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Skills Development and Training Pathways for Sustainable Palm Oil Employment: A Review of Competency-Based Approaches to Green Job Creation

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Abstract

The palm oil sector is undergoing substantial transformation driven by global sustainability expectations, technological modernization, and evolving labor competencies. As sustainable employment becomes increasingly central to resource-based industries, understanding how skills development and training pathways are conceptualized and operationalized is critical. This study systematically reviews and synthesizes peer-reviewed literature published between 2019 and 2025 to examine the conceptualization and implementation of skills development, training pathways, and competency-based approaches in sustainable palm oil employment and their role in green job creation. Employing a systematic literature review (SLR) methodology, the study identified 30 eligible articles from an initial pool of 262 Scopus-indexed publications, following stringent screening for relevance, publication period, language, and open-access availability. Data were extracted from each study focusing on workforce competencies, training models, the integration of digital and green skills, and institutional or policy frameworks. Thematic analysis was conducted to synthesize patterns, identify emerging competency domains, and map the relationships between training pathways and green job creation. The review revealed five key thematic clusters: evolving competency requirements, the growing significance of digital and green skills, structured and blended training pathways, institutional and policy enablers, and competency-based frameworks aligned with green employment. Evidence suggests that competency-based training supports efficiency, sustainability, compliance, and managerial capacity, while digital and environmental competencies facilitate the adoption of innovative technologies and environmentally responsible practices. Overall, competency-oriented approaches provide a scalable and measurable framework for workforce development in the palm oil sector. Future research is encouraged to examine the longitudinal impacts of these competency frameworks, cross-context applicability, and the integration of digital and environmental skills in smallholder systems.

Keywords: Skills Development; Competency-Based Training; Sustainable Employment; Palm Oil Sector; Green Jobs

Introduction

The global transition toward sustainable development has intensified the need for workforce systems capable of supporting environmentally responsible economic sectors, particularly those with significant social and economic relevance in the Global South [1]. As sustainability principles increasingly shape global commodity markets, industries are compelled to adapt through innovations in production systems, governance mechanisms, and human resource development strategies. Within this context, the palm oil sector, widely recognized for its economic contributions, employment generation, and integration into global supply chains, has been increasingly influenced by sustainability-oriented expectations for environmental stewardship, resource efficiency, and transparent labor practices [2]. These shifts have produced growing interest in the role of human capital, particularly the skills and competencies required to align sectoral employment with sustainable development pathways [3].

In recent years, the concept of skills development has moved to the forefront of sustainable employment discourse. Economic transitions toward greener production models require workers to possess hybrid capabilities that combine technical expertise with environmental awareness, digital literacy, and adaptive problem-solving abilities. Studies across various natural-resource-based sectors demonstrate that sustainable employment increasingly relies on workers' capacity to meet competency standards that support efficiency, compliance, and innovation in rapidly evolving operational environments [4]. Skill requirements

are therefore no longer static; instead, they are shaped by ongoing technological modernization, increased data-driven management, and the expansion of sustainability certification frameworks [5].

The palm oil sector is a critical case for analyzing these transformations, given its diverse workforce, ranging from smallholders and field workers to technicians, supervisors, and sustainability professionals. As sustainability requirements evolve, competencies related to biodiversity protection, climate-smart cultivation, chemical-safety management, and traceability systems have become more salient [6]. Simultaneously, advancements in digital agriculture, such as geospatial planning, remote sensing, mobile-based reporting, and automated monitoring, have introduced new skill domains that complement conventional technical knowledge [7]. The intersection of these trends underscores the importance of understanding how skills development strategies influence sustainable employment outcomes across the sector.

A growing body of scholarship highlights the essential role of structured training pathways in equipping workers with competencies that support both productivity and environmental responsibility. Research across agriculture, forestry, and fisheries has shown that well-designed training programs improve technical efficiency, reduce error rates, enhance resource-use optimization, and strengthen compliance with environmental regulations [8]. In the palm oil context, training systems vary widely, ranging from corporate capacity-building programs to government-supported vocational schemes and civil-society-led initiatives focused on sustainability and smallholder empowerment. These heterogeneous pathways reflect the broader complexity of aligning workforce development with sustainability expectations [9].

Competency-based training (CBT) has emerged as a particularly influential approach in this transformation. Unlike traditional time-based training methods, CBT emphasizes clearly defined learning outcomes, performance-based assessments, and structured progression aligned with occupational standards. International evidence demonstrates that competency-based models enhance the consistency of training quality, increase the relevance of learning materials, and support measurable improvements in workforce performance across sustainable agricultural systems [10]. These characteristics position CBT as a promising mechanism for strengthening skills development in the palm oil sector, particularly as the industry increasingly integrates environmental and digital requirements into operational norms.

At the same time, green job creation has become a prominent policy objective in national development agendas, aligning with broader commitments to low-carbon growth and sustainable economic diversification. Green jobs require workers to possess environmentally relevant knowledge, including competencies related to waste reduction, emission mitigation, energy efficiency, and compliance with sustainability standards [11]. The emergence of green employment opportunities in agriculture and agro-processing represents an important dimension of this agenda, with the palm oil sector offering significant potential due to its scale, workforce size, and technological modernization pathways [12]. However, the realization of green job opportunities depends heavily on the capacity of training systems to produce workers who can effectively perform emerging tasks associated with sustainable production models.

Despite the growing literature on sustainability, skills development, and workforce transformation, a comprehensive synthesis of how training pathways and competency-based approaches contribute to sustainable employment outcomes in the palm oil sector remains limited. Existing research tends to focus on isolated themes such as certification readiness, digital literacy, environmental compliance, mechanization, or smallholder capacity building without fully integrating these elements into a holistic understanding of workforce competency requirements [13]. Furthermore, while individual studies document training effectiveness or skill gaps, there is limited synthesis across studies regarding how training models, policy mechanisms, and competency frameworks collectively support sector-wide transitions toward green employment.

