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REVIEW

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Green human resources management and green innovation: a meta-analytic review of strategic human resources levers for environmental sustainability

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Abstract
Green Human Resource Management (GHRM) has become a vital lever for driving organizational sustainability, yet the empirical relationship between GHRM and Green Innovation (GI) remains fragmented and inconclusive. This meta-analysis integrates findings from 52 peer-reviewed studies published between 2015 and 2025, encompassing 23,103 observations, to estimate the overall effect of GHRM on GI and to examine the influence of specific HR practices and contextual moderators. Grounded in the Ability–Motivation–Opportunity (AMO) framework, the Resource-Based View (RBV), and the Theory of Planned Behavior (TPB), the study reveals a significant positive pooled effect, affirming that GHRM is a consistent and influential driver of GI. Among HR practices, green-linked compensation demonstrated the strongest impact, surpassing training and recruitment. Moderator analyses reveal that effect sizes differ meaningfully by industry type, firm size, and year of publication, but not by country development status or statistical method. These results contribute to theoretical advancement by integrating behavioral, strategic, and cognitive perspectives on sustainability-oriented innovation. Practically, the findings offer actionable insights for managers and policymakers on designing effective GHRM systems that stimulate eco-innovation. This study delivers the first quantitative synthesis clarifying when, where, and how GHRM enhances green innovation across diverse sectors and economies, providing a robust foundation for future research and strategy in sustainability-driven human capital development.

Keywords Green human resource management, Ability-motivation-opportunity, Strategic HRM, Environmental sustainability, Sustainable competitive advantage

1 Introduction

Mounting scientific warnings about planetary boundaries, ever-tougher ESG-disclosure mandates, and vocal investor coalitions have turned environmental performance from a peripheral compliance item into a core benchmark of corporate legitimacy [1–3]. Boards that once viewed carbon targets as reputational window dressing now recognize that decarbonization, circularity, and zero-waste routines underpin access to capital and market share. Because every sustainability milestone ultimately materializes through employee behavior, who a firm hires, how it trains, what it rewards, and which suggestions it heeds, scholars have begun to treat the human-resource system itself as an engine of ecological advantage. This paradigm, labelled Green Human Resource Management (GHRM), is defined as the deliberate infusion of environmental objectives into recruitment, training, appraisal, compensation, and participatory mechanisms that give employees latitude to innovate [4–6].

GHRM begins at the selection gate: job ads flag ecological values, interviews probe candidates' sustainability mind-sets, and onboarding socializes newcomers into low-carbon norms [7, 8]. Continuous green training then deepens life-cycle analysis, pollution-prevention, and eco-design skills [9, 10]. Performance-management systems extend the logic by integrating carbon, waste, or water key performance indicators into appraisal scorecards [11, 12]. Eco-linked bonuses, stock options, or public recognition translate those metrics into tangible motivation [13, 14]. Finally, suggestion schemes, hackathons, and cross-functional green teams grant employees the opportunity to pilot eco-innovations that might never surface through top-down channels [15, 16]. In aggregate, these practices activate the Ability–Motivation–Opportunity (AMO) levers that behavioral-HRM research has shown to underpin superior performance outcomes [17–19]. Given these levers, GHRM is widely assumed to foster the ultimate sustainability outcome Green Innovation (GI), by mobilizing employee capacity to conceive and implement environmental solutions.

GI serves as the central outcome of this study and refers to novel product, process, service, or organizational improvements that mitigate ecological harm while improving business value [4, 5]. Over the past two decades, the notion of Green Innovation (GI) has broadened beyond incremental pollution-control devices to encompass any novel product, process, managerial routine, or marketing strategy that simultaneously cuts ecological footprints and improves economic returns [20, 21]. Contemporary examples range from plant-based formulations and biodegradable packaging [22, 23] to digital-twin optimization of renewable-energy micro-grids and closed-loop water systems [24]. On the managerial front, ISO 14001 dashboards, greenhouse-gas–linked budgeting, and board-level sustainability committees embed ecological thinking into decision routines [25, 26]. Marketing teams, for their part, now leverage blockchain-enabled traceability and carbon-neutral branding to reassure increasingly climate-literate customers [27, 28]. Firms that master this innovation agenda post more green patents, secure higher ESG scores, and generate a larger share of revenue from eco-products [12, 29].

A growing empirical literature situates GHRM as a prime antecedent of these outcomes. In heavy manufacturing, studies show that green recruitment, targeted upskilling, and KPI-linked incentives accelerate both eco-product design and process redesign [24, 30, 31]. Hospitality research reports that empowerment-oriented rewards spark service creativity and reduce food waste [10, 32]. Healthcare and higher-education settings link green training to campus recycling, energy-efficient facilities, and sustainability curricula [25, 33, 34]. Emerging-economy evidence reveals that GHRM can even compensate for weak environmental regulation by nurturing internal eco-capabilities in Ghana, Pakistan, Zimbabwe, and Jordan [9, 35–37]. Large-sample Chinese investigations further demonstrate that firms with higher ratios of green-skilled staff record more eco-patent applications and faster digital eco-transformation [38, 39]. Recent work literature continues to affirm GHRM's relevance. Studies such as [11, 12, 30, 33, 36] confirm that green hiring and upskilling significantly boost firm-level green innovation, particularly when combined with strong top-management support and knowledge-sharing systems. These findings support our assumption that GHRM enhances green practices and innovation by embedding sustainability values into human capital systems.

Yet the magnitude of reported effects is anything but uniform. Two Pakistani hotel studies, conducted within a year of each other and using similar scales, deliver vastly different coefficients one strong, one weak [16, 18]. Spanish evidence shows negligible influence of GHRM in wineries but sizeable effects in eco-technology SMEs [22, 40]. Scholars disagree about the dominant HR lever: training and empowerment surface as most influential in textiles [9], whereas eco-linked compensation leads in electronics and bonus-driven hospitality [15, 39]. Sectoral examinations likewise diverge, with process-efficiency gains dominating heavy industry results [24, 41] and marketing differentiation prevailing in service contexts [28, 42].

Three diagnosable issues underpin these inconsistencies. First, conceptual aggregation remains pervasive: many authors cram heterogeneous HR practices into a single composite score and treat green innovation as an undifferentiated outcome, obscuring which levers drive which innovations [43, 44]. Second, methodological heterogeneity muddies comparison. Variance-based PLS-SEM, popular for formative constructs, regularly inflates path coefficients relative to covariance-based SEM, hierarchical regression, PROCESS mediation, or fuzzy-set qualitative comparative analysis [5, 27, 32, 34]. Third, contextual diversity matters: national development level, industry environmental intensity, and firm size can magnify or mute individual HR levers, yet few studies test these boundary conditions in a unified framework [9, 45].

Systematic evidence syntheses could, in principle, reconcile such variation, but existing reviews fall short of the task. [46] meta-analyzed 75 studies yet target economic performance, treating environmental constructs merely as mediators. [47] pool "sustainable performance" indices that conflate environmental, social, and operational metrics, leaving the innovation dimension underspecified. [48] provides a narrative review with no pooled statistics and only cursory treatment of innovation outcomes. In short, no prior synthesis squarely estimates the population-level effect of Green HRM on Green Innovation, disaggregates HR practices, and systematically probes contextual moderators.

The present study addresses this void. We compiled 52 peer-reviewed articles covering a sample size of 23,103, published between 2015 and early 2025, that report a quantitative association between at least one GHRM practice and a clearly defined GI outcome. The evidence base spans textiles, electronics, chemicals, hospitality, health care, education, and public services across Brazil, China, Ghana, India, Jordan, Malaysia, Pakistan, Saudi Arabia, Spain, Turkey, the UAE, Vietnam, and Zimbabwe. Using random-effects modelling, we estimate a grand-mean correlation, then deploy robust-variance meta-regression to test how country development status, industry type, firm size, and statistical method moderate that link. Crucially, we disaggregate GHRM into four constituent practices recruitment and selection, training and development, performance management, and compensation, to detect differential potency.

