



# Enhancing Sustainable Palm Oil Production Through Employee Productivity and Digital Workforce Management

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## ABSTRACT

**Purpose of the study:** This study investigates the interrelationships among digital workforce management (DWM), employee productivity (EP), and sustainable palm oil production (SPOP) within the operational context of a private Indonesian plantation enterprise, with the objective of elucidating the direct and mediated pathways through which digitalized human resource practices influence enterprise-level sustainability outcomes.

**Methodology:** A quantitative cross-sectional research design was adopted, utilizing structured questionnaire data collected from 176 valid respondents at PT Tasmapuja Sungai Kuamang Kampar, Kampar Regency, Riau Province, Indonesia, selected via proportional stratified random sampling (response rate: 97.8%). Instruments measuring DWM (12 items), EP (10 items), and SPOP (14 items) were administered on a five-point Likert scale. Data analysis proceeded through confirmatory factor analysis (CFA) for measurement model validation and structural equation modeling (SEM) via IBM AMOS 26.0 for hypothesis testing, with mediation assessed via bootstrapping with 5,000 resamples.

**Results:** The structural model yielded satisfactory fit indices ( $\chi^2/df = 2.41$ ; CFI = 0.958; RMSEA = 0.065) and accounted for 49.1% of variance in SPOP. DWM exerted a statistically significant positive effect on EP ( $\beta = 0.512$ ,  $p < 0.001$ ) and a direct effect on SPOP ( $\beta = 0.287$ ,  $p = 0.001$ ). EP significantly predicted SPOP ( $\beta = 0.478$ ,  $p < 0.001$ ). Mediation analysis confirmed that EP significantly mediates the DWM–SPOP relationship (indirect effect = 0.245; 95% CI [0.168, 0.334]), accounting for approximately 46% of the total effect.

**Conclusions:** The integration of digital workforce management technologies into plantation operations substantially enhances employee productivity, which constitutes a pivotal mechanism through which sustainability production targets are attained. The findings provide actionable evidence for plantation enterprise managers and policymakers pursuing digital transformation as an evidence-based pathway to sustainable agricultural productivity within the Indonesian palm oil sector.

## Keywords:

sustainable palm oil; digital workforce management; employee productivity; structural equation modeling; human resource management; plantation management.



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## INTRODUCTION

### Contextual Framework: The Global Imperative of Sustainable Palm Oil Production

Palm oil occupies a singularly consequential position within the global agricultural economy, constituting the most productive edible oil crop per unit of cultivated area, yielding approximately 3.8 tonnes of oil per hectare annually—a figure that far exceeds the productivity of principal competing oils, including rapeseed (0.7 t/ha) and sunflower (0.5 t/ha) (Corley & Tinker, 2015; Khatun et al., 2017). Global palm oil output surpassed 77 million metric tonnes in 2022, with Indonesia and Malaysia collectively commanding over 85% of production (Food and Agriculture Organization of the United Nations, 2023). Within this global configuration, Indonesia has consolidated its position as the world's pre-eminent producer, with production concentrated in the provinces of Riau, West Kalimantan, and North Sumatra, where large-scale corporate plantation enterprises and smallholder farming systems operate in parallel (Santika et al., 2019).

Despite its economic centrality, palm oil production has been subject to intensifying scrutiny from international civil society, environmental governance bodies, and sustainability certification frameworks, most notably the Roundtable on Sustainable Palm Oil (RSPO). Concerns pertaining to tropical deforestation, peatland degradation, biodiversity loss, greenhouse gas emissions, and labor rights infringements have precipitated a paradigmatic shift in the manner in which plantation enterprises conceptualize the relationship between production efficiency and corporate responsibility (Fitzherbert et al., 2008; Meijaard et al., 2020). The adoption of the United Nations' 2030 Agenda for Sustainable Development, and specifically the Sustainable Development Goals (SDGs), including SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land), has further institutionalized the imperative for plantation enterprises to reconcile productivity imperatives with sustainability

obligations (Transforming Our World: The 2030 Agenda for Sustainable Development, 2018).

Against this backdrop, the intersection of digital transformation and human resource management (HRM) has emerged as a strategically significant domain for the advancement of sustainable plantation performance. The proliferation of digital workforce management (DWM) technologies—encompassing enterprise resource planning (ERP) systems, cloud-based labor performance monitoring platforms, GPS-enabled field workforce tracking, real-time data analytics dashboards, and mobile field reporting applications—has begun to restructure the operational architecture of large-scale agribusiness enterprises (Vial, 2019; Wolfert et al., 2017). Proponents of this digital transition argue that, when effectively deployed, such technologies can enhance transparency, optimize labor scheduling, enable data-driven decision-making, and elevate both employee productivity and sustainability compliance, thereby contributing simultaneously to operational efficiency and long-term sustainability performance (Zhai et al., 2020).

