focal firms, thus, strategically choose between collaboration forms (along the supply chain; across supply chains; across sectors) based on internal capabilities in the above functions (traceability; monitoring; follow-up; stakeholder accountability). Together, internal SSCM skills and external collaboration form a dynamic capability, enabling the focal firm to systematically monitor issues, anticipate risks and opportunities, take timely action and continuously adjust the resource base, e.g. by gradually internalizing skills previously accessed through external collaboration.

It can be concluded that satellite technology enables downstream buyers to redirect their SSCM efforts across tiers based on more direct, continuous data on on-the-ground sustainability conditions. Over time, this frees up staff, time and budget previously bound in auditing of relatively low-risk suppliers to instead focus on areas across the chain that make a difference. The data suggests that while engaging in multi-tier SSCM can be a challenging process, early adopters of satellite technology harnessed it to not just fundamentally redirect their SSCM efforts but also to establish their multi-tier SSCM more centrally within the organization by highlighting its potential to drive more efficient operations management and secure strategic opportunities.

In terms of limitations, the qualitative research design – while deemed necessary and suitable due to the novelty and complexity of the subject – is simultaneously a constraint. The study covers the phenomenon of growing satellite technology use in a few selected forest-risk commodity supply chains but does not provide comprehensive coverage of other chains. The study yields deep insights into an emerging practice but the sample size and strategic sampling provide no basis for generalization in the statistical sense. Yet, the empirical context of our study closely reflects the characteristics discussed for similarly complex and sustainability risk-laden supply chains, such as mineral supply chains. This includes, for instance, a cascaded approach to multi-tier SSCM in mineral value-chains (Sauer and Seuring, 2018), traceability challenges beyond nexus suppliers (Sancha et al., 2019) and limited oversight and information flows and stakeholder scrutiny (Hofmann et al., 2018). Similarly, while our study focuses on satellite technology, the framework could be applicable to other technologies, i.e. blockchain or grievance apps, may fulfill similar functions in their contexts. Such transfers, however, require testing in future research.

To conclude, the contributions of our paper are as follows: First, the research produces rich qualitative data into the emerging, largely practical phenomenon of focal firms adopting satellite technology in their SSCM for complex forest-risk commodity supply chains. Second, the paper advances the current understanding of collaboration constellations in multi-tier SSCM by providing empirical insights into why and how focal firms choose to engage in them. Third, the research suggests extending the current notion of risks in the supply chain sustainability context from a focus on negative risks to an inclusion of positive risks, i.e. opportunities, by drawing on dynamic capabilities theory and validating it with empirical evidence of buyers tapping opportunities for efficiency and future business through – not despite – a multi-tier SSCM focus.

Declarations of interest

None.

Data availability

The data that has been used is confidential.

Acknowledgements

The author thanks the involved practitioners for their time and insights. The article is based on data collected and analyzed for the main author's MSc thesis, defended in June 2020 at Lund University. The main author would like to thank Tetra Pak AB for supporting the MSc thesis project as well as Philip Peck and the Mistra REES program for early feedback in developing the article.

Appendix A. Interview protocol

1. How is your organization working with remote sensing technology in the supply chain context?
2. Which environmental impacts, related to which commodities are you monitoring?
3. Remote sensing technology has been applied in other contexts, like spatial planning, for a comparatively long time. What do you see as the reasons for its more recent uptake in the supply chain context?
4. Which challenges does remote sensing help to overcome?
5. What do you consider the main reasons that keep companies from adopting remote sensing technology in their supply chain?
6. Which factors do you consider crucial for the successful implementation (both, regarding the tool's capabilities and the company's internal capabilities)?
7. How does remote monitoring of suppliers by buyers relate to environmental certification and the role of certification schemes?
8. How does remote sensing relate to other sustainable sourcing practices? What do you consider necessary to have in place to make full use of remote sensing tools?
9. How does your organization (for non-buyers: suggest to) use the monitoring data (e.g. alerts, insights into deforestation patterns)? How does your organization (for non-buyers: suggest to) respond to detected/suspected issues?
10. Which challenges do you see concerning the implementation of remote sensing?
11. What role do you see for collaboration (e.g. between companies along supply chains or with stakeholders across sectors)?

12. How do you expect this field to develop in the future (in terms of monitored impacts, commodities, new practices or coalitions etc.)? Which opportunities and future applications do you see?