Our inquiry is anchored in a tri-theoretical lens. AMO theory explains how specific HR levers cultivate the competence, drive, and discretion employees need to innovate sustainably [17]. The Resource-Based View clarifies why green human capital, once accumulated, becomes a valuable, rare, and difficult-to-imitate resource that fuels patentable eco-innovation and shields competitive advantage. The Theory of Planned Behavior adds a micro-psychological layer, elucidating how GHRM shapes attitudes, subjective norms, and perceived control that, in turn, catalyze green-innovation intentions [49, 50]. Nesting AMO's behavioral triggers within RBV's resource logic and TPB's intentional pathways equips us to interpret both main effects and boundary conditions.

Four research questions guide the analysis. First, what is the pooled correlation between holistic GHRM and Green Innovation? Second, which specific HRM practice exerts the strongest incremental influence? Third, how do contextual factors development status, industry type, and firm size condition the relationship? Fourth, does methodological choice (SEM versus regression) systematically bias reported effects? Answering these questions generates four contributions. Conceptually, we provide the first clean population estimate of the GHRM-GI linkage. Empirically, we reconcile conflicting primary findings and chart moderator patterns. Theoretically, we show that AMO, RBV, and TPB jointly explain sustainable innovation outcomes. Practically, we pinpoint high-leverage HR levers and context-specific guidance for managers seeking to mobilize human capital for ecological advantage.

By clarifying when, where, and how GHRM catalyzes Green Innovation, this meta-analysis equips scholars with a firmer evidentiary platform and offers practitioners concrete levers for orchestrating the human side of the sustainability transition. In a world racing toward net-zero, understanding the HR architecture that unlocks employee ingenuity may prove as decisive as any technological breakthrough. Table 1 summarizes selected empirical studies examining the GHRM–GI relationship. As shown, there is considerable variation in theoretical grounding, analytical approaches, measurement constructs, and reported findings, highlighting conceptual and empirical fragmentation in the literature.

2 Literature review

2.1 Green human resource management (GHRM)

GHRM refers to the strategic embedding of environmental sustainability into HR practices to foster a workforce aligned with corporate eco-goals [4]. The process begins with green recruitment, selecting candidates whose values and skills support low-carbon strategies. Green training equips employees with competencies in life-cycle analysis, pollution prevention, and circular economy thinking [10, 53]. Environmental key performance indicators (KPIs) are integrated into performance appraisals to reinforce accountability [11, 53]. Reward systems, including eco-linked bonuses and public recognition, tie motivation to sustainability outcomes [13]. Empowerment structures and cross-functional green teams provide opportunity for innovation [15, 16]. By enhancing ability, motivation, and opportunity, GHRM builds green human capital that supports innovation-led sustainability [38, 44].

2.2 Green innovation (GI)

GI encompasses the development and implementation of products, processes, managerial practices, and marketing strategies that reduce environmental impact while delivering economic value [20, 21]. Product innovations include biodegradable materials,

Table 1 Summary of Selected Empirical Studies on the Relationship between Green Human Resource Management and Green Innovation

Authors	Data (n)	Theory	Independent variable	Outcome Variable(s)	Selected Key Findings
[35]	294	AMO, RBV	Green recruitment, training, and compensation	Green Innovation	GHRM enhances green product/process innovation by embedding environmental values into core HR functions. The study shows that when employees are selected and rewarded based on eco-criteria, firms develop internal capabilities to drive innovation
[14]	257	Stakeholder Theory, Supplies-Values Fit	Green hiring, training, appraisal, rewards	Green Innovation	GHRM significantly boosts GI through enhanced employee commitment to environmental goals. The study highlights that alignment between organizational green values and employee beliefs strengthens innovation outcomes, especially in SMEs
[45]	335	RBV	Green HRM bundle (recruitment, training, performance)	Green Innovation	In resource-rich settings, GHRM builds firm-level green competencies that are rare and inimitable, enabling firms to embed sustainability into innovation routines. Strong effect observed among Saudi SMEs
[18]	205	Human Capital Theory	Green training, recruitment, performance-based rewards	Green Innovation	Despite a relatively weaker direct correlation, the study shows that GHRM indirectly fosters GI through the development of green human capital and environmental knowledge. Mediation paths explain more variance than the direct GHRM → GI link
[51]	380	AMO, Green Organizational Culture	Green hiring, training, rewards	Green Innovation	GHRM strengthens green work engagement and organizational culture, which in turn mediates GI. The findings underscore the importance of fostering an eco-conscious workplace climate for sustained innovation in agri-based SMEs
[9]	438	AMO Theory	Recruitment, training, performance incentives	Green Innovation	GHRM creates a high-performance green work system in Pakistani SMEs. The study demonstrates that bundled HR practices not only influence GI directly but also cultivate eco-creative routines, leading to innovation in design, processes, and products

Table 1 (continued)

Authors	Data (n)	Theory	Independent variable	Outcome Variable(s)	Selected Key Findings
[22]	196	RBV, Green Intellectual Capital (GIC), TMEA	Green hiring and job design	Ambidextrous Green Innovation	GHRM promotes both exploratory and exploitative GI. Green Intellectual Capital mediates the relationship, while top management's environmental awareness enhances the effect, confirming the role of leadership in shaping dual-mode innovation
[52]	450	Knowledge Management, Sustainability Theory	Green HRM bundle	Green Innovation	GHRM's direct influence on GI is weak, but green knowledge management significantly mediates this link. The study indicates that HR practices must be reinforced by knowledge-sharing systems to catalyze innovation
[10]	615	AMO, Sustainability Culture	Green recruitment, training, performance appraisal	Green Innovation	GHRM enhances employee-driven green creativity in tourism. The study confirms a partial mediation effect via sustainability-oriented culture, showing how HRM can activate deeper behavioral change toward innovation in service contexts

energy-efficient designs, and plant-based alternatives that enhance environmental performance and market differentiation [22, 23]. Process innovations adopt cleaner production systems, such as digital twin optimization, closed-loop water use, and renewable energy integration, to minimize emissions and waste [24, 41]. Managerial GI introduces systems like ISO 14001, green KPIs, and sustainability governance frameworks [25, 39]. Marketing GI leverages eco-branding, carbon–neutral campaigns, and blockchain traceability to appeal to environmentally conscious stakeholders [27, 28]. GI outcomes are evaluated via ESG scores, green patent counts, zero-waste benchmarks, and eco-product revenue shares [38, 39]. Table 2 summarizes how GHRM and GI constructs have been defined and operationalized across studies included in this review.

2.3 Theoretical background

Growing stakeholder pressure for environmental accountability has compelled firms to search inward for innovation triggers. GHRM the systematic greening of recruitment, training, appraisal, rewards, and employee involvement, has consequently moved centre stage as a mechanism for embedding ecological values into organizational routines [4, 13]. Empirical evidence across manufacturing [23, 24], hospitality, and healthcare [16, 33] confirms that well-designed GHRM bundles not only reduce environmental footprints but also drive green process, product, and service innovations.

Building on this momentum, the current meta-analysis draws on three complementary perspectives Ability–Motivation–Opportunity (AMO) theory, the Resource-Based View (RBV), and the Theory of Planned Behavior (TPB) to unpack the multilevel pathways

Table 2 Definitions of core constructs in the reviewed literature and the range of studies that operationalize them

Construct	Concise definition adopted across studies	Sample articles
Green Recruitment & Selection	Incorporating ecological criteria into job ads, person specifications, and interview protocols to attract candidates who value sustainability	[10, 23, 28, 34, 44, 53, 54]
Green Training & Development	Structured learning that equips employees with eco-design, waste-minimization and energy-efficiency skills and mind-sets	[9–11, 15, 23, 29]
Green Compensation & Rewards	Linking monetary bonuses, promotions, or symbolic recognition to the achievement of sustainability targets or eco-innovative ideas	[14, 27, 28, 34, 53, 54]
Green Product Innovation	Design of goods/services that reduce life-cycle environmental impact (e.g., biodegradable materials, low-energy features)	[22–24, 43, 44, 53]
Green Process Innovation	Adoption of cleaner production techniques, circular resource loops, or digital eco-efficiency tools to cut waste and emissions	[10, 11, 24, 29, 39, 41]
Green Managerial Innovation	Introduction of new environmental management systems, governance structures, or decision routines (e.g., ISO 14001, green KPIs in dashboards)	[15, 25, 29, 39, 55]
Green Marketing Innovation	Novel branding, labelling, or communication strategies that emphasize ecological attributes and shape stakeholder perceptions	[15, 27, 29, 42, 53]

through which GHRM influences green innovation and examine how contextual factors may amplify or weaken this relationship. A content audit of the 52 primary studies included in this meta-analysis reveals a strong theoretical underpinning: 31 studies adopt the AMO framework (e.g., [10, 44]), 19 use RBV to conceptualize green human capital as a strategic resource (e.g., [14, 29]), and 15 draw on TPB to explain employees' green innovation intentions (e.g., [50, 56]). Nine studies integrate at least two of these frameworks, while four use all three, highlighting an emerging, though fragmented, convergence that this synthesis aims to consolidate.