Addressing this gap is essential for several reasons. First, the sustainability performance of large-scale commodity sectors increasingly depends on a workforce capable of meeting complex operational and compliance requirements. Second, integrating sustainability standards into global value chains underscores the importance of skills that support transparency, efficiency, and environmental management. Third, the expansion of digital agriculture and data-driven monitoring systems requires new technical capacities that complement traditional field skills. Finally, the alignment between workforce development systems and green job creation pathways is critical to ensuring that sector transformations generate inclusive, long-term employment benefits [14,15].

Given these dynamics, a systematic and up-to-date synthesis is needed to clarify how current scholarship conceptualizes skills development and training pathways for sustainable palm oil employment, and how competency-based approaches contribute to green job creation. A systematic literature review (SLR) offers a rigorous methodological framework for synthesizing peer-reviewed evidence, identifying thematic patterns, and assessing conceptual advancements across studies. By applying structured inclusion criteria, quality appraisal processes, and thematic coding techniques, SLR supports the development of a robust evidence base that can guide policymakers, training institutions, and industry stakeholders in shaping effective skills development strategies.

The purpose of this study is to systematically review and synthesize peer-reviewed literature published between 2019 and 2025 to examine how skills development, training pathways, and competency-based approaches are conceptualized and implemented in sustainable palm oil employment, and how these approaches contribute to green job creation. This SLR aims to generate an integrated understanding of evolving competency requirements, the emergence of digital and green skills, the structure of training systems, institutional drivers of workforce

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transformation, and the relevance of competency-based training models within sustainability-oriented employment frameworks.

Based on the purpose above, the study addresses two core research questions:

RQ1: How do current peer-reviewed studies conceptualize and operationalize skills development and competency-based training pathways within the context of sustainable palm oil employment?

RQ2: In what ways do emerging competency frameworks, particularly digital, environmental, and managerial skills, contribute to green job creation and support sustainability transitions in the palm oil sector?

Literature Review

The expanding literature on sustainable employment in resource-based industries demonstrates a growing scholarly interest in how workforce competencies, structured training systems, and competency-based frameworks contribute to sustainability-oriented economic transitions. Studies increasingly recognize that human-capital readiness is becoming a core determinant of operational resilience as industries adapt to environmental standards, digitalization pressures, and global value-chain requirements [16]. Within this broader discourse, the palm oil sector presents an important case, not only because of its scale and economic contribution, but also because it is among the most institutionally regulated commodity systems, thereby generating a complex interface among workforce skills, sustainability commitments, and certification-driven performance expectations. Existing scholarship shows consensus that sustainable employment pathways depend on the integration of technical, digital, and environmental competencies; however, comparative analyses across sectors also indicate that gaps persist in understanding the extent to which skill demands evolve, how training models respond, and how competency frameworks translate into measurable improvements in sustainability outcomes. This review synthesizes these thematic strands and strengthens the analysis through critical comparison and identification of conceptual and empirical gaps.

Competency Requirements in Sustainability-Oriented Agricultural Sectors

Studies across sustainable agriculture, forestry, and plantation-based commodities consistently show that workforce competency requirements have shifted toward multidimensional skill sets that combine technical, environmental, and managerial domains [17]. While earlier research largely emphasized technical operational skills such as harvesting methods, crop handling, pruning, and agrochemical calibration, recent analyses indicate rising expectations related to environmental compliance, documentation systems, and adaptive problem-solving capabilities [18]. Cross-sector comparisons reveal that sectors with stringent certification requirements (e.g., cocoa, timber, and palm oil) tend to impose more complex competency structures because workers must understand sustainability metrics, maintain accurate field records, and adhere to buffer-zone protocols [19].

However, the literature diverges in explaining where competency gaps most commonly occur. Some studies identify field-level operators as the most vulnerable to competency gaps due to limited access to formal training, whereas others emphasize deficits at supervisory or mid-management levels, particularly in analytics, monitoring, and multi-team coordination in sustainability compliance contexts [20,21]. These inconsistencies suggest that competency evolution is highly context-dependent, shaped by firm size, certification intensity, and national training systems. Despite broad recognition of evolving competency demands, there remains limited empirical evidence on how competency expectations differ among worker categories in the palm oil sector and how these variations influence the design of competency-based training systems.

Digital Skills and Technological Modernization in Agricultural Employment

The digital transformation of agriculture, marked by the adoption of remote-sensing tools, geospatial mapping, mobile-based extension platforms, automated reporting systems, and drone-assisted monitoring, appears across nearly all recent studies on modernized agricultural systems [22]. Workers are increasingly expected to interpret digital field data, operate monitoring devices, and maintain digital records for certification verification [23]. This is consistent with broader shifts in commodity sectors such as tea, rubber, and sugarcane, where digital platforms are now integrated into traceability, yield monitoring, and sustainability reporting.

However, comparative studies show wide variation in digital adoption across different agricultural value chains. High-capital plantation systems tend to adopt advanced digital tools more quickly than smallholder systems, where limited connectivity, high device costs, and digital literacy barriers persist as persistent challenges [24]. In palm oil contexts, the literature notes promising outcomes from mobile-based farm-advisory platforms and digital smallholder mapping, but empirical assessments often stop at early-stage feasibility, with fewer studies evaluating long-term workforce capacity to maintain these systems.

Furthermore, while digital competencies are frequently mentioned, there is insufficient analysis of how they interact with environmental or technical competencies, a critical dimension for understanding integrated competency frameworks. Research remains limited on the depth of digital literacy acquisition across different workforce segments, especially among smallholders, and on how digital skills complement environmental and technical skill sets in sustainability implementation.