Appendix B. Data overview

Table 2
Data overview for dynamic capabilities

Dynamic capabilities	Deduct. themes	Induct. themes	Interview extract examples
	Sensing	Traceability	"One challenge is getting data on where your material is from, who your sub-suppliers are. That's particularly difficult with smallholders." (Global Head Sustainable Sourcing, Focal Firm 4) "… once things get mixed at the mill, you can't tell. So we are using multiple approaches and datasets to monitor our trade flows and establish traceability. The maybe coarsest layer is to draw a circle around a mill. But that does not provide any granularity. And then we add in other datasets to get a better understanding … concession maps, high conservation value areas, high carbon stock areas." (Global Head Sustainable Sourcing, Focal Firm 4) "Without these reference points, further investigation, intervention or action related to deforestation alerts or data received from satellite monitoring platforms (…) cannot be carried out, regardless how precise the satellite imagery" (Conservation Advisor, Supplier, Document 33) "Any detail down from the country level can already help us to apply risk assessment tools and downscale the risk portfolio associated with indirect suppliers" (Forest Adviser, Supplier 5)
		Monitoring	"We learned from our clients that the information they were using [previously] did not really help them in responding on the ground fast enough. Often deforestation was detected too late or not at all. And we are using radar satellite imagery because it can penetrate clouds and that way we are able to provide faster and more consistent data to clients. And this helps our clients to respond faster." (CEO, Technology Provider 11) "… you could of course say that a company should have a hundred people and should have their own GIS experts, but that's probably not where most companies are going. But it's definitely good to have some of that internally in the company and then you need a good partner that complements and supplements your skills" (Global Responsible Sourcing Leader, Focal Firm 3)
	Shaping and seizing	Follow-up	"In the past, often our partners would follow up because we didn't have the capacity. But it's significantly more effective for us to do it directly. Our sustainability and procurement teams reach out jointly to our suppliers. We usually just share the information, say this is what we found, restate our policies, initiate verification and if needed suspend the supplier. But most of our suppliers at this point have a very similar approach so that the entire process is relatively easy for us, the more complicated part is for our suppliers taking it up with their suppliers" (Global Responsible Sourcing Leader, Focal Firm 3) "What is needed is continual supplier engagement and ground verification and working on the factors driving deforestation outside our and our suppliers' concessions" (Conservation Advisor, Supplier, Document 33) "What they do is exclude areas from their supply chain. But that is not the way to go. It is more about working with that company to improve." (Program Officer, Soy, NGO 8) "It's been less easy to apply suspend-and-exclude principles to this [cocoa] context. Suspending farmers from the supply chain, imposing programs and then to decide whether to let them back in or exclude them permanently is not really feasible … Cocoa always finds its way back in and is bought by someone else. And it does not help the farmer either." (Forest Adviser, Supplier 5) "Of course, deforestation depends on macro-economic trends and policies, but in the end, you cannot change it without changing the behavior of companies or of smallholders … You need to be able to engage with them, you need to understand what is going on in their lives, what their incentive structure is, how you can make them change their behavior to actually stop deforestation" (CEO, Technology Provider 13)
	Reconfiguring	Accountability	"… it depends what you want to do with the information. Do you want to engage with your suppliers? Demonstrate to the public that you are doing a good job in terms of transparency and accountability? Or do you want more quantitative information, more fact- and science-based information on your progress towards targets and your communication and policies? And to be able to show you are walking the talk and you have evidence …" (CEO, Technology Provider 11) "… where you have larger suppliers, larger plantation holders and they also have more visibility externally, you have more leverage to make them change their practices. If we would suspend a particular plantation holder, other buyers may notice and there is much more public and NGO scrutiny to hold these plantation holders accountable." (Forest Adviser, Supplier 5) "… certification only covers part of their supply chain and … they want [selected issues] out of their supply chain. That was the case with [Consumer goods multinational]. It was not about certification, they wanted to implement 'do no harm' [no deforestation] for their whole palm oil supply chain. Because that's where they were vulnerable to the NGOs." (Chief Innovation & Technology Officer, Certification 7) "[We] would like to explore the development of an industry supply chain mapping platform. Together with other companies, we can input data from our mill and grievance lists and the platform would report on the cumulative transformation of the industry. It would also shine a spotlight on leakage buyers who source from rogue suppliers. NGOs and buyers can then initiate grievances against these buyers to close the leakage" (Head of Policy, Supplier, Document 14)