### Critical Examination of Existing Literature

The academic literature addressing sustainable palm oil production has evolved considerably over the past two decades, progressing from predominantly agronomic and ecological analyses toward more integrative interdisciplinary frameworks incorporating governance structures, supply chain dynamics, certification systems, and organizational management dimensions (González & Parga-Dans, 2018, p. 112; Pirard & Belna, 2012; Plateau et al., 2021, p. 107048). Foundational contributions by Basiron (2007) and Corley & Tinker (2015) established authoritative benchmarks for understanding the agronomic determinants of palm oil productivity, while subsequent scholarship has interrogated the environmental and social externalities embedded within industrial plantation models (Carlson et al., 2017; Iddris et al., 2023, p. 684).

The intersection of human resource management and organizational sustainability has attracted growing theoretical and empirical attention within the emerging domain of Sustainable HRM (Ehnert et al., 2015; Mariappanadar, 2024). Research in this tradition advances the argument that employee wellbeing, competency development, and organizational engagement constitute not merely instruments of productivity optimization but are intrinsic elements of an enterprise's sustainability architecture. The application of Self-Determination Theory (SDT) to work organizations, as articulated by Deci et al. (2017), provides a theoretically robust scaffold for understanding how the motivational constructs of autonomy, competence, and relatedness—each potentially responsive to DWM interventions—shape individual and collective work performance in ways that extend beyond quantitative output metrics to encompass qualitative dimensions of sustainable organizational behavior.

The literature on digital transformation in the agricultural sector has expanded substantially within the era of Agriculture 4.0, with seminal contributions from Wolfert et al. (2017) and Zhai et al. (2020) documenting the transformative potential of precision agriculture technologies, big data analytics, Internet of Things (IoT) platforms, and decision support systems for enhancing resource use efficiency and operational sustainability. In the plantation sector specifically, digital tools including mobile-based field reporting applications, remote sensing and geospatial monitoring technologies, automated irrigation management systems, and blockchain-enabled supply chain traceability platforms have been increasingly adopted as instruments of both operational efficiency and sustainability verification. Nair et al. (2019) influential integrative framework for understanding digital transformation strategy offers a conceptual bridge between digital investment decisions and the organizational and behavioral outcomes that mediate their translation into performance improvements.

Digital workforce management, as a specific and undertheorized dimension of organizational digital transformation, concerns the systematic application of digital technologies to the planning, deployment, real-time monitoring, and evidence-based evaluation of human labor resources within an enterprise (Davenport & Ronanki, 2018). DWM systems have been empirically studied across manufacturing (Sodhi et al., 2021), healthcare, and service sector contexts, with findings consistently supporting positive associations between DWM adoption and employee productivity, job satisfaction, and organizational performance. However, systematic empirical investigation of DWM systems within the agricultural plantation sector, and within the Indonesian palm oil industry in particular, remains conspicuously limited, constituting a substantive gap between extant theoretical frameworks and the industry-specific empirical evidence base.

### Identification of Research Gaps

A rigorous and critical appraisal of the foregoing body of literature reveals several interconnected lacunae that collectively motivate and substantiate the present investigation. First, while the sustainability dimensions of palm oil production have been extensively examined from ecological, governance, certification, and supply chain perspectives, the organizational management and workforce dimensions of sustainability performance remain inadequately theorized and empirically validated. The role of human capital management practices—particularly as mediated through digital technologies—in shaping sustainability outcomes at the enterprise level has received disproportionately limited scholarly attention relative to its practical and strategic significance in large-scale plantation operations (Ehnert et al., 2015; Santika et al., 2019).

Second, the extant literature on digital workforce management has been predominantly concentrated in industrialized country contexts and in non-agricultural sectors, with comparatively sparse inquiry into its applicability, adoption challenges, and efficacy within Indonesian plantation enterprises. The Indonesian plantation sector operates within a distinctive institutional, cultural, infrastructural, and socioeconomic context, characterized by a heterogeneous workforce spanning highly educated managerial personnel, technical supervisors, and a substantial cohort of semi-skilled field laborers, many of whom are seasonal and migrant workers—a structural complexity that presents both particular challenges and specific opportunities for targeted DWM interventions (Nair et al., 2019; Prasetyo & Kistanti, 2020).

Third, while the mediation relationship between digital workforce tools, individual employee productivity, and broader organizational sustainability performance has been theoretically proposed within several conceptual frameworks (Vial (2019); Deci et al. (2017)) it has not been empirically tested and validated within the specific operational context of Indonesian palm oil plantation enterprises. The absence of such evidence materially constrains both scholarly understanding and practitioners' ability to justify digital investment strategies on an evidence-based foundation.