The AMO theory [17] posits that employees deliver optimal performance when they have the ability, motivation, and opportunity to act. GHRM activates these levers: green training enhances ability by deepening environmental knowledge [53, 57]; eco-linked appraisal and incentives stimulate motivation [32]; and empowerment programs expand opportunity by granting employees the latitude to propose and implement sustainable ideas [58]. Meta-analytic evidence reinforces this mechanism. For instance, [10] shows that green training and suggestion schemes significantly boost employee green creativity in Turkish tourism firms. Similarly, [9] finds that in Pakistani textile SMEs, green rewards amplify the impact of skill development on innovative performance.

Studies with larger samples underscore that bundled practices outperform isolated initiatives. [53] demonstrate that Chinese multisector firms achieve superior green innovation only when training, appraisal, and rewards are strategically aligned, validating AMO's complementarities thesis. Likewise, [36] reports that in Jordanian industries, empowerment mediates the training–innovation relationship, with innovation outcomes occurring only when employees are granted agency to act. These findings support the AMO proposition that the payoff from GHRM hinges on the simultaneous enhancement of all three levers ability, motivation, and opportunity.

While AMO explains how GHRM activates green innovation, the RBV explains why it matters strategically. According to RBV, human capital can become a source of sustained competitive advantage when it is valuable, rare, inimitable, and non-substitutable [59]. Employees with deep green expertise cultivated through consistent HR investment meet these criteria due to their tacit environmental knowledge and internalized pro-ecological values [60]. [61] further contends that dynamic capabilities are rooted in micro foundations such as HR routines. Recent evidence substantiates this view: [29] show that Chinese manufacturers with higher ratios of green-skilled staff file significantly more green patents. [39] find that empowerment-oriented HR systems enhance the transformation of human capital into patentable eco-innovations in electronics firms. In resource-constrained contexts, such as SMEs, GHRM emerges as a cost-effective alternative to formal R&D, converting scarce green talent into a strategic asset [14]. Thus, RBV positions GHRM as the human capital engine that sustains green competitive advantage.

The Theory of Planned Behavior [49] adds a psychological dimension, positing that behavior is driven by intention, which in turn is shaped by attitudes, subjective norms, and perceived behavioral control. GHRM influences all three. Green training reshapes attitudes by embedding environmental stewardship as a core organizational value [62]. Public recognition and visible leadership support reinforce pro-environmental norms [63], and empowerment enhances employees' sense of control, increasing their likelihood of engaging in green behaviors. [50] confirm this mechanism in Chinese firms, showing that perceived GHRM improves self-efficacy, which then drives green innovation. Similarly, [56] find that in Chinese hospitality, GHRM cultivates a green psychological climate that channels employee intentions into innovative outcomes. TPB thereby explains why even well-trained employees innovate only when they perceive social and organizational support to do so.

By synthesizing AMO, RBV, and TPB, we construct a multilevel framework that captures the behavioral, organizational, and strategic dynamics through which GHRM influences green innovation. We define green innovation broadly to include product, process, managerial, and marketing innovations [2, 20, 21]. AMO provides insight into the internal HR mechanisms; RBV frames these mechanisms as firm-level resources; and TPB captures the cognitive–affective pathways that convert HR cues into innovative action. This tri-theoretical integration is supported across various industries and development contexts, manufacturing [24], services [25], hospitality [15], and SMEs [44] underscoring the model's empirical and conceptual generalizability. Together, these theoretical foundations ground the hypotheses that follow, linking specific GHRM bundles to green innovation performance while accounting for moderating contingencies such as industry type, country context, publication year, and statistical method.

2.4 Hypotheses building

2.4.1 Green Human resource management and green innovation

GHRM has gained prominence as a strategic mechanism for promoting GI, especially as firms respond to escalating environmental expectations. Based on the AMO framework, GHRM aligns HR functions, such as eco-conscious recruitment, green training, sustainability-based performance management, and environmental rewards with organizational sustainability goals. These practices foster employees' environmental skills (ability), stimulate eco-behavior through incentives (motivation), and create participatory avenues to initiate or support green initiatives (opportunity) [10, 31, 35, 56, 64]. For instance, when employees are selected based on sustainability values and empowered through environmental education and innovation platforms, they are more likely to generate green solutions in processes and products [30, 65].

The Resource-Based View (RBV) frames GHRM as a driver of green human capital an intangible asset that underpins long-term competitive advantage through innovation. Firms that institutionalize GHRM build rare and inimitable capabilities that translate into sustainable product design, waste reduction, and eco-efficiency. Empirical evidence across manufacturing [66], healthcare [33], and education [25] confirms that green-aligned HR systems foster cultures of experimentation and continuous improvement. Recent studies affirm that in dynamic or weakly regulated environments, GHRM not only supports compliance but cultivates proactive green capabilities and innovation agility [56].

TPB complements this view by highlighting how GHRM shapes employee intentions and behaviors toward innovation. Practices like goal setting, recognition, and career development signal normative and attitudinal support for green action, enhancing behavioral control and innovation intent [50, 67]. Employees in green-oriented HR climates exhibit higher engagement in sustainability efforts and greater initiative in generating eco-innovations [37, 51, 65]. Based on this multi-theoretical grounding and cross-sectoral evidence, we propose:

H1 *Green Human Resource Management has a significant positive relationship with Green Innovation.*

2.4.2 Differential effects of GHRM practices on green innovation

GHRM has emerged as a key enabler of GI, aligning employee behaviors with organizational sustainability goals. Drawing on the AMO theory and the RBV, numerous studies emphasize the integrative impact of green recruitment, training, and compensation in shaping innovative ecological outcomes [23, 30, 35]. However, recent empirical evidence and theoretical discourse suggest that the effects of individual GHRM practices may vary in magnitude and mechanism. For example, green compensation, by linking financial and non-financial rewards to sustainability performance, offers a more immediate motivational trigger for green behavior compared to longer-term developmental levers like training or value-based alignment through recruitment [14, 40, 45, 56].

From an AMO perspective, while green recruitment influences employee values (ability), and green training enhances environmental competencies (ability), green compensation uniquely reinforces motivation**,** which is critical for action initiation and sustained innovation behavior. Prior research has shown that eco-linked incentives promote proactive employee engagement, green creativity, and experimentation [39, 65]. Moreover, in complex HR systems, the intercorrelation among practices can lead to multicollinearity, which may obscure the distinct effect of each practice unless explicitly tested [30]. This methodological challenge underscores the value of disaggregating the GHRM construct and empirically examining differential effects.

To address this, our study explicitly compares the influence of green compensation against other HR practices within the GHRM bundle. Anchoring these comparisons in AMO theory, we test whether green compensation exerts a stronger influence on GI relative to green training and green recruitment. This approach contributes to theory refinement by identifying high-impact HR levers and supports managerial decisions in prioritizing resource allocation. Accordingly, we propose the following hypotheses:

H1a *Green Compensation has a stronger positive effect on Green Innovation than Green Training & Development.*

H1b *Green Compensation has a stronger positive effect on Green Innovation than Green Recruitment & Selection.*

2.5 Moderators

2.5.1 Industry type as a moderator of the GHRM–GI relationship

The impact of GHRM on GI varies considerably across industries, shaped by context-specific dynamics that influence how the AMO mechanisms function. In large-scale manufacturing sectors, green training, job rotation, and performance-linked eco-incentives develop employee capabilities aligned with the RBV, which views human capital as a source of strategic advantage [23, 41]. These practices help transform technical competencies into process-level innovations. Conversely, Small and Medium-sized Enterprises, often operating with limited R&D infrastructure and constrained resources, tend to rely more on green recruitment and training as cost-effective strategies for internal capability development [35, 44]. In hospitality industries, where service delivery is driven by employee customer interaction, opportunity-enhancing GHRM tools, such as empowerment and suggestion schemes, are more critical [27, 68]. Similarly, in service sectors like healthcare and education, which emphasize behavioral and cultural change over technical redesign, participatory governance and green rewards play a central role in stimulating eco-innovation [25]. Recent empirical studies confirm that GHRM is particularly pivotal in resource-constrained and people-intensive sectors, where external drivers of innovation are weak or inconsistent [56, 65]. In contrast, in capital-intensive or regulation-heavy industries, formal compliance systems, eco-certifications, and external incentives often complement or substitute for internal HR-driven green initiatives, reducing the relative influence of GHRM [69]. Drawing on this synthesis, we hypothesize that.