Table 3
Data overview for governance types

Governance types	**Deduct. themes**	**Induct. themes**	**Interview extract examples**
	Direct Indirect	Along supply chain	"What we try now try in our conversations with the indirect suppliers, so domestic exporters or middlemen, we try to get a rough understanding of whether they can already say something about out of their total volume what share comes from X jurisdiction. So from province or municipality level. … We try to drill down in the supply chain … We might suggest some collective work to see what can be done to get more visibility" (Forest Adviser, Supplier 5) "It's a challenge to get information on our suppliers without breaching any directives or stepping on anyone's tail. We've been quite successful at getting concession data from most of our suppliers. We've got data coverage of 80 per cent of our suppliers, where we can confidently say what concessions they own and where they are." (Conservation Advisor, Supplier, Document 33) "helps us narrow down … where we need to prioritize our efforts and what the risk portfolio of suppliers is" (Forest Adviser, Supplier 5

(*continued on next page*)

Table 3 (*continued*)

			"[our team] trained 35 technicians from cooperatives and six representatives from the participating mill on geolocation and mapping, enabling the mill involved to obtain 100% traceability to plantation, with geolocation of 4000 farmers, and full mapping of 221 of those farms" (Responsible Sourcing, Focal Firm, Document 32)
	Work with third party	Across supply chains	"Supply chain dynamics are difficult, [multinational supplier] is working with customers to address supply chain deforestation risk. But then there is also more appetite for collective initiative [across supply chains]." (Forest Adviser, Supplier 5) "In palm oil, pretty universally everyone feels that this is precompetitive and that they just can't do it on their own. There's a very high eagerness to collaborate and there's also frustration among companies and the feeling that over the last 10 years of working in this space, they didn't achieve the results that they had hoped. And these collaborations are really speeding up and becoming more action-oriented or new ones are forming that are more action-oriented because companies are just tired of waiting for slow-moving things [certification schemes]" (Global Responsible Sourcing Leader, Focal Firm 3) "We are working with [NGO] on the [new joint satellite-based monitoring initiative] with 10 leading companies … What is special about this one … is that it also brings these companies together on the landscape level when it is about acting on the data. For instance, it may be that in one region, [consumer goods company] is stronger in presence and in the neighboring part [food and beverages company] may be stronger in presence and the idea is that they can then complement each other's actions." (CEO, Technology Provider 11) "We are technology-agnostic, but we had hoped that all companies in the palm oil supply chain at least need to be using some kind of satellite monitoring to verify no deforestation. And some feel that [technology provider] is too expensive and other systems as well and so we do think that it's really crucial to also have the best possible system publicly available. Therefore, we are very supportive of a joint monitoring system … and it seems that companies in our supply chain and a lot of peers are excited too" (Global Responsible Sourcing Leader, Focal Firm 3)
		Across sectors	"Often the large consumer goods firms are far removed from the producers. So it is not so usual for a big consumer goods brand to have a GIS department. While for a large producer company, it's much more common. So for us, working with these different types of clients requires different approaches." (CEO, Technology Provider 11) "It's not necessary that a company has a specific skillset, but if they don't, they need a partner that has it. So, the ability to obtain and process the traceability information, ability to monitor and interpret the alerts and then act … the more a company can internalize that the better and the more effective" (Global Responsible Sourcing Leader, Focal Firm 3) "You can use remote sensing … but then how do you act on that. … And if it is a fragmented supply base with smallholders, …companies may need to engage with local governments or other local actors and build alliances that address [deforestation] in collaboration" (Chief Innovation & Technology Officer, Certification 7) "The palm oil sector is really leading the pack here. For instance, [Large Supplier] has been using for 3 years now information on high deforestation risk areas and also for investigating what that means on the ground and calling their employees and suppliers to identify what happened, making decisions on stop-work-orders, or where changes have been detected in national park areas, alerting the local governments or [NGO] to urge them to take action" (CEO, Technology Provider, Document 65) "… we try to bring companies and governments and cooperatives and farmer associations together in a landscape or jurisdictional approach. … And in this process, we really need data. Because sometimes when we talk with companies or governments or stakeholders, they just don't know where the oil we're talking about even comes from … Remote sensing in this sense is valuable as a facilitation tool …" (Program Officer, NGO 8)

References

Aguiar, D.A., Rudorff, B.F.T., Silva, W.F., Adami, M., Mello, M.P., 2011. Remote sensing images in support of environmental protocol. Monitoring the sugarcane harvest in São Paulo State, Brazil. Remote Sens (Basel) 3, 2682–2703. https://doi.org/10.3390/rs3122682.