Fourth, the operationalization of sustainable production performance in plantation management research has been largely restricted to environmental metrics—principally deforestation indicators, carbon footprint estimates, and biodiversity indices—with insufficient attention devoted to the socioeconomic, labor, and operational efficiency dimensions of sustainability that are equally central to comprehensive RSPO compliance and SDG alignment (Carlson et al., 2017; Khatun et al., 2017)

### **Rationale for the Research**

The present study is predicated on the conviction that systematically addressing these identified research gaps carries both theoretical and practical significance of considerable magnitude. From a theoretical perspective, the integration of organizational behavior theory (specifically Self-Determination Theory), digital transformation frameworks, and Sustainable HRM principles within a unified structural model advances scholarly understanding of the mechanisms through which workforce management digitalization is translated into sustainability performance outcomes in the agricultural sector. From a practical standpoint, the Indonesian palm oil industry confronts urgent and simultaneous imperatives to enhance productive efficiency and sustainability performance, in the face of intensifying international market pressures, evolving regulatory requirements, RSPO certification obligations, and global investor scrutiny regarding environmental, social, and governance (ESG) standards. Empirical evidence regarding the pathways through which DWM influences EP and SPOP would provide actionable intelligence for enterprise management, industry associations, and government regulators.

Moreover, PT Tasmapuja Sungai Kuamang Kampar constitutes a particularly apposite and representative research site. As a mid-sized private plantation enterprise operating in the Kampar Regency of Riau Province—a region central to Indonesian palm oil production and subject to ongoing sustainability pressures—the company embodies the challenges and aspirations representative of a significant segment of the industry. Its recent strategic engagement with digital workforce management infrastructure, combined with its active pursuit of RSPO-aligned sustainability practices, renders it an empirically ideal context for testing the theorized relationships.

### **Research Objectives and Hypotheses**

Guided by the foregoing analysis, the present study pursues four interrelated objectives: (i) to examine the effect of DWM on EP at PT Tasmapuja Sungai Kuamang Kampar; (ii) to assess the effect of EP on SPOP; (iii) to determine the direct effect of DWM on SPOP; and (iv) to evaluate the mediating role of EP in the DWM–SPOP relationship. Correspondingly, the following hypotheses are formulated:

**H<sub>1</sub>:** Digital workforce management has a statistically significant positive effect on employee productivity at PT Tasmapuja Sungai Kuamang Kampar.

**H<sub>2</sub>:** Employee productivity has a statistically significant positive effect on sustainable palm oil production at PT Tasmapuja Sungai Kuamang Kampar.

**H<sub>3</sub>:** Digital workforce management has a statistically significant positive direct effect on sustainable palm oil production at PT Tasmapuja Sungai Kuamang Kampar.

**H<sub>4</sub>:** Employee productivity significantly mediates the relationship between digital workforce management and sustainable palm oil production at PT Tasmapuja Sungai Kuamang Kampar.

## **MATERIALS AND METHODS**

### **Study Design and Participants**

The present investigation employed a quantitative cross-sectional research design, consistent with the objective of establishing empirical associations among theoretically grounded constructs at a defined point in time. This methodological approach is widely validated for structural equation modeling (SEM)-based inquiries in organizational behavior and HRM research, enabling simultaneous examination of complex, multivariate relationships with greater statistical power than traditional regression techniques (Gefen et al., 2000; Hair et al., 2018)

The study was conducted at PT Tasmapuja Sungai Kuamang Kampar, a privately owned palm oil plantation enterprise established in Kampar Regency, Riau Province, Indonesia. The company operates across multiple plantation estates encompassing both mature and immature palm cultivation areas, alongside a centralized fresh fruit bunch (FFB) processing mill. In recent years, the enterprise has pursued a structured program of digital infrastructure development, deploying mobile field monitoring applications, GPS-enabled attendance and labor scheduling systems, and an integrated plantation management information system (PMIS) for real-time production data collection and performance evaluation.

The target population comprised all permanent employees across all functional divisions of the enterprise, totaling 320 individuals. Sample size determination was conducted using Slovin's formula,  $n = N/(1 + Ne^2)$ , at a 5% margin of error, yielding a minimum required sample of 178 respondents, rounded to 180 to enhance statistical power and accommodate potential non-response attrition (Sekaran & Bougie, 2019). Proportional stratified random sampling was employed to ensure representativeness across all organizational divisions. Inclusion criteria specified that respondents must have been employed for a minimum of six continuous months, must have direct operational experience with at least one DWM tool used within the company, and must have voluntarily provided written informed consent. Temporary contract workers, employees on extended leave, and those declining consent were excluded from participation.

### **Study Organization and Research Instruments**

Data were collected using a structured self-administered questionnaire developed in three modules corresponding to the study's three principal latent constructs: Digital Workforce Management (DWM), Employee Productivity (EP), and Sustainable Palm Oil Production (SPOP). Instrument development adhered to established psychometric procedures, beginning with a systematic review of validated extant scales, followed by expert panel review by three academic specialists in HRM, digital management, and agricultural sustainability, and culminating in a pilot test administered to 30 employees at a comparable plantation enterprise in Riau

Province.