H2 *The relationship between GHRM and GI is moderated by industry type.*

2.5.2 Country development level as a moderator of the GHRM–GI relationship

Differences in national development status significantly shape the institutional environments in which firms operate, affecting how internal mechanisms like GHRM translate into green innovation. In developing economies, underdeveloped environmental infrastructure, weak enforcement, and fragmented eco-policies often constrain firms' access to external sustainability resources. Consequently, organizations rely more heavily on internally cultivated capabilities through green recruitment, training, and incentive systems to build environmental competence and innovation capacity. This aligns with the AMO theory, which posits that employee ability, motivation, and opportunity must be activated internally to drive behavioral outcomes in low-support settings [9, 35, 56]. The RBV reinforces this logic: in resource-constrained contexts, GHRM becomes a pivotal strategic asset for building green knowledge that is valuable, rare, and difficult to imitate, key enablers of innovation [56, 65].

By contrast, firms in developed countries operate within robust institutional ecosystems that include advanced recycling infrastructure, stringent environmental regulations, and widespread sustainability norms. These external mechanisms can substitute for, or reinforce, GHRM-driven green initiatives. The TPB suggests that stronger social norms and greater perceived behavioral control in these settings encourage pro-environmental behavior, potentially diminishing the marginal influence of internal HR systems [45, 65]. Additionally, recent studies show that contextual factors such as institutional development moderate knowledge flows, environmental engagement, and digital absorptive capacity, all critical to GHRM effectiveness [56, 65, 69]. Given these institutional asymmetries, we hypothesize that;

H3 *The relationship between Green Human Resource Management and Green Innovation is moderated by country development level.*

2.5.3 Publication year as a moderator of the GHRM–GI relationship

The effectiveness of GHRM in promoting GI has evolved over time, reflecting changes in institutional support, environmental policy, and internal firm capacities. Earlier studies (2019–2020) typically examined isolated HR practices and applied inconsistent GI metrics, limiting theoretical depth and empirical comparability [32, 40]. As environmental regulations such as ISO 14001 gained traction and global climate accords influenced organizational priorities, firms began adopting more structured GHRM bundles. Drawing from the AMO theory, this shift implies that firms have increasingly invested across ability-enhancing (e.g., training), motivation-enhancing e.g., green rewards, and opportunity-enhancing e.g., employee involvement levers leading to more robust green innovation outcomes over time [39].

From the RBV, maturing GHRM systems represent unique and inimitable organizational capabilities that develop cumulatively, thus strengthening their contribution to sustainable innovation. The TPB theory further suggests that as societal norms and stakeholder expectations around environmental sustainability intensify, employees' pro-environmental attitudes and perceived behavioral control increase, enhancing the effectiveness of GHRM interventions [56, 65]. Recent studies increasingly measure advanced GI outcomes such as green digitization and circular production [24, 56], reflecting both conceptual maturity and methodological progress. Additionally, research shows that managerial environmental concern and green absorptive capacity both more prominent in recent studies, amplify GHRM's innovation impact over time [56, 69]. Taken together, these theoretical and empirical developments support our hypothesis that;

H4 *The relationship between GHRM and GI is moderated by year of study.*

2.5.4 Statistical method as a moderator of the GHRM–GI relationship

Methodological differences can significantly affect reported effect sizes between GHRM and GI. SEM, encompassing both PLS and AMOS approaches, models latent constructs and complex paths, enabling nuanced estimation of AMO dimensions [23]. SEM is also more accommodating to non-normal data and formative constructs, potentially leading to higher coefficients. In contrast, regression-based methods typically offer more conservative estimates due to stricter assumptions and different treatments of measurement error [52]. From an RBV perspective, accurately measuring intangible assets like green HRM capabilities is essential for assessing strategic value. AMO and TPB constructs, especially motivation and behavioral control, are sensitive to how reflective and formative items are treated, which varies by method. Meta-analytic comparisons show that SEM studies tend to yield stronger GHRM–GI linkages than regression-based approaches [14, 22]. Accordingly, we hypothesize that.

H5 *The relationship between GHRM and GI is moderated by the statistical method used.* Figure 1 presents the conceptual model guiding this meta-analysis, illustrating the direct relationship between GHRM and GI, GHRM dimensions and GI, as well as the hypothesized moderators.

3 Methodology

3.1 Search strategy and study selection

Following the PRISMA 2020 guidelines for transparent and systematic evidence synthesis [70], we conducted a structured literature search in March 2025 across four major databases: EBSCO, Scopus, Wiley Online Library, and Google Scholar. Our goal was to identify peer-reviewed, English-language empirical studies published between January 2015 and February 2025, which was the final month included in the search timeline. A comprehensive Boolean search strategy was applied to the titles, abstracts, and keywords of retrieved records, combining terms related to green human resource management (e.g., "green human resource management," "Green HRM," "GHRM") with those related to green innovation (e.g., "green innovation," "eco-innovation," "environmental innovation"). This search yielded a total of 823 unique records after duplicate removal, which were then screened for eligibility.

Two independent reviewers screened titles and abstracts against predefined eligibility criteria: (1) studies had to employ a quantitative research design and report a zero-order correlation (r) or convertible regression coefficient (β) linking at least one discrete GHRM practice (e.g., green recruitment, training, compensation, or performance management) to a GI outcome; and (2) the outcome must be a clearly defined form of green innovation, excluding studies that focused only on general sustainability or environmental performance. This screening yielded 142 full-text articles, which were further reviewed for methodological sufficiency. Studies were excluded if they were qualitative, conceptual, literature reviews, conference papers, or lacked extractable effect sizes. We complemented the search with backward reference checks (ancestry approach) and a

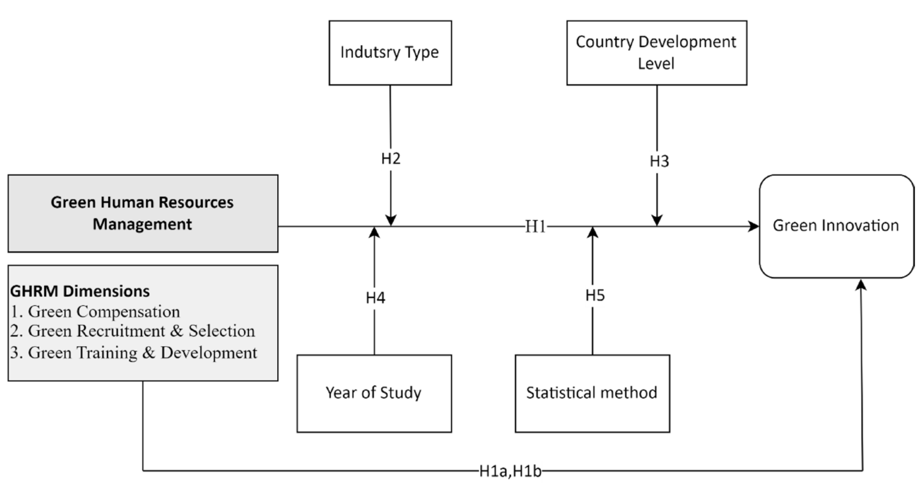

Fig. 1 Study conceptual model

targeted scan of SSRN for unpublished manuscripts. Ultimately, 52 studies met all inclusion criteria. The complete study selection process is summarized in the PRISMA flow diagram (Fig. 2).