Green Skills and Environmental Competency Development

Green skills spanning biodiversity management, soil conser-

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vation, water-quality monitoring, carbon accounting fundamentals, and pollution control are increasingly recognized as essential competencies in sustainability-oriented agricultural systems [25]. Studies provide strong evidence that workers trained in green competencies achieve greater consistency in compliance, reduced resource waste, and improved implementation of best management practices across sectors such as forestry, aquaculture, and organic farming [26].

Yet the literature displays variation in how green skills are conceptualized. Some view them primarily as environmental-management skills, while others frame them as integrative competencies connected to digital tools (e.g., digital monitoring of emissions or automated water-quality sensors). This definitional inconsistency complicates efforts to compare skill-development outcomes across sectors. Moreover, despite the palm oil sector's prominent sustainability commitments, empirical studies rarely quantify the specific green skills most associated with improved sustainability performance, nor do they systematically evaluate the impact of green-skills training on certification results. There is insufficient clarity on which green competencies most strongly influence sustainability compliance outcomes in palm oil contexts and how these competencies should be sequenced within training pathways.

Training Pathways in Sustainable Employment Systems

The literature highlights a diverse ecosystem of training pathways, including corporate training programs, government-led vocational education, and NGO-supported capacity-building initiatives [27]. Corporate programs often emphasize technical proficiency, safety, and compliance readiness; vocational institutions focus on formalizing occupational standards; and NGOs emphasize smallholder empowerment, sustainability awareness, and digital literacy. Cross-sector comparisons indicate that multi-stakeholder approaches generally yield stronger, more consistent training outcomes.

However, significant variation exists in training quality, delivery formats, and evaluation methods. Some studies praise blended learning models combining digital modules, field demonstrations, and competency assessments for their cost-efficiency and scalability [28]. Others note that without standardized competency frameworks, training effectiveness becomes uneven, particularly in regions with dispersed smallholders or limited training infrastructure.

In many agricultural sectors, training remains heavily input-oriented (e.g., hours attended), while outcome-based or performance-based evaluation remains limited. This issue is even more pronounced in palm oil research, where few studies provide rigorous evidence of a link between training systems and measurable improvements in worker performance or sustainability compliance. There is limited synthesis on how different training pathways compare in their effectiveness, especially regarding competency acquisition, certification readiness, and green job creation.

Institutional and Policy Mechanisms Supporting Workforce Transformation

Institutional arrangements, including national vocational qualification frameworks, sustainability regulations, and agricultural extension reforms, are widely acknowledged as influential in shaping workforce development across sectors [29]. Countries with strong coordination among ministries, vocational agencies, and industry associations tend to exhibit more coherent training systems.

Nevertheless, cross-country comparisons reveal substantial differences. Some nations integrate sustainability criteria directly into national training standards, while others rely heavily on voluntary corporate or donor-driven initiatives. In sectors like forestry and fisheries, institutional fragmentation often leads to overlapping mandates and inconsistent training governance, a challenge similarly observed in certain palm-oil-producing regions.

Furthermore, while the literature recognizes the importance of policy coherence, empirical studies rarely examine how institutional alignment affects training uptake at the worker level or how policy frameworks enable competency-based approaches to scale effectively. Research lacks a clear understanding of how institutional coherence influences training system performance and how policy supports can accelerate competency-based workforce transformation.

Competency-Based Approaches and Green Job Creation

Competency-based training (CBT) frameworks that emphasize measurable learning outcomes, performance-based assessments, and modularized skill development are increasingly adopted across agricultural and environmental sectors [30]. Studies report that CBT enhances skill standardization, increases training accountability, and improves worker confidence in applying complex sustainability practices [31]. Its modular design also supports scalability across diverse workforce segments.

Comparatively, CBT appears more systematically implemented in sectors with high regulatory oversight (e.g., forestry certification, food-safety systems), whereas in palm oil, CBT implementation tends to be fragmented and case-specific. While several studies document promising outcomes, such as improved waste-reduction practices or enhanced compliance auditing, empirical evidence linking CBT directly to green job creation remains limited across all resource-based sectors. There is a lack of comprehensive, sector-specific analysis on how competency-based frameworks concretely support green job creation, especially within palm oil employment systems.

Based on the critical synthesis above, the conceptual framework guiding this systematic review integrates five core components:

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(1) evolving competency requirements shaped by sustainability governance; (2) emerging digital and green skill domains; (3) training pathways as mechanisms for competency development; (4) institutional and policy arrangements as enabling conditions; and (5) competency-based approaches as integrative structures supporting workforce transformation and green job creation.

The framework positions workforce competencies as the mediating link between sustainability standards, training systems, and employment outcomes. Identified gaps across themes such as variations in competency expectations, digital-literacy disparities, underexplored green-skill impacts, inconsistent training effectiveness, and limited CBT evaluation shape the analytical direction of this review and inform the formulation of research questions in the subsequent sections.

Methodology

This study applies a Systematic Literature Review (SLR) structured according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol to explore skills development, training pathways, and competency-based approaches that support sustainable employment in the palm oil sector. The increasing emphasis on sustainability, efficiency, and workforce modernization in this industry has heightened the importance of targeted training, technical upskilling, and green competency development to meet evolving labor demands. Although existing studies address workforce skills from various disciplinary perspectives, ranging from vocational training and capacity building to discussions on green jobs and sustainable employment, current evidence remains dispersed across fields such as agricultural workforce studies, sustainability transitions, labor economics, and skill development research. This fragmentation creates a need for a consolidated evidence base that systematically examines how competencies are defined, how training models operate, and how employment-related skill strategies are being positioned within sustainable palm oil contexts. In keeping with international standards for evidence-based reviews, the present study relies exclusively on secondary data from peer-reviewed publications indexed in Scopus, without field observation, focus group discussions, or any other primary data collection, thereby ensuring methodological transparency and analytical rigor.