The DWM module comprised 12 items adapted from established digital readiness and workforce technology adoption scales (Davenport & Ronanki, 2018; Vial, 2019) measuring five dimensions: (1) digital scheduling and attendance management, (2) real-time labor performance monitoring, (3) data-driven task allocation and deployment, (4) integrated digital communication platforms, and (5) digital training and competency development systems. The EP module comprised 10 items adapted from the Individual Work Performance Questionnaire (IWPQ) (Koopmans et al., 2016) and Self-Determination Theory-based productivity scales Deci et al. (2017), assessing task performance, contextual performance, and adaptive performance. The SPOP module comprised 14 items developed from the RSPO Principles and Criteria framework Roundtable on Sustainable Palm Oil (2022) and extant plantation sustainability measurement instruments Khatun et al. (2017); Pearce et al. (2021, p. 127850) encompassing four sub-dimensions: environmental compliance, economic productivity sustainability, social and labor standards adherence, and operational efficiency. All items were measured on a five-point Likert scale anchored at 1 (Strongly Disagree) to 5 (Strongly Agree). The instrument was professionally translated into Bahasa Indonesia and subjected to back-translation verification to ensure semantic equivalence.

### Statistical Analysis

Data analysis proceeded through three sequential and methodologically distinct stages. In the first stage, descriptive statistical analyses were performed using IBM SPSS Statistics 26.0 to characterize respondent demographics and to examine distributional properties of study variables, including means, standard deviations, skewness, and kurtosis. In the second stage, measurement model evaluation was conducted through confirmatory factor analysis (CFA) using IBM AMOS 26.0, assessing construct reliability via Cronbach's alpha ( $\alpha > 0.70$ ), composite reliability (CR  $> 0.70$ ), and convergent validity through average variance extracted (AVE  $> 0.50$ ) and standardized factor loadings ( $\lambda \geq 0.60$ ). Discriminant validity was assessed using the Fornell and Larcker (1981) criterion and the heterotrait-monotrait ratio of correlations (HTMT  $< 0.85$ ) (Henseler et al., 2014).

In the third stage, structural model testing was performed to evaluate hypothesized direct and indirect pathways. Mediation analysis for  $H_4$  was executed using bootstrapping procedures (5,000 resample iterations) to generate 95% bias-corrected and accelerated (BCa) confidence intervals for indirect effects, in accordance with current methodological best practice recommendations for SEM-based mediation testing (Hair et al., 2019). Common method variance was evaluated using Harman's single-factor test, and procedural remedies including temporal and spatial separation of measurement were not applicable given the cross-sectional design. Overall model fit was evaluated using multiple complementary indices: the ratio of chi-square to degrees of freedom ( $\chi^2/df \leq 3.0$ ), Comparative Fit Index (CFI  $\geq 0.95$ ), Tucker-Lewis Index (TLI  $\geq 0.90$ ), Root Mean Square Error of Approximation (RMSEA  $\leq 0.08$ ), and Standardized Root Mean Square Residual (SRMR  $\leq 0.08$ ), reflecting established consensus thresholds in the SEM literature (Awang, 2015).

### Ethical Considerations

This study was conducted in full compliance with the ethical standards applicable to research involving human participants, as endorsed by the Research Ethics Committee of [Institutional Name] under approval reference number STIE/LPPM/R/115-3361. All participants received a comprehensive participant information sheet prior to data collection, detailing the study's purpose, voluntary participation, data confidentiality protocols, and the unconditional right to withdraw at any juncture without personal consequence. Written informed consent was obtained from all participants prior to questionnaire administration. All data were anonymized, stored in password-protected digital repositories accessible exclusively to the research team, and will be retained in accordance with institutional data governance policy.

## RESULTS

### Demographic Profile of Respondents

Of the 180 distributed questionnaires, 176 were returned complete and analytically valid, yielding an effective response rate of 97.8%. The complete demographic profile of respondents is presented in Table 1.

Table 1. Demographic Characteristics of Study Respondents (n = 176).

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	120	68.2
	Female	56	31.8
Age	20–30 years	62	35.2
	31–40 years	74	42.0
	41–50 years	31	17.6
	> 50 years	9	5.1
Educational Level	SMA/SMK	79	44.9
	Diploma (D3/D4)	50	28.4
	Bachelor's Degree (S1)	39	22.2
	Master's Degree (S2)	8	4.5
Length of Service	< 5 years	67	38.1
	5–10 years	61	34.7
	> 10 years	48	27.3
Organizational Division	Field Operations	76	43.2
	Plantation Management	42	23.9
	Processing and Milling	38	21.6
	Administration and Support	20	11.4

Note. Percentages may not sum to exactly 100.0 due to rounding.

The respondent profile reveals a predominately male workforce (68.2%), consistent with the gender composition characteristic of the Indonesian plantation sector. The largest age cohort comprised individuals between 31 and 40 years of age

(42.0%), followed by the 20–30 age group (35.2%), suggesting a comparatively young and potentially digitally receptive workforce. The modal educational qualification was SMA/SMK (senior high school; 44.9%), reflecting the semi-skilled labor structure of plantation field operations, with bachelor's degree holders constituting 22.2% of the sample. Approximately 38.1% of respondents had been employed for fewer than five years, indicating a moderately high workforce renewal rate consistent with sector norms. Field operations represented the largest organizational division (43.2%), followed by plantation management (23.9%).