3.2 Inclusion and exclusion criteria

To ensure methodological rigor and construct precision, we applied strict inclusion criteria. Eligible studies were required to be peer-reviewed, empirical, and published in English between January 2015 and March 2025, with full-text availability. Each study had to report a quantitative relationship between at least one specific GHRM practice such as green recruitment, training, compensation, or performance management and a clearly operationalized GI outcome. Acceptable GI outcomes included eco-innovation, green product or process innovation, environmental technological advancements, or sustainability-driven innovation strategies. This definitional clarity aligns with frameworks from prior meta-analytic research [71, 72].

To preserve construct validity, we excluded studies that used broader or ambiguous outcomes such as environmental performance, sustainable performance, CSR, or general innovativeness, even if labeled under the umbrella of innovation. This was critical to avoid conceptual overlap and ensure comparability across studies. We also excluded qualitative-only studies, conceptual or theoretical articles, literature reviews, and conference proceedings. Studies lacking extractable effect sizes (e.g., no reported r or convertible β) were similarly removed. In cases of duplicate datasets across

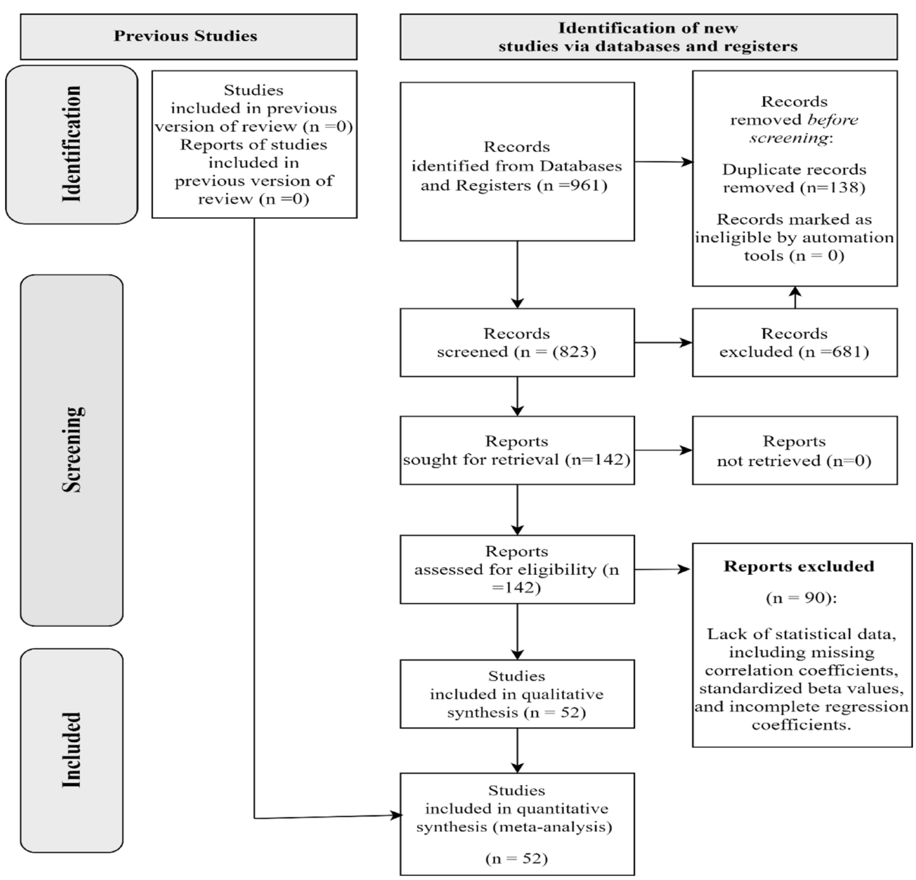

Fig. 2 PRISMA 2020 flow diagram of study selection process for the meta-analysis on GHRM and green innovation

multiple publications, only the most comprehensive or methodologically robust study was retained. This rigorous filtering process ensured the final meta-analytic sample reflected a focused and high-quality evidence base on the GHRM–GI relationship.

In this meta-analytic procedure, green performance management was coded as a distinct GHRM practice but was analytically subsumed under green compensation due to empirical overlap in the primary studies. Specifically, in numerous cases, performance appraisals were directly tied to eco-incentives, rendering the constructs functionally inseparable. Therefore, compensation was treated as inclusive of performance-based appraisals unless a study clearly differentiated them. For the overall effect of GHRM on GI, we included both studies that assessed disaggregated GHRM practices and those that utilized a bundled GHRM construct. Bundled studies were retained in the overall pooled estimate only if GHRM was explicitly measured as a multi-dimensional construct with empirical indicators. These were tagged separately during coding and excluded from practice-level comparisons to preserve statistical independence and avoid double-counting. This methodological distinction enabled robust comparisons while maintaining conceptual clarity and data integrity.

3.3 Data extraction and coding

We developed a standardized coding protocol grounded in best-practice meta-analytic guidelines [73] to ensure transparency and replicability. Two coders independently extracted key study attributes into a structured spreadsheet. Extracted variables included bibliographic information (author(s), publication year, journal), contextual features (country, development status, industry type, and firm size), focal constructs (specific GHRM practices and types of green innovation), and statistical parameters (effect size, sample size, p-values, standard errors, and analytic method). Theoretical frameworks used by each study, such as the AMO theory, RBV, or TPB, were also documented.

As part of the coding protocol, structured content audit was conducted to assess the theoretical grounding of the included studies. Coders systematically reviewed each article's introduction, theoretical framework, and discussion sections to identify explicit references to core theories. A predefined checklist was used to code for the presence and application of the AMO theory, RBV, and TPB. Discrepancies in coding were resolved through consensus discussions or arbitration by a third reviewer. This process ensured a deeper understanding of the theoretical landscape and informed interpretation of heterogeneity and moderation analyses.

For subgroup analyses, we systematically recoded certain contextual variables. Countries were categorized using the World Bank's 2023 income classification, with high-income economies coded as "developed" and all others as "developing." Industry types were grouped into five categories based on descriptive content from the original articles: Hospitality, Large Manufacturing Firms, Services, SMEs, and Multisector. Statistical analysis methods were recoded into two broad categories: regression-based approaches (e.g., hierarchical regression, OLS) and SEM. Although all effect sizes were standardized and converted to Pearson's r for comparability across studies, we retained the original statistical method as a moderator. When a study reported multiple GHRM–GI relationships (e.g., training to product innovation and compensation to process innovation), each unique pair was initially coded. However, to maintain independence of effect sizes, we aggregated multiple outcomes per study into a single effect size during the meta-analytic phase. Inter-coder reliability was high (ICC = 0.94), and discrepancies were resolved through discussion.

3.4 Quality assessment and publication bias

To assess methodological rigor, a criteria adapted from prior meta-analyses [70, 74, 75], focusing on each study's sampling strategy, construct validity, and statistical reporting quality. For publication bias assessment, we conducted multiple diagnostic approaches. Funnel plot symmetry was evaluated visually, and Egger's regression intercept test was applied to detect small-study effects. Where asymmetry was indicated, the Duval and Tweedie trim-and-fill method was used to estimate potential missing studies and adjust pooled estimates. Begg and Mazumdar's rank correlation test was also employed to assess bias related to study precision. Additionally, we conducted fail-safe N calculations to estimate the number of missing studies required to nullify observed effects, and Orwin's method to assess the robustness of the pooled effect size. P-curve analysis was not conducted due to the limited number of statistically significant effect sizes within some subgroups.

3.5 Meta-analytic metric and effect size integration

This meta-analysis employed the Pearson correlation coefficient (r) as the primary meta-analytic metric for synthesizing the relationship between GHRM and GI. The choice of r was based on three justifications: (a) it is widely interpretable across disciplines; (b) it allows standardized synthesis when correlation values are not directly reported [76]; and (c) it remains the most commonly adopted metric in management meta-analyses [77]. Where studies did not report r directly, we derived it from alternative effect sizes such as standardized beta coefficients, p-values, or t-values, following established conversion guidelines. For regression coefficients, we used the transformation formula proposed by [78]:

$$r \approx 0.98\beta + 0.05\lambda, \quad \text{where} \quad \lambda = \begin{cases} 1, & if\ \beta > 0 \\ 0, & if\ \beta < 0 \end{cases}$$

When p-values were the only statistic reported, we applied [79] method for estimating r. These conversions allowed for consistent effect size comparisons across studies. To maintain independence among effect sizes, we averaged multiple correlations reported within a single study. Specifically, 8 of the 52 studies reported more than one effect size (e.g., green compensation vs. green recruitment). We followed meta-analytic best practices [80, 81] to calculate a single composite r per study, minimizing variance inflation and ensuring robust statistical inference.