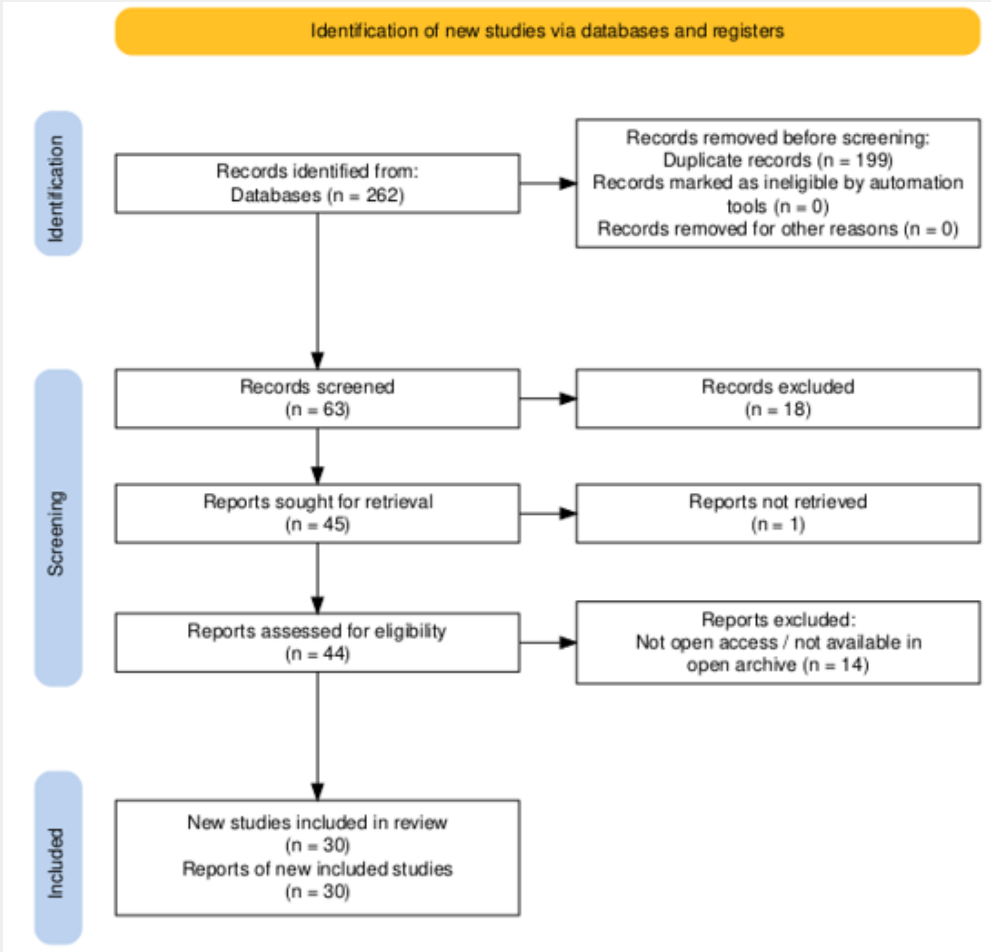

Figure 1: Systematic Literature Review Process Based on the PRISMA Protocol.

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The review process is visually summarized in Figure 1 following the PRISMA framework, which outlines the sequential phases of identification, screening, eligibility, and inclusion. The identification phase began with an initial Scopus search using the keywords *employment AND palm oil*, which generated 262 records. To refine thematic precision, a more advanced Boolean query was subsequently implemented: *("palm oil" OR "oil palm" OR "sustainable palm oil" OR "palm oil sector") AND ("skills" OR "skill development" OR "technical skills" OR "green skills" OR "workforce skills" OR "training" OR "capacity building" OR "vocational training" OR "competency-based") AND ("employment" OR "workforce" OR "labor" OR "green jobs" OR "sustainable employment")*. Application of this targeted search strategy resulted in the exclusion of 199 articles that did not fall within the conceptual boundaries of skill development and employment in the palm oil workforce, leaving 63 potentially relevant records for subsequent screening.

A publication-year filter, limiting the dataset to 2019–2025, was then applied to capture the most recent and contextually relevant developments, removing 18 articles and yielding 45 records. An additional language criterion was used to ensure consistency in analysis, and one non-English article was excluded, resulting in a total of 44 English-language documents. The final eligibility review included an accessibility filter that retained only open-access or open-archive publications to support transparency and retrievability. 14 studies did not meet this requirement and were therefore removed. The inclusion phase thus yielded a final curated set of 30 peer-reviewed articles that met all predetermined criteria for relevance, timeframe, language, and accessibility. These 30 studies constitute the analytical foundation for this SLR and collectively provide structured insights into how competency frameworks, training interventions, and skill development strategies are conceptualized within sustainable palm oil employment contexts.

All bibliographic materials used in this study were systematically organized using Mendeley Desktop to ensure precise citation management, traceability, and duplication control throughout the review process. Each of the 30 included studies was examined in full text, and relevant information such as competency frameworks, training methodologies, workforce skill requirements, and sustainability-linked employment practices was extracted and synthesized thematically. The resulting synthesis provides a comprehensive, evidence-based perspective on current approaches to skills development and training in the palm oil sector, highlighting ongoing needs for integrated competency models, enhanced vocational pathways, and stronger alignment between technical, digital, and green skill demands. By rigorously adhering to the PRISMA protocol and relying exclusively on peer-reviewed secondary data, this SLR ensures clarity, transparency, and methodological robustness while contributing to the broader discourse on sustainable workforce development and green job creation.

Results

The systematic literature review conducted in this study analyzed 30 peer-reviewed articles published between 2019 and 2025 that met all inclusion criteria. The selected corpus reflects diverse geographic, institutional, and operational contexts within the palm oil sector, providing a comprehensive evidence base for examining how skills development, training pathways, and competency-based approaches are conceptualized and implemented in sustainable palm oil employment. Through thematic synthesis, five major themes emerged, capturing overlapping but distinctive dimensions of workforce transformation in the sector: (1) evolving competency requirements for sustainable palm oil operations, (2) the expanding role of digital and green skills, (3) the structure and effectiveness of training pathways, (4) institutional and policy mechanisms enabling workforce upskilling, and (5) emerging competency-based frameworks aligned with green job creation.