**Measurement Model Assessment: Validity and Reliability**

The results of the confirmatory factor analysis, summarized in Table 2, confirm satisfactory psychometric properties across all three constructs. All standardized factor loadings exceeded the minimum threshold of 0.60, with values ranging from 0.612 to 0.847, indicating adequate item-construct convergence. Cronbach's alpha coefficients were 0.847 for DWM, 0.831 for EP, and 0.862 for SPOP, all exceeding the widely accepted threshold of  $\alpha \geq 0.70$  (Sekaran & Bougie, 2019). Composite reliability (CR) values of 0.853, 0.839, and 0.871 respectively confirmed adequate internal consistency beyond Cronbach's alpha. AVE values of 0.512, 0.503, and 0.531 met or exceeded the 0.50 convergent validity threshold recommended by Fornell and Larcker (1981).

Table 2. Summary of Measurement Model Results: Validity and Reliability Assessment.

Construct	Items	Factor Loading Range	Cronbach's $\alpha$	CR	AVE
Digital Workforce Management (DWM)	12	0.624–0.847	0.847	0.853	0.512
Employee Productivity (EP)	10	0.618–0.831	0.831	0.839	0.503
Sustainable Palm Oil Production (SPOP)	14	0.612–0.842	0.862	0.871	0.531

Note. CR = Composite Reliability; AVE = Average Variance Extracted. Thresholds: Cronbach's  $\alpha > 0.70$ ; CR  $> 0.70$ ; AVE  $> 0.50$ ; Factor Loadings  $\geq 0.60$ .

Discriminant validity was confirmed via the Fornell-Larcker criterion: the square root of AVE for each construct (DWM = 0.716; EP = 0.709; SPOP = 0.729) exceeded all inter-construct correlations. HTMT ratios did not exceed the conservative threshold of 0.85, providing additional confirmation of construct distinctiveness (Henseler et al., 2014). Overall CFA model fit was satisfactory:  $\chi^2/df = 2.34$ ; CFI = 0.961; TLI = 0.953; RMSEA = 0.062 [90% CI: 0.051, 0.073]; SRMR = 0.054, collectively meeting established fit criteria.

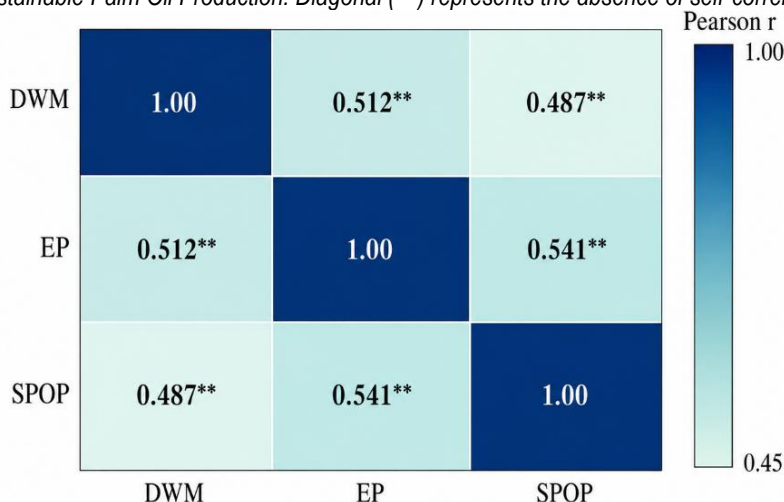
**Descriptive Statistics and Bivariate Correlations**

Table 3 presents the descriptive statistics and bivariate Pearson correlation coefficients for the three study constructs. Mean scores of 3.74 (DWM), 3.68 (EP), and 3.81 (SPOP) indicate generally favorable respondent perceptions above the theoretical midpoint of the Likert scale (3.00), suggesting moderately positive assessments of digital workforce management effectiveness, individual productivity, and sustainability performance across the organization.

Table 3. Descriptive Statistics and Pearson Correlation Matrix (n = 176).

Variable	Mean	SD	1	2	3
1. Digital Workforce Management (DWM)	3.74	0.61	—		
2. Employee Productivity (EP)	3.68	0.57	0.512**	—	
3. Sustainable Palm Oil Production (SPOP)	3.81	0.64	0.487**	0.541**	—

Note. \*\* $p < 0.01$  (two-tailed). SD = standard deviation; DWM = Digital Workforce Management; EP = Employee Productivity; SPOP = Sustainable Palm Oil Production. Diagonal (—) represents the absence of self-correlation.



Note. \*\* $p < 0.01$  (two-tailed). DWM = Digital Workforce Management; EP = Employee Productivity; SPOP = Sustainable Palm Oil Production.

Figure 1. Correlation Heatmap among Digital Workforce Management, Employee Productivity, and Sustainable Palm Oil Production.