3.6 Meta-analysis and meta-regression procedures

We employed a random-effects model to conduct the meta-analysis, acknowledging the substantial heterogeneity across the 52 included studies in terms of theoretical framing (e.g., AMO, RBV, TPB), methodological approaches (e.g., SEM-PLS, AMOS, OLS), and contextual factors. This model assumes that true effect sizes vary across studies due to both sampling error and real between-study differences [82], making it more appropriate than a fixed-effects approach. To manage statistical non-independence, we computed a composite effect size per study, following established guidelines [80], thereby avoiding bias from multiple estimates within the same study.

To assess whether specific GHRM dimensions differentially influence GI, we conducted a meta-regression using Robust Variance Estimation (RVE) implemented in Python (statsmodels). This approach accounts for within-study dependence and mitigates inflated standard errors caused by correlated outcomes. Effect sizes were first transformed to Fisher's Z scores for estimation, then back-transformed to Pearson's r for interpretation. Standard errors were derived from sample sizes, and GHRM dimensions were dummy-coded, using Green Compensation as the reference category. Estimates were evaluated based on confidence intervals, p-values, and the model R^2.

4 Results

4.1 Descriptive profile of empirical studies on the GHRM–GI link

4.1.1 Annual growth of publications on GHRM–GIe GHRM–GI link

As illustrated in Fig. 3, scholarly interest in the link between GHRM and GI has shown a steady upward trend from 2019 to 2024. The number of publications remained low in 2019 and 2020, with only one publication each year. Interest began to build in 2021 with 4 publications and further increased to 7 in 2022. A notable surge occurred in 2023 and 2024, each recording 18 publications, the highest volume over the observed period. This sharp growth reflects increasing recognition of GHRM as a critical enabler of green innovation, aligned with the broader global emphasis on sustainability and responsible organizational practices.

4.1.2 Geographical trends in empirical research on the GHRM–GI link

Figure 4 presents the geographical distribution of empirical studies exploring the relationship between GHRM and GI. The data reveals a strong regional concentration, with Pakistan contributing the highest number of studies (13), followed by China (10). A second tier of countries, Malaysia, Saudi Arabia, Spain, Indonesia, and India, each contributed three studies, reflecting moderate engagement. Meanwhile, a broader group of 17 countries, including Ghana, Zimbabwe, Egypt, Bangladesh, Vietnam, Turkey, and Northern Cyprus, are represented by only one study each, indicating limited but emerging scholarly interest. Notably, although most studies originated from developing and

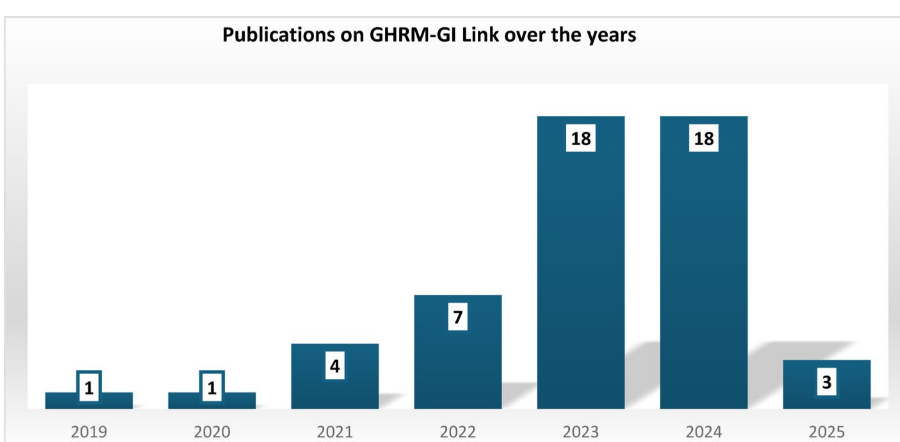

Fig. 3 Annual growth of publications on the GHRM–GI link (2019–2024)

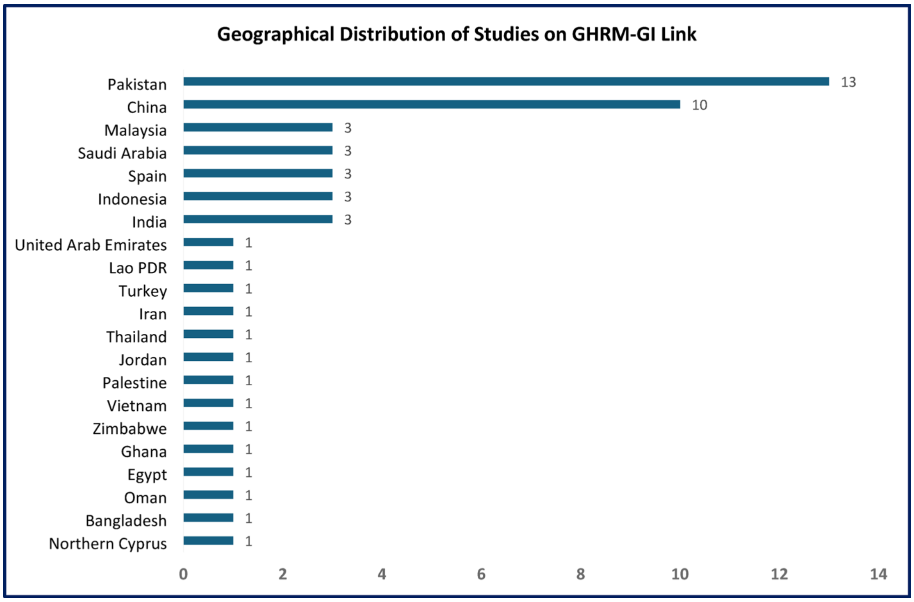

Fig. 4 Geographical trends in empirical research on the GHRM–GI link

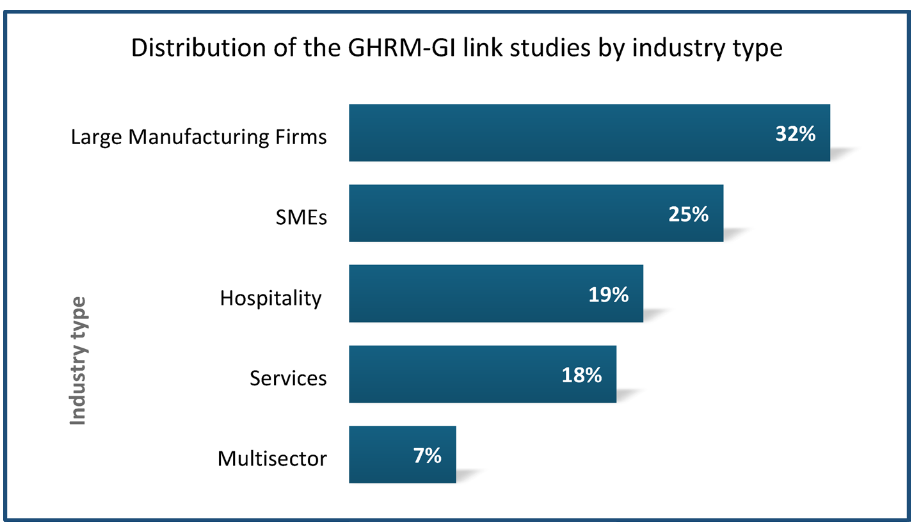

Fig. 5 Distribution of empirical studies on the GHRM–GI link by industry type

emerging economies, significant geographical gaps remain, especially across Sub-Saharan Africa and Latin America.