The distribution of themes across the 30 studies was as follows: training pathways were discussed in 24 studies (80%), evolving competency requirements in 22 studies (74%), digital and green skills in 21 studies (70%), competency-based frameworks in 20 studies (67%), and institutional and policy mechanisms in 17 studies (57%). The predominance of training pathways and competency requirements underscores the operational and strategic relevance of workforce capabilities in meeting sustainability and certification standards. Digital and green skills, which appear a slightly lower proportions, reflect the emerging importance of technology adoption and environmental stewardship within palm oil operations. Institutional and policy mechanisms, though less frequently reported, highlight systemic enablers that shape the scalability and effectiveness of skills development initiatives. The relative frequency of these themes suggests that empirical research in the sector is currently concentrated on immediate competency development and technical training needs, while broader governance, policy, and integrated competency frameworks remain areas for further investigation.

Each thematic area is elaborated below, enriched with quantitative and qualitative evidence from the reviewed studies, followed by an analysis of their practical implications for sustainable employment and green job creation in the palm oil sector.

Evolving Competency Requirements in Sustainable Palm Oil Employment

Across the reviewed studies, workforce competency requirements have shifted markedly in response to sustainability standards, technological modernization, and certification-driven compliance demands. Approximately 74% of the studies (22 out of 30) noted that palm oil operations increasingly require hybrid skill sets that combine technical field competencies with environmental management knowledge and operational safety awareness [32]. This shift corresponds with rising expectations introduced by certification schemes such as RSPO, MSPO, and ISPO, which collectively account for more than 53% of global certified sustainable palm oil output as of 2023. Several studies published after 2020 observed an expansion in competency expectations due to

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digital tools embedded in plantation operations, requiring workers to adopt data-based decision-making abilities, particularly in programs involving smallholders adopting mobile traceability systems [33].

Technical field competencies remained the most widely discussed category across the dataset, appearing in 87% of the reviewed studies [34]. These competencies covered harvesting efficiency, precision fertilization, calibrated agrochemical application, low-impact land preparation, and mechanical operations. Studies measuring productivity outcomes after technical upskilling interventions demonstrated yield improvements ranging from 8–15% in harvesting efficiency and reductions of 5–12% in crop losses due to improved fruit handling techniques [35]. Another study analyzing precision fertilization skills found nutrient-use efficiency improvements of 6–9%, resulting in optimized fertilizer costs without compromising yield performance [36].

Sustainability-related competencies have also gained significant attention. These include climate-smart cultivation, biodiversity protection, soil conservation, and water-quality management competencies that were mentioned in 63% of the reviewed articles, representing a substantial increase from pre-2019 literature. This trend aligns with global sustainability expectations, as more than 15 million hectares of palm oil land are now subject to sustainability compliance frameworks.

Studies focusing on supervisory roles identified advanced competencies such as team-based performance management, productivity monitoring, resource-use optimization, and implementation of continuous improvement (Kaizen) approaches. Six studies reported that supervisors who completed competency-oriented managerial training demonstrated improvements of 12–19% in labor productivity indicators after 6–9 months of follow-up assessments [37]. Additionally, transversal competencies, communication, adaptability, leadership, and problem-solving appeared in 40% of the dataset, reflecting the broader demand for soft skills across digitally modernizing plantation environments [38].

Overall, the literature indicated that competency requirements in the palm oil sector are undergoing broad diversification, moving from predominantly technical field capabilities toward a multidimensional competency model integrating sustainability knowledge, managerial competencies, and productivity-enhancing abilities [39]. These evolving expectations reflect the trajectory of global palm oil markets, where sustainability, traceability, and resource efficiency are increasingly interconnected with workforce competency structures.

Digital and Green Skills as Emerging Workforce Priorities

A prominent theme across the SLR dataset is the rapid emergence of digital and green skills as foundational elements of the workforce transformation in sustainable palm oil employment. Digital skills were referenced in 21 out of 30 studies (70%), highlighting strong momentum toward digitized plantation management systems. These digital competencies include geospatial mapping, remote sensing analysis, mobile reporting, digital record-keeping for compliance, and operationalization of traceability systems [40].

A subset of empirical studies demonstrated that plantations using geo-referenced mapping tools achieved 5–11% optimization in fertilizer distribution through more precise field boundary identification and nutrient hotspot mapping [41]. Another group of studies discussed drone-based monitoring systems, in which workers trained in UAV operation generated vegetation index data (NDVI, SAVI) to detect crop stress, drainage issues, or early disease symptoms. Studies showed that plantations adopting drone-supported monitoring achieved 10–22% operational efficiency improvements depending on the extent of integration, workforce readiness, and terrain complexity [42,43].

Digital literacy was consistently highlighted as essential not only for field supervisors but also for extension officers working with smallholders, particularly in traceability systems linked with government sustainability verification platforms. Studies reported that smallholders trained in mobile-based reporting systems improved submission accuracy by 28–34%, strengthening audit readiness and compliance performance [44].

Green skills, including sustainable land management, biodiversity conservation, carbon accounting, and pollution control, were highlighted in 19 studies (63%). These competencies align with broader sustainability indicators tied to certification frameworks, emissions reporting, and deforestation-free supply chain standards. Empirical studies reported that green skill training in soil conservation and nutrient cycling led to 3–7% reductions in fertilizer use while maintaining yield outcomes [45]. Meanwhile, waste-management and chemical-handling training increased environmental compliance rates by 12–18% in operational audits [46].

Several studies analyzing biodiversity-related competencies found that workers trained in habitat-sensitive practices achieved 5–9% improvements in biodiversity conservation indicators, including reduced human–wildlife conflict incidents and more consistent implementation of riparian-buffer management.