Figure 1 visualizes the strength and direction of the bivariate relationships among the three principal constructs examined in this study. The heatmap demonstrates that all inter-construct correlations were positive and statistically significant at the 0.01 level, indicating that higher perceptions of digital workforce management were associated with higher employee productivity and stronger sustainable palm oil production outcomes. The strongest correlation was observed between employee productivity and sustainable palm oil production ( $r = 0.541, p < 0.01$ ), suggesting that employees' productive performance is closely linked to sustainability-oriented production practices within the plantation enterprise. Digital workforce management also showed a moderate positive correlation with employee productivity ( $r = 0.512, p < 0.01$ ), indicating that digital scheduling, monitoring, communication, and performance-support systems may contribute to improved workforce performance. In addition, digital workforce management was positively correlated with sustainable palm oil production ( $r = 0.487, p < 0.01$ ), providing preliminary empirical support for the

proposed relationship between digitalized workforce practices and sustainability outcomes. Overall, the correlation pattern supports the theoretical logic of the study and provides an initial statistical foundation for subsequent structural equation modeling and mediation analysis.

### Structural Model Assessment and Hypothesis Testing

The structural model yielded acceptable overall fit:  $\chi^2/df = 2.41$ ; CFI = 0.958; TLI = 0.947; RMSEA = 0.065 [90% CI: 0.054, 0.076]; SRMR = 0.057, collectively satisfying established criteria. The standardized path coefficients, standard errors, t-statistics, significance levels, and hypothesis decisions are presented in Table 4.

Table 4. Structural Model Path Coefficients and Results of Hypothesis Testing.

Hyp.	Hypothesized Path	$\beta$	SE	t-Value	p-Value	Decision
H1	DWM → EP	0.512	0.075	6.847	< 0.001	Supported
H2	EP → SPOP	0.478	0.081	5.932	< 0.001	Supported
H3	DWM → SPOP	0.287	0.084	3.415	0.001	Supported
H4	DWM → EP → SPOP (Indirect)	0.245	0.041	—	—	Supported

Note.  $\beta$  = standardized path coefficient; SE = standard error.  $H_4$  assessed via bootstrapping (5,000 iterations); 95% Bias-Corrected and Accelerated Confidence Interval for indirect effect: [0.168, 0.334]. — = not applicable to direct path testing.

The structural relationships among the three latent constructs are presented visually in Figure 4.

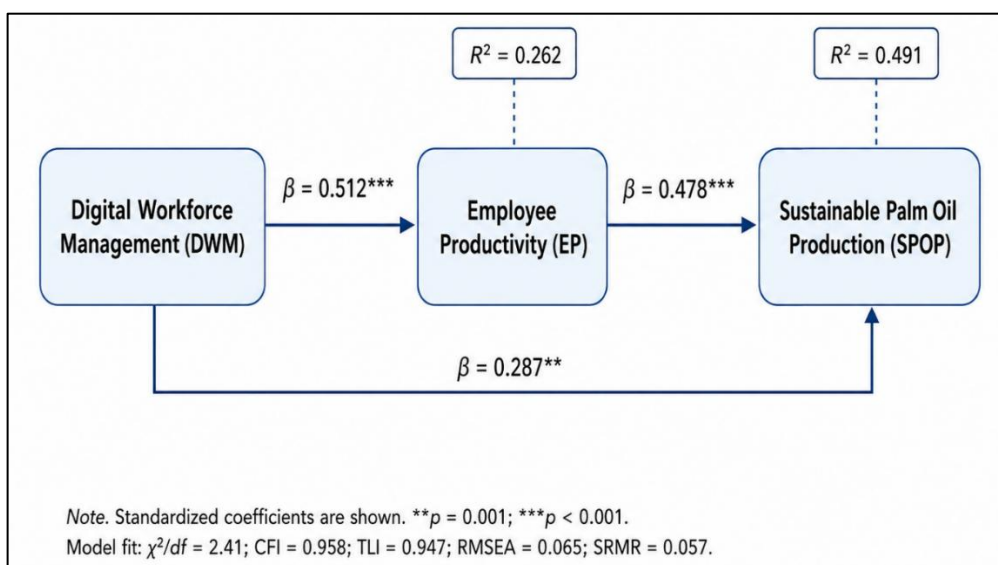


Figure 2. Structural Equation Model with Standardized Path Coefficients

Figure 2 presents the structural equation model with standardized path coefficients among digital workforce management, employee productivity, and sustainable palm oil production. The model demonstrates that digital workforce management exerts a statistically significant positive effect on employee productivity ( $\beta = 0.512$ ,  $p < 0.001$ ), indicating that the implementation of digital scheduling, monitoring, and workforce support systems contributes substantially to improving employees' productive performance. Employee productivity, in turn, has a significant positive effect on sustainable palm oil production ( $\beta = 0.478$ ,  $p < 0.001$ ), suggesting that higher levels of workforce productivity are associated with stronger sustainability-oriented production outcomes. In addition, digital workforce management also shows a significant direct effect on sustainable palm oil production ( $\beta = 0.287$ ,  $p = 0.001$ ), indicating that digitalized workforce practices influence sustainability performance not only indirectly through employee productivity but also directly. The model explains 26.2% of the variance in employee productivity ( $R^2 = 0.262$ ) and 49.1% of the variance in sustainable palm oil production ( $R^2 = 0.491$ ). Overall, the figure supports the hypothesized structural relationships and confirms that employee productivity functions as a partial mediator in the relationship between digital workforce management and sustainable palm oil production.