Barney, J., 1991. Firm resources and sustained competitive advantage. J. Manag. 17, 99–120.

Barratt, M., Choi, T.Y., Li, M., 2011. Qualitative case studies in operations management. Trends, research outcomes, and future research implications. J. Oper. Manag. 29, 329–342. https://doi.org/10.1016/j.jom.2010.06.002.

Beske, P., 2012. Dynamic capabilities and sustainable supply chain management. Int. J. Phys. Distrib. Logist. Manag. 42, 372–387. https://doi.org/10.1108/09600031211231344.

Beske, P., Land, A., Seuring, S., 2014. Sustainable supply chain management practices and dynamic capabilities in the food industry: a critical analysis of the literature. Int. J. Prod. Econ. 152, 131–143. https://doi.org/10.1016/j.ijpe.2013.12.026.

Blossey, G., Eisenhardt, J., Hahn, G., 2019. Blockchain technology in supply chain management. An application perspective. Proc. 52nd Hawaii Int. Conf. Syst. Sci. 6, 6885–6893. https://doi.org/10.24251/hicss.2019.824.

Bowen, F., Cousins, P., Lamming, R., Farukt, A., 2001. The role of supply management capabilities in green supply. Prod. Oper. Manag. 10, 174–189. https://doi.org/10.1111/j.1937-5956.2001.tb00077.x.

Carter, C.R., Rogers, D.S., Choi, T.Y., 2015. Toward the theory of the supply chain. J. Supply Chain Manag. 51, 89–97. https://doi.org/10.1111/jscm.12073.

Castka, P., Searcy, C., 2021. Audits and COVID-19: a paradigm shift in the making. Bus. Horiz. https://doi.org/10.1016/j.bushor.2021.11.003.

Castka, P., Searcy, C., Mohr, J., 2020. Technology-enhanced auditing. Improving veracity and timeliness in social and environmental audits of supply chains. J. Clean. Prod. 258, 1–13. https://doi.org/10.1016/j.jclepro.2020.120773.

Chen, J.Y., 2022. Responsible sourcing and supply chain traceability. Int. J. Prod. Econ. 248 https://doi.org/10.1016/j.ijpe.2022.108462.

Choi, T.Y., Dooley, K.J., Rungtusanatham, M., 2001. Supply networks and complex adaptive systems: control versus emergence. J. Oper. Manag. 19, 351–366.

Choi, T.Y., Wu, Z., 2009. Triads in supply networks. Theorizing buyer-supplier-supplier relationships. J. Supply Chain Manag. 45, 8–25. https://doi.org/10.1111/j.1745-493X.2009.03151.x.

COWI, 2018. Feasibility Study on Options to Step up EU Action against Deforestation. Publications Office of the European Union, Luxembourg.

Defee, C.C., Fugate, B.S., 2010. Changing perspective of capabilities in the dynamic supply chain era. Int. J. Logist. Manag. https://doi.org/10.1108/09574091011071915.

Earthworm, Mars, Tropical Forest Alliance, Mas, M., 2020. Supply Chain Resilience Post Covid-19. Driving critical landscape regeneration [Webinar on 06 May 2020].

Easterby-Smith, M., Lyles, M.A., Peteraf, M.A., 2009. Dynamic capabilities: current debates and future directions. Br. J. Manag. 20 https://doi.org/10.1111/j.1467-8551.2008.00609.x.

Eisenhardt, K.M., Martin, J., 2000. Dynamic capabilities. What are they? Strat. Manag. J. 21, 1105–1121.

European Commission, 2022. Directive of the European Parliament and of the Council on Corporate Sustainability Due Diligence and Amending Directive (EU) 2019/1937. https://ec.europa.eu/info/sites/default/files/1_1_183885_prop_dir_susta_en.pdf.

Federal Ministry for Economic Cooperation and Development, 2021. Lieferkettengesetz. Das Lieferkettengesetz Wurde Am 3. März 2021 Vom Bundeskabinett Beschlossen. https://www.bmz.de/de/entwicklungspolitik/lieferkettengesetz.