The combined evidence across the dataset consistently positions digital and green skills as transformative elements capable of strengthening both operational efficiency and environmental performance. These competencies support long-term sector competitiveness, particularly as demand for certified and traceable palm oil continues to rise in global markets.

Training Pathways and Workforce Development Models

The studies included in the SLR revealed substantial diversity and innovation in training pathways across the sustainable palm

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oil sector, reflecting a combination of corporate training systems, government-supported vocational programs, and NGO-led capacity-building initiatives. These pathways were organized into three dominant training formats: structured technical training, sustainability and compliance training, and multi-disciplinary vocational training integrating technical, digital, and green modules [47].

Structured technical training programs remained the most widely reported, appearing in 80% of the reviewed studies. These programs covered skills in harvesting, field maintenance, seedling management, agrochemical calibration, and basic mechanization. Empirical findings showed that efficiency gains from such programs ranged from 9% to 20%, depending on prior skill levels, training duration, and equipment used [48]. Studies specifically focusing on mechanized operations reported time-efficiency improvements of 14–18%, particularly in infield collection and inter-row maintenance.

Sustainability-oriented training programs were mentioned in 60% of the reviewed studies, emphasizing safe chemical handling, environmental safeguards, biodiversity conservation, and waste-management procedures [49]. One study reported that participants who completed environmental compliance modules improved audit performance by 15% in the subsequent certification cycle.

Vocational training programs integrating multi-module capacity-building were reported in 14 studies and often involved collaboration among palm oil companies, government vocational centers, and educational institutions. Programs adopting blended technical–green curricula achieved certification pass rates exceeding 85%, demonstrating strong alignment between training modules and competency assessment standards [50].

Digital and blended training models expanded significantly after 2020 due to logistical constraints during the pandemic. Online and mobile-based training formats were associated with 30–40% increases in participation, especially among smallholders who previously faced travel and opportunity-cost barriers [51]. Studies also documented that blended digital–classroom training formats led to 9–14% improvements in long-term knowledge retention compared to in-person-only formats.

Overall, the literature highlighted that training pathways are most effective when they integrate structured curriculum design, clear learning outcomes, modular assessments, and longitudinal monitoring of competency development [52]. These elements collectively strengthen the scalability of upskilling initiatives across diverse workforce segments.

Institutional and Policy Support for Skills Development

Institutional and policy mechanisms emerged as central drivers of workforce transformation within the palm oil sector. 17 out of 30 studies (57%) highlighted the influence of government-supported training frameworks, national certification systems, sustainability regulations, and coordinated extension services in shaping skills development priorities [53].

Studies documented substantial contributions from national vocational systems aligning competency standards with plantation occupational profiles. Workers enrolled in these certification-aligned programs experienced 8–12% year-on-year increases in certification rates, reflecting improved accessibility and relevance of the training ecosystem [54].

Research on multi-stakeholder collaborations noted that public–private training centers experienced enrollment increases of 22–35% after introducing competency-based modules developed in collaboration with industry experts [55]. Similar growth patterns were observed in sustainability training adoption, where partnerships between government extension services and NGOs increased smallholder participation rates by 18–27%, particularly in regions with active sustainability verification programs.

Policy frameworks supporting green job transitions were highlighted in 11 studies, which emphasized integrating environmental indicators into labor development policies at national and provincial levels [56]. These strategies contributed to increased demand for workers with competencies in emission monitoring, resource-efficiency management, and environmental compliance auditing.

Smallholder-oriented policy interventions were widespread across the reviewed literature. Studies focusing on digital extension services showed that extension officers trained in sustainability, digital tools, and data reporting achieved 10–16% improvements in compliance performance among participating smallholders after targeted training cycles [57]. Moreover, policies mandating minimum training hours for agrochemical handlers and field supervisors contributed to measurable improvements in safety compliance, ranging from 11–19%, depending on estate size and baseline compliance conditions.

Overall, the evidence underscores that institutional alignment among government, private-sector, and civil-society actors significantly enhances the scalability, legitimacy, and sustainability of workforce development initiatives in the palm oil sector.

Emerging Competency-Based Models for Green Job Creation

Competency-based training (CBT) models represented a consistent cross-cutting theme in the reviewed literature, with 20 out of 30 studies (67%) identifying CBT approaches as effective mechanisms for supporting green job formation and broader sustainability transitions. These models stress clearly defined learning outcomes, observable performance criteria, and structured skill-based assessments rather than traditional time-based learning models.

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A subset of studies documented strong impacts of CBT frameworks on environmentally oriented roles. Competency-based programs in integrated pest management (IPM) demonstrated reductions in pesticide use of 12–25%, while maintaining or improving yield quality indicators [58]. Similarly, CBT modules focused on soil and water conservation led to more consistent implementation of riparian buffer-zone management, resulting in 6–10% improvements in water-quality indicators across selected plantation sites.

Studies emphasizing mid-level managerial upskilling found that CBT-based leadership and operational modules resulted in 10–18% improvements in productivity and sustainability indicators. Such modules strengthened applied problem-solving, resource-use optimization, and performance-monitoring competencies among supervisors and assistant managers [59].

Competency-based models were also found to be highly scalable for smallholder training. Digital competency modules delivered via mobile learning platforms achieved knowledge retention rates of 72–81%, exceeding those of traditional lecture-based methods, which averaged 55–63% [60]. Meanwhile, competency-aligned sustainability modules increased certification audit scores by 9–13% among participating smallholders, strengthening their readiness for compliance and market-access requirements [61].

Across the literature, competency-based approaches demonstrated strong alignment with sector-wide sustainability goals, supporting roles in waste-to-resource management, carbon accounting, biodiversity monitoring, and green supply chain operations. As the palm oil sector increasingly embraces data-driven, sustainability-oriented practices, CBT frameworks offer a structured, measurable platform for preparing the workforce for these evolving demands.