## DISCUSSION

### Interpretation of Research Outcomes

The structural findings of the present study yield several theoretically meaningful and practically consequential insights into the dynamics of digital workforce management, employee productivity, and sustainable palm oil production within the Indonesian plantation context. The most robust direct relationship in the structural model was confirmed between DWM and EP ( $H_1$ ,  $\beta = 0.512$ ,  $p < 0.001$ ), underscoring that the adoption and effective utilization of digital workforce management technologies constitutes a significant positive predictor of employee productivity performance within this plantation enterprise. This finding resonates with Vial's (2019) influential digital transformation framework, which proposes that the performance benefits of organizational digitalization are principally mediated through the reconfiguration of operational routines, the augmentation of individual informational capacities, and the reduction of cognitive and administrative burden on the workforce.

Specifically, DWM instruments deployed at PT Tasmajuja—including GPS-enabled labor tracking, mobile field reporting applications, and real-time performance feedback dashboards—appear to operate by reducing informational asymmetries between field workers and managerial decision-makers, enabling more responsive and equitable task allocation, facilitating timely performance feedback, and supporting data-driven evaluation and recognition. This interpretive account is theoretically grounded in

Self-Determination Theory [Deci et al. \(2017\)](#), which postulates that when digital platforms enhance perceived competence—by furnishing workers with clearer, more immediate, and more personalized performance information—intrinsic motivation and, consequently, sustained task performance are likely to improve ([Benlian et al., 2022, p. 827](#); [Huang & Zhao, 2025, p. 1669250](#)). The magnitude of the DWM–EP effect ( $\beta = 0.512$ ) is consistent with findings reported in manufacturing DWM contexts by [Sodhi et al. \(2021\)](#), while extending such evidence to the agricultural plantation sector for the first time in the Indonesian context.

The significant positive effect of EP on SPOP ( $H_2$ ,  $\beta = 0.478$ ,  $p < 0.001$ ) corroborates the theoretical argument that workforce performance constitutes a critical determinant of enterprise-level sustainability outcomes. In the plantation context, higher-performing employees appear to contribute to sustainable production through more precise harvesting practices that minimize loose fruit losses and ensure optimal FFB ripeness standards, more rigorous adherence to environmental and agrochemical use protocols, more consistent compliance with RSPO-aligned labor and safety standards, and greater operational efficiency in input utilization. These findings are substantively consistent with the sustainable HRM literature's central proposition—as articulated by [Ehnert et al. \(2015\)](#) and [Stahl et al. \(2019, p. 100711\)](#)—that productive, motivated, and well-managed employees are foundational enablers of enterprise sustainability performance.

### Comparison with Antecedent Studies

The confirmed direct effect of DWM on SPOP ( $H_3$ ,  $\beta = 0.287$ ,  $p = 0.001$ ) demonstrates that digital workforce management generates sustainability benefits through channels partially independent of the employee productivity pathway. These additional mechanisms plausibly include real-time environmental monitoring and reporting, automated regulatory and RSPO compliance documentation, digitally enhanced supply chain traceability, and the operational efficiencies generated by precision labor deployment and resource scheduling. This finding resonates with [Wolfert et al. \(2017\)](#) argument that digital platforms in agriculture enable simultaneous optimization of productivity and environmental performance through enhanced data visibility and decision support, and with [Zhai et al. \(2020\)](#) documentation of decision support systems as facilitators of resource use efficiency across multiple sustainability dimensions.

The mediation finding ( $H_4$ ) is particularly theoretically and strategically significant. The confirmation that EP partially mediates the DWM–SPOP relationship—with EP accounting for approximately 46% of the total effect of DWM on SPOP—provides empirical validation for a sequential organizational mechanism wherein digital workforce management first enhances individual-level productivity, which in turn constitutes a lever for enterprise-level sustainability performance. This pattern of partial mediation suggests that DWM influences SPOP through both human-mediated and direct technology-mediated channels simultaneously, a nuance with important managerial and policy implications ([Li et al., 2026](#); [Raut et al., 2020, p. 102190](#)). Organizations that invest in DWM tools without concurrently investing in the human factors—motivation, capability, and workplace context—that mediate productivity impacts may realize only a partial return on their digital investments ([Trenerry et al., 2021, p. 620781](#)).

Comparative analysis with the broader literature reveals important convergences and contextual specificities. [Davenport and Ronanki \(2018\)](#) similarly observed that AI-augmented workforce management systems generate performance benefits contingent upon organizational readiness and individual workforce capability, a finding parallel to the present study's demonstration that EP mediates the DWM–SPOP pathway. The higher magnitude of the indirect EP pathway (0.245) relative to the direct DWM pathway (0.287) in determining SPOP suggests that human factors—rather than purely technological mechanisms—are the primary conduit through which digital management translates into sustainability performance in this plantation context, a finding that diverges subtly from [Saleem et al. \(2021\)](#) manufacturing findings where direct technological effects on output were more pronounced.