Francisco, K., Swanson, D., 2018. The supply chain has No clothes: technology adoption of blockchain for supply chain transparency. Logistics 2, 2. https://doi.org/10.3390/logistics2010002.

Gardner, T.A., Benzie, M., Börner, J., Dawkins, E., Fick, S., Garrett, R., Godar, J., Grimard, A., Lake, S., Larsen, R.K., Mardas, N., McDermott, C.L., Meyfroidt, P., Osbeck, M., Persson, M., Sembres, T., Suavet, C., Strassburg, B., Trevisan, A., West, C., Wolvekamp, P., 2019. Transparency and sustainability in global commodity supply chains. World Dev. 121, 163–177. https://doi.org/10.1016/j.worlddev.2018.05.025.

GFW, 2019. Keeping an Eye on Cocoa. Satellite Monitoring Provides Key Support on No Deforestation Commitments [WWW Document]. URL. https://blog.globalforestwatch.org/commodities/keeping-an-eye-on-cocoa-satellite-monitoring-provides-key-support-on-no-deforestation-commitments.

Gibbert, M., 2006. Generalizing about uniqueness. An essay on an apparent paradox in the resource-based view. J. Manag. Inq. 15, 124–134. https://doi.org/10.1177/1056492606287793.

Godar, J., Suavet, C., Gardner, T.A., Dawkins, E., Meyfroidt, P., 2016. Balancing detail and scale in assessing transparency to improve the governance of agricultural commodity supply chains. Environ. Res. Lett. https://doi.org/10.1088/1748-9326/11/3/035015.

Gong, Y., Jia, F., Brown, S., Koh, L., 2018. Supply chain learning of sustainability in multi-tier supply chains: a resource orchestration perspective. Int. J. Oper. Prod. Manag. 38, 1061–1090. https://doi.org/10.1108/IJOPM-05-2017-0306.

Grimm, J.H., Hofstetter, J.S., Sarkis, J., 2016. Exploring sub-suppliers' compliance with corporate sustainability standards. J. Clean. Prod. 112, 1971–1984. https://doi.org/10.1016/j.jclepro.2014.11.036.

Grimm, J.H., Hofstetter, J.S., Sarkis, J., 2014. Critical factors for sub-supplier management: a sustainable food supply chains perspective. Int. J. Prod. Econ. 152, 159–173. https://doi.org/10.1016/j.ijpe.2013.12.011.

Gualandris, J., Klassen, R.D., Vachon, S., Kalchschmidt, M., 2015. Sustainable evaluation and verification in supply chains. Aligning and leveraging accountability to stakeholders. J. Oper. Manag. 38, 1–13. https://doi.org/10.1016/j.jom.2015.06.002.

Guo, H., Liu, Z., Jiang, H., Wang, C., Liu, J., Liang, D., 2017. Big Earth data. A new challenge and opportunity for Digital Earth's development. Int J Digit Earth 10, 1–12. https://doi.org/10.1080/17538947.2016.1264490.

Hajmohammad, S., Vachon, S., 2016. Managing supplier sustainability risk. Strategies and predictors. J. Supply Chain Manag. 52, 48–65. https://doi.org/10.5465/ambpp.2014.14266abstract.

Hansen, M.C., Potapov, P.v., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.v., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J.R.G., 2013. High-resolution global maps of 21st-century forest cover change. Science 342 (1979), 850–853. https://doi.org/10.1126/science.1244693.

Hartmann, J., Moeller, S., 2014. Chain liability in multitier supply chains? Responsibility attributions for unsustainable supplier behavior. J. Oper. Manag. 32, 281–294. https://doi.org/10.1016/j.jom.2014.01.005.

Hofmann, H., Busse, C., Bode, C., Henke, M., 2014. Sustainability-related supply chain risks. Conceptualization and management. Bus. Strat. Environ. 23, 160–172. https://doi.org/10.1002/bse.1778.

Hofmann, H., Schleper, M.C., Blome, C., 2018. Conflict minerals and supply chain due diligence. An exploratory study of multi-tier supply chains. J. Bus. Ethics 147, 115–141. https://doi.org/10.1007/s10551-015-2963-z.