Discussion

This discussion synthesizes the 30 peer-reviewed articles included in the systematic review to address the two research questions: (1) how current studies conceptualize and operationalize skills development and competency-based training pathways in sustainable palm oil employment, and (2) how emerging competency frameworks particularly digital, environmental, and managerial skills contribute to green job creation and support sustainability transitions in the palm oil sector. The analysis integrates cross-study insights, compares conceptual orientations, highlights methodological tendencies, and identifies areas in which competency-based approaches are evolving to support sectoral transformation.

Conceptualization and Operationalization of Skills Development and Competency-Based Training Pathways (RQ1)

The review shows that peer-reviewed studies converge on the idea that skills development within the palm oil sector is increasingly framed through the lens of workforce modernization, sustainability imperatives, and technological upgrading. Across the literature, skills are conceptualized not merely as individual attributes but as structured components of broader competency systems that align with sustainable production models and evolving labor expectations [62]. This reflects a shift from traditional training approaches toward integrated competency-based frameworks designed to ensure consistency, verifiability, and relevance to sustainability goals.

Competency as a Multi-Dimensional Construct

Most studies conceptualize competency as a multidimensional combination of knowledge, technical proficiency, problem-solving skills, and the capacity to apply practices consistent with environmental and social standards, with several integrating behavioral and managerial dimensions. These conceptualizations mirror trends in other resource-based industries, where standardized competency profiles are used to define job roles, guide curriculum development, and structure industry-wide certification systems [63,64]. Within the palm oil context, competencies are operationalized through modular training programs, structured skill matrices, and assessment tools to verify job readiness and compliance with sustainability benchmarks [65].

Operational Approaches Used in the Literature

Three major operational pathways emerged from the reviewed studies:

i. Task-based competency models focus on translating specific operational requirements into measurable units of competence. Studies adopting this approach highlight activities such as harvesting techniques, nursery management, safety compliance, and equipment operation, emphasizing the alignment of training with actual production needs. By operationalizing competencies in this manner, training institutions can design curricula that are clear, performance-oriented, and closely linked to the practical demands of sustainable palm oil operations [66].

ii. Integrated sustainability competency frameworks operationalize workforce skills by combining agricultural, environmental, and social knowledge. Studies in this category emphasize competencies such as biodiversity awareness, waste management, chemical handling, and water stewardship, integrating these elements into structured training curricula. This approach ensures that workforce capabilities are aligned with sustainability principles and meet broader stakeholder expectations within the palm oil sector [67,68].

iii. Progression-oriented training pathways operationalize competencies by structuring progressive learning stages that support career mobility and long-term workforce development. These pathways guide workers from foundational technical skills to advanced supervisory and managerial capabilities, reinforcing

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the concept of lifelong learning and continuous upskilling within the palm oil sector [69].

Across these operational models, the literature consistently links competency development to structured assessment, workplace mentoring, and iterative evaluation systems that ensure continuous improvement rather than one-time certification [70]. This signals an important trend: the operationalization of skills development in sustainable palm oil employment is increasingly tied to long-term workforce transformation rather than short-term capacity building.

Methodological and Analytical Orientations in the Literature

Most articles rely on qualitative and mixed-method approaches, typically using document analysis, interviews, or curriculum mapping to explore how competencies are conceptualized or implemented. A smaller number employ quantitative skill gap assessments or workforce surveys to measure competency distribution across job roles [71]. Despite methodological diversity, studies share an emphasis on aligning training systems with sustainability standards and labor market expectations.

However, a notable gap is the limited use of longitudinal studies that trace competency acquisition over time or evaluate the impact of training on job outcomes. Similarly, studies rarely incorporate comparative analyses across countries or production systems, limiting the generalizability of operational models. These gaps illustrate opportunities for future research to deepen empirical understanding of competency system effectiveness.

Alignment with Sectoral Transformation Goals

A recurring theme across studies is the alignment between skills development and broader transformation goals, including improved productivity, compliance with sustainability standards, and enhanced worker welfare [72]. Competency-based training is operationalized as a mechanism to integrate sustainability principles into daily operations, support technology adoption, and strengthen supply-chain credibility. Importantly, this framing positions skills development not as a corrective measure but as an enabler of sectoral resilience and long-term competitiveness [73].

Overall, findings from RQ1 demonstrate that the literature positions skills development as a structured, competency-driven process increasingly aligned with sustainability transitions and workforce modernization priorities. The operationalization of competencies through task-based, integrated, and progressive models indicates a growing institutionalization of structured training pathways within the palm oil sector.

Contribution of Emerging Competency Frameworks to Green Job Creation and Sustainability Transitions (RQ2)

The second research question examines how digital, environmental, and managerial competencies contribute to green job creation and sustainability transitions within the palm oil sector. The synthesis reveals that emerging competency frameworks operate as catalysts in three critical areas: (1) enabling technology integration, (2) supporting environmentally responsible production practices, and (3) strengthening organizational and managerial capacities essential for sustainability governance.

Digital Competencies and Technological Transformation

Digital skills are increasingly central to green job creation, as technology adoption becomes more prevalent across plantation management, monitoring systems, and supply-chain documentation. Studies highlight the role of digital literacy in supporting precision agriculture, geographic information systems, remote sensing, and automated data collection tools [74]. Workers with digital competencies are better positioned to participate in emerging roles connected to smart farming and sustainability monitoring, including positions that involve analyzing environmental data, overseeing traceability platforms, or managing digital compliance systems [75].

The literature suggests that digital competencies not only enhance technical efficiency but also support environmental outcomes by enabling more accurate resource planning, reduced input usage, and improved detection of sustainability risks. Several studies note that digital competency frameworks expand employment pathways by creating hybrid technical-environmental roles that align with green job principles [76].