4.1.3 Distribution of empirical studies on the GHRM–GI link by industry type

Figure 5 profiles sectoral emphases within the GHRM–GI evidence base. Large manufacturing firms dominate, accounting for 32% of studies, unsurprising given their resource intensity and regulatory exposure. SMEs follow at 25%, reflecting growing interest in how smaller enterprises mobilize HR levers for sustainable innovation despite limited capacity. Hospitality (19%) and broader service industries (18%) collectively form a substantial but secondary cluster, signaling recognition that knowledge and people-centric sectors also leverage green HRM for green innovation outcomes.

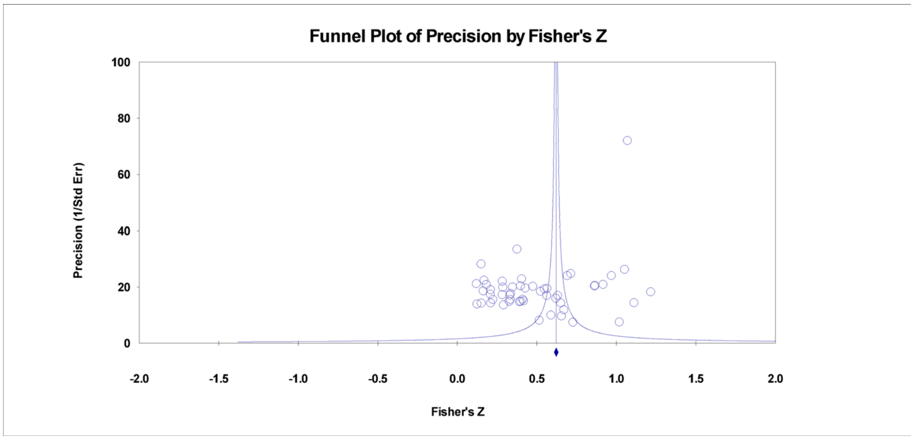

Fig. 6 Funnel Plot of Fisher's Z Against Standard Error for Included Studies

Table 3 Diagnostics of publication bias and effect size robustness

Test	Statistic / Result
Funnel Plot (Visual)	Asymmetry observed in lower-precision studies
Egger's Regression Intercept	Intercept = − 9.32, 95% CI [− 13.39, − 5.25], p (2-tailed) = 0.00003
Duval & Tweedie Trim & Fill	No studies trimmed; adjusted effect size unchanged (r = 0.465)
Begg & Mazumdar Rank Correlation	Kendall's Tau = 0.080, p = 0.403
Classic Fail-safe N	Z = 72.16, p < 0.001; 10,442 null-effect studies needed to nullify findings
Orwin's Fail-safe N	Observed r = 0.552; trivial r = 0.00; 0.00 mean effect in missing studies

Table 4 Overall meta-analysis of GHRM on green innovation (random-effects model)

Category	K	MES (r)	− CI	+ CI	Z	*p*	Q	df(Q)	*p*(Q)
Fixed Effects Model	52	0.552	0.543	0.561	93.60	< 0.001	2797.20	51	< 0.001
Random Effects Model	52	0.465	0.383	0.539	9.91	< 0.001	–	–	–

4.2 Robustness tests

Figure 6 and Table 3 present results from multiple robustness tests assessing the reliability of the meta-analytic findings. Although the funnel plot shows mild asymmetry among lower-precision studies, Egger's test confirmed small-study effects (intercept = − 9.32, p < 0.001). However, the Duval and Tweedie trim-and-fill procedure identified no missing studies, and the adjusted effect size remained unchanged (r = 0.465). Begg and Mazumdar's test was non-significant (p = 0.403). Classic fail-safe N estimated that 10,442 null studies would be required to nullify the results, and Orwin's method indicated none could reduce the observed effect (r = 0.552) to trivial. Overall, these diagnostics show that although some small-study inflation exists, it is not strong enough to dislodge the central finding; the pooled effect remains broadly robust.

4.3 Overall effect of GHRM on green innovation

A random-effects meta-analysis was conducted to estimate the overall effect of GHRM on GI, synthesizing 52 effect sizes drawn from diverse institutional, regional, and industrial contexts. The analysis produced a statistically significant pooled mean effect size of r = 0.46 (Z = 9.91, p < 0.001), with a 95% confidence interval ranging from 0.38 to 0.54 (Table 4). This indicates a moderately strong and consistent positive association between GHRM and GI practices. The narrow confidence interval affirms the precision of the

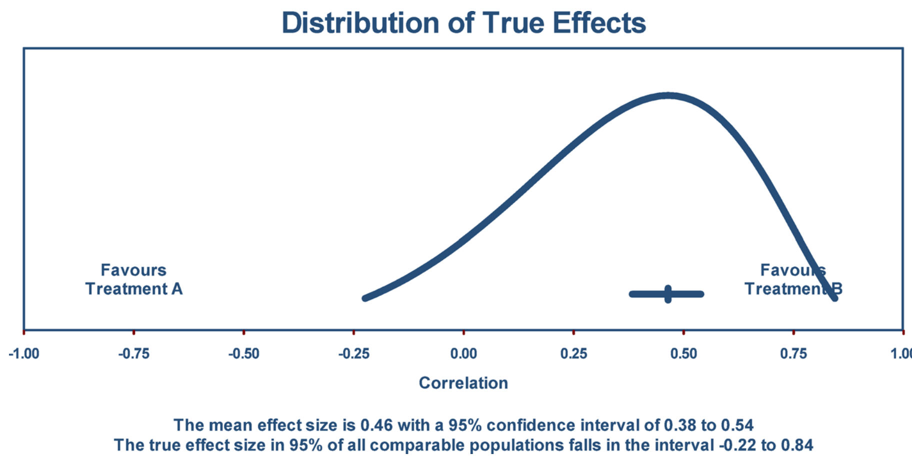

Fig. 7 Distribution of true effect sizes for the gHRM–GI relationship

Table 5 Sensitivity analysis of pooled effect size after removing one influential study (random effects model)

Model	k (Studies)	Effect Size (r)	95% CI	Z-value	*p*-value	Q	I^2 (%)	Tau^2
Random Effects Model	51	0.465	[0.383, 0.539]	9.91	< 0.001	2797.20	98.18	0.130

estimate, while the substantial heterogeneity ($Q = 2797.20$, $p < 0.001$; $I^2 = 98.18\%$) signals meaningful variation in effect sizes across studies, justifying the use of a random-effects model.

Figure 7 visually supports this finding, showing that the distribution of true effects falls within a 95% prediction interval of [− 0.22, 0.84], suggesting that while the average effect is positive, some variability should be expected in future studies. Collectively, the results offer strong empirical support for Hypothesis 1 (H1), which posited a positive relationship between GHRM and GI. They also reinforce theoretical arguments from the RBV and AMO theory, emphasizing the critical role of human capital systems in advancing sustainability-driven innovation.

4.4 Sensitivity analysis

To assess result stability, we conducted a sensitivity analysis by removing the most influential study under the random-effects model. The pooled effect size remained unchanged at $r = 0.465$ (95% CI [0.383, 0.539], $p < 0.001$). Heterogeneity also persisted ($Q = 2797.20$, $I^2 = 98.18\%$, $\tau^2 = 0.130$), indicating that no single study unduly influenced the findings. This confirms the robustness and reliability of the observed positive relationship between GHRM and GI (Table 5).

4.5 Differential effects of GHRM dimensions on green innovation

To assess whether disaggregated GHRM practices differ in their effects on GI, we conducted a Robust Variance Estimation (RVE) meta-regression using 19 effect sizes drawn from studies that reported individual GHRM dimensions separately (Table 6). These were distributed as follows: Green Compensation ($k = 7$), Green Recruitment & Selection ($k = 6$), and Green Training & Development ($k = 6$). A standard subgroup analysis was not feasible due to the high risk of inflated variance and dependency among effect sizes within studies, making RVE the most appropriate approach for clustered data.