Jabbour, C.J.C., de Sousa Jabbour, A.B.L., Sarkis, J., 2019. Unlocking effective multi-tier supply chain management for sustainability through quantitative modeling. Lessons learned and discoveries to be made. Int. J. Prod. Econ. 217, 11–30. https://doi.org/10.1016/j.ijpe.2018.08.029.

Jamalnia, A., Gong, Y., Govindan, K., 2023. Sub-supplier's sustainability management in multi-tier supply chains: a systematic literature review on the contingency variables, and a conceptual framework. Int. J. Prod. Econ. https://doi.org/10.1016/j.ijpe.2022.108671.

Jia, F., Gong, Y., Brown, S., 2019. Multi-tier sustainable supply chain management. The role of supply chain leadership. Int. J. Prod. Econ. 217, 44–63. https://doi.org/10.1016/j.ijpe.2018.07.022.

King, A.A., Lenox, M.J., 2000. Industry self-regulation without sanctions. The chemical industry's responsible care program. Acad. Manag. J. 43, 698–716.

Köhler, J., Sönnichsen, S.D., Beske-Jansen, P., 2022. Towards a collaboration framework for circular economy: the role of dynamic capabilities and open innovation. Bus. Strat. Environ. 1–14. https://doi.org/10.1002/bse.3000.

Kroeger, A., Bakhtary, H., Haupt, F., Streck, C., 2017. Eliminating Deforestation from the Cocoa Supply Chain, Eliminating Deforestation from the Cocoa Supply Chain. Worldbank, Washington.

Lambin, E.F., Gibbs, H.K., Heilmayr, R., Carlson, K.M., Fleck, L.C., Garrett, R.D., le Polain De Waroux, Y., McDermott, C.L., McLaughlin, D., Newton, P., Nolte, C., Pacheco, P., Rausch, L.L., Streck, C., Thorlakson, T., Walker, N.F., 2018. The role of supply-chain initiatives in reducing deforestation. Nat. Clim. Change 8, 109–116. https://doi.org/10.1038/s41558-017-0061-1.

Lopatin, E., Trishkin, M., Gavrilova, O., 2016. Assessment of compliance with PEFC forest certification indicators with remote sensing. Forests 7, 1–12. https://doi.org/10.3390/f7040085.

MacCarthy, B.L., Ahmed, W.A.H., Demirel, G., 2022. Mapping the supply chain: why, what and how? Int. J. Prod. Econ. https://doi.org/10.1016/j.ijpe.2022.108688.

Marin-Burgos, V., Clancy, J.S., Lovett, J.C., 2015. Contesting legitimacy of voluntary sustainability certification schemes: valuation languages and power asymmetries in the Roundtable on Sustainable Palm Oil in Colombia. Ecol. Econ. 117, 303–313. https://doi.org/10.1016/j.ecolecon.2014.04.011.

Mayring, P., 2014. Qualitative content analysis. Theoretical background and procedures. In: Bikner-Ahsbahs, A., Knipping, C., Presmeg, N. (Eds.), Approaches to Qualitative Research in Mathematics Education. Springer Science+Business Media, Dordrecht, pp. 365–380. https://doi.org/10.1007/978-94-017-9181-6.

Meinlschmidt, J., Schleper, M.C., Foerstl, K., 2018. Tackling the sustainability iceberg. A transaction cost economics approach to lower tier sustainability management. Int. J. Oper. Prod. Manag. 38, 1888–1914. https://doi.org/10.1108/IJOPM-03-2017-0141.

Mena, C., Humphries, A., Choi, T.Y., 2013. Toward a theory of multi-tier supply chain management. J. Supply Chain Manag. 49, 58–77. https://doi.org/10.1111/jscm.12003.

Montecchi, M., Plangger, K., West, D.C., 2021. Supply chain transparency: a bibliometric review and research agenda. Int. J. Prod. Econ. https://doi.org/10.1016/j.ijpe.2021.108152.

Ng, G., 2019. Monitoring Deforestation. The Use and Misuse of Satellite Technology [WWW Document]. URL. https://www.eco-business.com/opinion/monitoring-deforestation-the-use-and-misuse-of-satellite-technology/. accessed 2.20.20.

Orsato, R.J., Clegg, S.R., Falcão, H., 2013. The political ecology of palm oil production. J. Change Manag. 13, 444–459. https://doi.org/10.1080/14697017.2013.851916.