### Implications of the Findings

The theoretical implications of the present study are manifold. It advances the Sustainable HRM literature by furnishing the first empirical evidence, to the authors' knowledge, that DWM is a significant antecedent of both employee productivity and sustainability outcomes in the Indonesian plantation sector, thereby extending the applicability of [Vial's \(2019\)](#) digital transformation framework and ([Deci et al., 2017](#)) Self-Determination Theory to a context—the emerging economy agricultural plantation—hitherto largely beyond their empirical reach. Additionally, the partial mediation finding enriches theoretical models of organizational digitalization by demonstrating that technology-sustainability performance pathways operate through both direct technological mechanisms and behavioral human capital pathways simultaneously.

The practical implications are equally significant and directly actionable. For plantation enterprise managers, the findings provide robust empirical support for sustained, strategically intentional investment in DWM infrastructure, particularly in real-time performance feedback systems, digital labor scheduling and allocation tools, and digital competency development platforms. Critically, the mediation finding cautions that digital technology investment must be accompanied by deliberate parallel HRM practices—including motivational management, structured digital literacy training, and supportive supervisory practices—designed to translate technological capability into realized workforce productivity; digital tools alone are insufficient substitutes for human capital development and engagement interventions. For RSPO certification auditors and Indonesian government regulatory authorities, the findings advocate for the systematic incorporation of DWM assessment into sustainability compliance audit frameworks, given the demonstrated empirical pathway from DWM through EP to SPOP.

### Limitations of the Research

Several limitations inherent to the present study design warrant transparent acknowledgment. First, the cross-sectional research design precludes definitive causal inference; while the structural relationships reported are consistent with theoretical causal propositions and satisfy statistical criteria for structural modeling, longitudinal designs are necessary to establish temporal precedence, eliminate reverse causality, and account for potential confounding variables. Second, the single-site design at PT Tasmaju Sungai Kuamang Kampar, while affording contextual depth and internal validity, constrains the external generalizability of findings to other plantation enterprises differing in size, ownership structure, regional context, or level of digital maturity. Third, self-reported questionnaire data introduce the possibility of common method bias; although Harman's single-factor test indicated that no single factor accounted for the majority of shared variance, objective alternative measures such as direct productivity records,

RSPO audit scores, or FFB yield data were not incorporated into the study design. Future research should triangulate perceptual measures with objective operational and sustainability performance indicators.

## CONCLUSION

The present study set out to empirically investigate the structural relationships among digital workforce management, employee productivity, and sustainable palm oil production within a representative Indonesian plantation enterprise, guided by an integrative theoretical framework drawing on Sustainable HRM theory, Self-Determination Theory, and digital transformation scholarship. All four hypothesized pathways were supported with statistical significance: DWM significantly enhances EP, EP significantly predicts SPOP, DWM exerts a direct positive effect on SPOP, and EP partially mediates the DWM–SPOP relationship, with the full structural model explaining 49.1% of variance in sustainable production outcomes. These findings collectively advance a theoretically coherent and empirically validated account of the mechanisms through which organizational digitalization translates into sustainability performance in the plantation sector.

The study reinforces the foundational principle of Sustainable HRM theory that the workforce is not merely a productive resource but a strategic sustainability asset whose engagement, digital capability, and motivational alignment are constitutive determinants of enterprise sustainability performance. Within the Indonesian palm oil industry—situated at the intersection of global commodity market pressures, evolving international sustainability governance frameworks, and national economic development imperatives—digital workforce management represents a high-leverage investment whose returns are contingent upon deliberate, people-centered HRM practices designed to actualize the productivity potential that digital tools enable. The 46% mediation ratio underscores that no amount of digital infrastructure investment can substitute for capable, motivated, and well-managed employees as the primary human agents of sustainable production.

From a policy standpoint, the present findings lend empirical support to the incorporation of digital workforce management standards within national palm oil sustainability policy frameworks and RSPO certification criteria, thereby institutionalizing the digital-productivity-sustainability nexus that this study has empirically documented for the first time in this sectoral context. The authors recommend that future research prioritize: (1) longitudinal designs to establish the temporal dynamics and causal ordering of the DWM–EP–SPOP relationship; (2) multi-site, multi-company comparative studies encompassing both corporate estates and smallholder models to enhance external validity; (3) qualitative investigation of the mechanisms through which specific DWM tools influence employee motivation and sustainability-oriented behavior; (4) integration of objective FFB yield records, water and energy use efficiency metrics, and RSPO audit compliance scores to validate and triangulate the present study's perceptual measures; and (5) cross-national comparative studies to assess the transferability of findings to other major palm oil producing nations, including Malaysia, Papua New Guinea, and Colombia.

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## CONFLICT OF INTERESTS

The authors declare no conflict of interest. No founding sponsor, funding agency, or institutional partner had any role in the design, execution, or reporting of this study; in the collection, analysis, or interpretation of data; in the writing of the manuscript; or in the decision to submit the results for publication.

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