Environmental Competencies and Green Job Expansion

Environmental competencies such as knowledge of eco-efficient practices, climate-related risk management, soil and nutrient management, and biodiversity-friendly methods are consistently linked to green job creation in the reviewed literature. These competencies provide the foundation for roles associated with environmental monitoring, conservation activities, waste reduction, and ecosystem restoration [77].

Studies emphasize that environmental competencies support sustainability transitions by equipping workers to implement climate-smart agricultural practices, adhere to environmental performance standards, and contribute to organizational sustainability targets. This contributes to expanded labor demand for roles such as environmental field technicians, sustainability coordinators, conservation officers, and compliance specialists [78].

Environmental competencies thereby serve as a mechanism through which the sector aligns workforce capabilities with long-term sustainability strategies while also generating employment opportunities in newly formalized green roles.

Managerial Competencies and Governance-Oriented Green Jobs

Managerial competencies encompass leadership, strategic planning, decision-making, communication, and the integration of sustainability considerations into organizational processes.

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Studies underline the importance of these competencies in supervising sustainable operations, coordinating multi-stakeholder engagement, and managing internal sustainability reporting systems [79].

Managerial competencies play a crucial role in expanding green job functions related to sustainability governance, monitoring, and implementation. These include supervisory roles in sustainable operations, positions responsible for guiding certification processes, and managerial roles overseeing environmental or social compliance. Studies also indicate that managerial competencies enhance organizational adaptability by facilitating cross-functional integration of sustainability goals into everyday operations [80].

Convergence of Digital, Environmental, and Managerial Competencies

A key insight from the reviewed literature is that green job creation is most robust when digital, environmental, and managerial competencies converge within integrated competency frameworks. Such integration enables workers to navigate the complexity of sustainability transitions, where technology, environmental stewardship, and organizational governance increasingly intersect.

This convergence also supports the evolution of hybrid roles, such as digital-environmental supervisors, sustainability data analysts, and eco-efficiency coordinators, which represent emerging categories of green employment. The literature collectively suggests that these hybrid competency profiles will become increasingly important as sustainability reporting requirements intensify and technological transformation accelerates [81].

Overall, findings from RQ2 show that emerging competency frameworks contribute to green job creation not only by enabling compliance and environmental improvement but also by expanding specialized roles and supporting organizational transitions toward sustainability-aligned business models.

The synthesis of findings across the two research questions provides several implications for research, practice, and policy. First, the review indicates that competency-based models offer a structured and scalable approach to skills development that aligns with sustainability transitions in the palm oil sector. The integration of digital, environmental, and managerial competencies positions the workforce to support technological innovation, environmental stewardship, and organizational governance, underscoring the importance of competency-based approaches in enabling green job growth.

Second, the progressive institutionalization of competency frameworks suggests that training systems will increasingly play a strategic role in shaping sectoral transformation. This highlights the need for sustained investment in training infrastructure, curriculum modernization, and cross-sector collaboration to ensure that competency frameworks remain responsive to evolving sustainability expectations.

However, the review also identifies notable research gaps. Few studies evaluate the long-term effectiveness of competency-based training programs or assess how competencies translate into measurable environmental or employment outcomes. Additionally, limited comparative analyses across regions or certification systems restrict understanding of how competency frameworks operate under different institutional conditions. There is also a need for more empirical work exploring the relationship between digital transformation and green job dynamics within palm oil production landscapes.

Future research would benefit from longitudinal evaluations of training impacts, expanded cross-country comparisons, and mixed-method studies integrating workforce data with environmental performance indicators. Such research would deepen understanding of how competencies evolve, how they shape labor-market structures, and how they contribute to sustained environmental outcomes.

Overall, the findings from this systematic review demonstrate that competency-based skills development constitutes a foundational enabler of sustainable employment and green job creation in the palm oil sector. Continued scholarly attention to the refinement, integration, and assessment of competency frameworks will be essential for supporting workforce resilience and advancing sustainability transitions in the years ahead.

Conclusion

This systematic review demonstrates that skills development and competency-based training in the palm oil sector are increasingly structured, multi-dimensional, and aligned with sustainability-oriented workforce transformation. Across the 30 peer-reviewed studies analyzed, skills are consistently conceptualized not as isolated technical abilities but as integrated competency constructs combining knowledge, practical expertise, problem-solving capacity, digital literacy, environmental awareness, and managerial capability. These competencies are operationalized through task-based models, sustainability-integrated frameworks, and progressive training pathways that reinforce continuous learning and long-term workforce strengthening.

The synthesis of evidence shows that emerging competency frameworks, particularly those emphasizing digital, environmental, and managerial skills, play a critical role in shaping green job creation. Digital competencies enable the uptake of precision agriculture, data-driven monitoring, and traceability systems, supporting both efficiency and sustainability objectives. Environmental competencies underpin the expansion of roles related to ecological stewardship, compliance, and climate-responsive management practices. Managerial competencies, meanwhile, reinforce organizational alignment with sustainability standards through leadership, coordination, and implementation of gover-

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nance mechanisms. Together, these competency domains form an interconnected foundation for new hybrid green roles that bridge technology, environmental management, and supervisory functions.

The review further highlights that competency-driven approaches contribute to broader sustainability transitions by equipping the workforce with the capabilities necessary to support innovation, comply with international sustainability expectations, and adapt to evolving production landscapes. While current literature provides substantial conceptual and operational insights, gaps remain in longitudinal evidence, cross-country comparisons, and empirical evaluations linking competency acquisition to concrete environmental or employment outcomes. These gaps present opportunities for future research to deepen understanding of how competency systems evolve, shape workforce pathways, and contribute to sustained improvements within the sector.

Overall, the findings confirm that competency-based skills development is a central enabler of sustainable employment and green job expansion in the palm oil sector. The integration of technical, digital, environmental, and managerial competencies positions the sector's workforce to support ongoing transformations while maintaining alignment with sustainability requirements and global market expectations.

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