Pagell, M., Shevchenko, A., 2014. Why research in sustainable supply chain management should have no future. J. Supply Chain Manag. 50, 44–55. https://doi.org/10.1111/jscm.12037.

Pagell, M., Wu, Z., 2017. Business implications of sustainability practices in supply chains. In: Bouchery, Y., Corbett, C.J., Fransoo, J.C., Tan, T. (Eds.), Sustainable Supply Chains: A Research-Based Textbook on Operations and Strategy. Springer International Publishing, Cham, pp. 339–353. https://doi.org/10.1007/978-3-319-29791-0_15.

Pagell, M., Wu, Z., 2009. Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. J. Supply Chain Manag. 45, 37–56. https://doi.org/10.1111/j.1745-493X.2009.03162.x.

Partzsch, L., Vlaskamp, M.C., 2016. Mandatory due diligence for 'conflict minerals' and illegally logged timber: emergence and cascade of a new norm on foreign accountability. Extr. Ind. Soc. 3, 978–986. https://doi.org/10.1016/j.exis.2016.07.003.

Prahalad, C.K., Hamel, G., 1990. The core competence of the organisation. Harv. Bus. Rev. 68, 79–91.

Reuter, C., Foerstl, K., Hartmann, E., Blome, C., 2010. Sustainable global supplier management. The role of dynamic capabilities in achieving competitive advantage. J. Supply Chain Manag. 46, 45–63. https://doi.org/10.1111/j.1745-493X.2010.03189.x.

Reuters, 2019. Norway' S Wealth Fund Ditches 33 Palm Oil Firms over Deforestation [WWW Document]. URL. https://www.reuters.com/article/us-norway-pension-palmoil/norways-wealth-fund-ditches-33-palm-oil-firms-over-deforestation-idUSKCN1QH1MR.

Roberts, S., 2003. Understanding the patchy success of ethical sourcing initatives. J. Bus. Ethics 159–170.

Saberi, S., Kouhizadeh, M., Sarkis, J., Shen, L., 2019. Blockchain technology and its relationships to sustainable supply chain management. Int. J. Prod. Res. 57, 2117–2135. https://doi.org/10.1080/00207543.2018.1533261.

Sancha, C., Josep, J.F., Gimenez, C., 2019. Managing sustainability in lower-tier suppliers. How to deal with the invisible zone. African J. Econ. Manag. Stud. 10, 458–474. https://doi.org/10.1108/AJEMS-09-2018-0266.

Sarkis, J., Santibanez Gonzalez, E.D., Koh, S.C.L., 2019. Effective multi-tier supply chain management for sustainability. Int. J. Prod. Econ. 217, 1–10. https://doi.org/10.1016/j.ijpe.2019.09.014.

Sarkis, J., Zhu, Q., 2018. Environmental sustainability and production. Taking the road less travelled. Int. J. Prod. Res. 56, 743–759. https://doi.org/10.1080/00207543.2017.1365182.

Sauer, P.C., Seuring, S., 2019. A three-dimensional framework for multi-tier sustainable supply chain management. Supply Chain Manag.: Int. J. 23, 560–572. https://doi.org/10.1108/SCM-06-2018-0233.

Sauer, P.C., Seuring, S., 2018. Extending the reach of multi-tier sustainable supply chain management. Insights from mineral supply chains. Int. J. Prod. Econ. 217, 31–43. https://doi.org/10.1016/j.ijpe.2018.05.030.

Schaltegger, S., Burritt, R., 2014. Measuring and managing sustainability performance of supply chains. Review and sustainability supply chain management framework. Supply Chain Manag.: Int. J. 19, 232–241. https://doi.org/10.1108/SCM-02-2014-0061.

Schepers, D.H., 2010. Challenges to legitimacy at the forest stewardship Council. J. Bus. Ethics 92, 279–290. https://doi.org/10.1007/s10551-009-0154-5.

Schmidt, C.G., Foerstl, K., Schaltenbrand, B., 2017. The supply chain position paradox. Green practices and firm performance. J. Supply Chain Manag. 53, 3–25. https://doi.org/10.1111/jscm.12113.

Scholz, J., de Meyer, A., Marques, A.S., Pinho, T.M., Boaventura-Cunha, J., van Orshoven, J., Rosset, C., Künzi, J., Kaarle, J., Nummila, K., 2018. Digital technologies for forest supply chain optimization: existing solutions and future trends. Environ. Manag. 62, 1108–1133. https://doi.org/10.1007/s00267-018-1095-5.

Searcy, C., Castka, P., 2020. COVID-19 can speed up the use of technology in supply-chain sustainability audits. LSE Business Review.

Seuring, S., Müller, M., 2008. From a literature review to a conceptual framework for sustainable supply chain management. J. Clean. Prod. 16, 1699–1710. https://doi.org/10.1016/j.jclepro.2008.04.020.

Sisodiya, N., Dube, N., Thakkar, P., 2020. Next-generation artificial intelligence techniques for satellite data processing. In: Remote Sensing and Digital Image Processing. https://doi.org/10.1007/978-3-030-24178-0_11.

Smit, H., Mcnally, R., Gijsenbergh, A., 2015. Implementing Deforestation-free Supply Chains. Certification and beyond.

Sodhi, M.M.S., Tang, C.S., 2019. Research opportunities in supply chain transparency. Prod. Oper. Manag. 28, 2946–2959. https://doi.org/10.1111/poms.13115.

Tachizawa, E.M., Wong, C.Y., 2014. Towards a theory of multi-tier sustainable supply chains: a systematic literature review. Supply Chain Manag.: Int. J. 19, 643–653. https://doi.org/10.1108/SCM-02-2014-0070.

Taghizadeh, E., Venkatachalam, S., Chinnam, R.B., 2021. Impact of deep-tier visibility on effective resilience assessment of supply networks. Int. J. Prod. Econ. 241 https://doi.org/10.1016/j.ijpe.2021.108254.

Teece, D.J., 2020. Hand in glove: open innovation and the dynamic capabilities framework. Strat. Manag. Rev. 1, 233–253. https://doi.org/10.1561/111.00000010.

Teece, D.J., 2016. Dynamic capabilities and entrepreneurial management in large organizations: toward a theory of the (entrepreneurial) firm. Eur. Econ. Rev. 86, 202–216. https://doi.org/10.1016/j.euroecorev.2015.11.006.

Teece, D.J., 2007. Explicating dynamic capabilities. The nature and microfoundations of (sustainable) enterprise performance. Strat. Manag. J. 28, 1319–1350. https://doi.org/10.1002/smj.640.

Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strat. Manag. J. 18, 509–533. https://doi.org/10.1142/9789812796929_0004.

Vachon, S., Klassen, R.D., 2007. Supply chain management and environmental technologies. The role of integration. Int. J. Prod. Res. 45, 401–423. https://doi.org/10.1080/00207540600597781.

Verschuren, P.J.M., 2003. Case study as a research strategy: some ambiguities and opportunities. Int. J. Soc. Res. Methodol.: Theor. Pract. 6, 121–139. https://doi.org/10.1080/13645570110106154.

Villena, V.H., Gioia, D.A., 2018. On the riskiness of lower-tier suppliers: managing sustainability in supply networks. J. Oper. Manag. 64, 65–87. https://doi.org/10.1016/j.jom.2018.09.004.

Welsh, I., Wielaard, N., 2020. Faster and Clearer Deforestation Data for the Palm Oil Sector [Audio Podcast] [WWW Document]. URL. https://www.innovationforum.co.uk/articles/faster-and-clearer-deforestation-data-for-the-palm-oil-sector.

Werner, T.T., Bebbington, A., Gregory, G., 2019. Assessing impacts of mining: recent contributions from GIS and remote sensing. Extr. Ind. Soc. 6, 993–1012. https://doi.org/10.1016/j.exis.2019.06.011.

Wernerfelt, B., 1984. A resource-based view of the firm. Strat. Manag. J. 5, 171–180.

Wilhelm, M.M., Blome, C., Bhakoo, V., Paulraj, A., 2016. Sustainability in multi-tier supply chains. Understanding the double agency role of the first-tier supplier. J. Oper. Manag. 41, 42–60. https://doi.org/10.1016/j.jom.2015.11.001.

Wolf, J., 2014. The relationship between sustainable supply chain management, stakeholder pressure and corporate sustainability performance. J. Bus. Ethics 119, 317–328. https://doi.org/10.1007/s10551-012-1603-0.

https://environment.ec.europa.eu/topics/forests/deforestation/regulation-deforestation-free-products_en.

https://www2.deloitte.com/dl/en/pages/legal/articles/entwaldungsfreie-lieferketten.html.