Table 6 Robust variance estimation (RVE) meta-regression of GHRM dimensions on green innovation

	Category	MES	SE	− CI	+ CI	*p*
H1a–b: GHRM Dimensions	Green Compensation (ref.)	0.318	0.070	0.172	0.450	0.000
	Green Recruitment & Selection	0.052	0.124	− 0.186	0.284	0.670
	Green Training & Development	− 0.112	0.073	− 0.260	0.042	0.153

Robust Variance Estimation (RVE) meta-regression clustered by Study ID. Green Compensation is the reference category. Model $R^2 = 0.128$; Adjusted $R^2 = -0.035$; overall model $p = 0.349$

Table 7 Subgroup meta-analysis of GHRM on green innovation

Category	k	MES	− CI	+ CI	Z	p	PI	Q	df(Q)	p(Q)
Year of Study										
Year 2019	1	0.770	0.343	0.933	3.02	0.0026	(0.098, 0.960)			
Year 2020	1	0.385	− 0.206	0.770	1.29	0.196	(− 0.447, 0.860)			
Year 2021	4	0.359	0.064	0.596	2.36	0.018	(− 0.314, 0.792)	19.53		
Year 2022	7	0.527	0.351	0.667	5.22	< 0.001	(− 0.077, 0.848)	185.53		
Year 2023	18	0.439	0.313	0.549	6.29	< 0.001	(− 0.170, 0.805)	264.63		
Year 2024	18	0.512	0.393	0.614	7.37	< 0.001	(− 0.077, 0.836)	1295.80		
Year 2025	3	0.175	− 0.177	0.487	0.97	0.331	(− 0.498, 0.716)	0.74		
Country development status										
Developed Economy	7	0.490	0.256	0.670	3.83	< 0.001	(− 0.241, 0.866)	240.29	6	< 0.001
Developing Economy	45	0.461	0.372	0.541	9.07	< 0.001	(− 0.235, 0.844)	2543.57	44	< 0.001
Industry type										
Hospitality Sector	9	0.287	0.074	0.476	2.61	0.009	(− 0.393, 0.764)	152.75	8	< 0.001
Large Manufacturing	17	0.479	0.344	0.594	6.29	< 0.001	(− 0.170, 0.838)	1054.15	16	< 0.001
Multisector	4	0.605	0.348	0.778	4.06	< 0.001	(− 0.056, 0.897)	77.26	3	< 0.001
Services Sector	8	0.449	0.241	0.618	3.99	< 0.001	(− 0.228, 0.834)	289.47	7	< 0.001
SMEs Sector	14	0.516	0.374	0.635	6.29	< 0.001	(− 0.125, 0.853)	492.81	13	< 0.001
Statistical Method										
Regression Method	9	0.554	0.388	0.685	5.71	< 0.001	(− 0.052, 0.861)	505.96	8	< 0.001
SEM Method	43	0.445	0.364	0.519	9.69	< 0.001	(− 0.166, 0.809)	1388.94	42	< 0.001

The RVE results support Hypotheses H1a–H1b, revealing that Green Compensation exerts a significantly stronger influence on GI than other GHRM practices. Green Compensation showed a significant positive effect ($r = 0.318$, $p = 0.000$, 95% CI [0.172, 0.450]), while Green Training & Development ($\beta = -0.112$, $p = 0.153$) and Green Recruitment & Selection ($\beta = 0.052$, $p = 0.670$) were non-significant relative to the compensation baseline. These findings affirm that compensation-based practices are more influential in driving eco-innovation outcomes, aligning with AMO theory's emphasis on motivational levers and the RBV's framing of incentives as strategic resources. Although the overall model explained 12.8% of the variance ($R^2 = 0.128$), it was not statistically significant ($p = 0.349$), suggesting contextual variation in practice-level effectiveness.

4.6 Moderator analysis

Tables 7 and 8 summarize the results of the subgroup and meta-regression analyses, respectively, evaluating key moderators of the relationship between GHRM and GI. These moderators include industry type, country development status, study year, and statistical method.

H2 proposed that industry type moderates the relationship between GHRM and GI. Industry type consistently emerged as a significant moderator. Subgroup analysis revealed stronger GHRM–GI associations among firms in multisector ($r = 0.605$,

Table 8 Meta-regression results (Random Effects Model, Reference = SMEs, 2022, SEM)

Category	k	MES	− CI	+ CI	Z	*p*
Intercept (SMEs, 2022, SEM)	52	0.529	0.392	0.648	7.41	< .001
Year of Study: 2019		0.097	− 0.154	0.354	0.77	.443
Year of Study: 2020		0.090	− 0.147	0.325	0.76	.450
Year of Study: 2021		− 0.126	− 0.312	0.063	− 1.31	.189
Year of Study: 2023		− 0.085	− 0.271	0.098	− 0.90	.370
Year of Study: 2024		− 0.088	− 0.269	0.087	− 0.95	.344
Year of Study: 2025		− 0.239	− 0.469	− 0.017	− 2.13	.033
Country: Developed		0.013	− 0.124	0.150	0.19	.853
Industry: Large Firms		0.152	0.008	0.293	2.06	.039
Industry: Multisector		0.202	0.007	0.392	2.04	.042
Industry: Services		0.229	0.025	0.427	2.21	.029
Statistical Method: Regression		0.003	− 0.138	0.139	0.04	.970

Note for all Tables: k = Number of studies; MES = Mean effect size; − CI = Lower 95% confidence bound; + CI = Upper 95% confidence bound; Z = Z-value; *p* = p-value; PI = Prediction interval; Q = Heterogeneity statistic; df(Q) = Degrees of freedom for Q; p(Q) = Significance of heterogeneity

$p < 0.001$), large manufacturing ($r = 0.479$, $p < 0.001$), and service sectors ($r = 0.449$, $p < 0.001$), compared to hospitality firms ($r = 0.287$, $p = 0.009$). These patterns were mirrored in the meta-regression, where large firms ($\beta = 0.152$, $p = 0.039$), multisector firms ($\beta = 0.202$, $p = 0.042$), and service firms ($\beta = 0.229$, $p = 0.029$) showed significantly higher effect sizes than SMEs, the reference category. These findings support H2, suggesting that larger and more diversified firms may be better positioned to leverage GHRM practices due to more formalized green HR systems and greater resource availability.

H3 posited that the relationship between GHRM and GI is moderated by country development status. Country development status showed robust positive effects in both developed ($r = 0.490$, $p < 0.001$) and developing countries ($r = 0.461$, $p < 0.001$). While the meta-regression found no statistically significant difference ($\beta = 0.013$, $p = 0.853$), the slightly higher effect in developed economies may reflect the presence of mature institutional frameworks, stricter regulatory environments, and stronger green innovation ecosystems. In contrast, firms in developing countries may depend more on internally driven initiatives, facing structural constraints and eco-infrastructure gaps. These results do not support H3, indicating that while contextual differences exist, development level does not significantly moderate the GHRM–GI link.

H4 suggested that study year moderates the relationship between GHRM and GI. Study year also moderated the GHRM–GI relationship. Studies from 2022 ($r = 0.527$) and 2024 ($r = 0.512$) reported the highest effects, with 2022 serving as the meta-regression reference. Other years such as 2023 ($r = 0.439$) and 2021 ($r = 0.359$) yielded significant but comparatively lower effect sizes. Notably, studies from 2025 reported a substantially weaker and non-significant relationship ($r = 0.175$, $p = 0.331$), with the meta-regression confirming a significant negative deviation from 2022 ($\beta = -0.239$, $p = 0.033$). This decline may be due to incomplete data for 2025, given that the year is ongoing and fewer studies may have been published or indexed at the time of analysis. These findings provide partial support for H4, suggesting that temporal dynamics can influence the observed effect of GHRM on GI.

H5 posited that statistical method moderates the GHRM–GI relationship. Statistical method showed minor variation in subgroup means, with regression-based studies ($r = 0.554$) slightly outperforming SEM-based studies ($r = 0.445$). However, this difference was not statistically significant in meta-regression ($\beta = 0.003$, $p = 0.970$), suggesting

Table 9 Summary of hypotheses

Hypothesis	Statement	Result
H1	The overall relationship between GHRM and GI is positive	Accepted
H1a	Green Compensation has a stronger positive effect on Green Innovation than Green Training & Development	Accepted
H1b	Green Compensation has a stronger positive effect on Green Innovation than Green Recruitment & Selection	Accepted
H2	The relationship between GHRM and GI is moderated by industry type	Accepted
H3	The relationship between GHRM and GI is moderated by country development level	Rejected
H4	The relationship between GHRM and GI is moderated by year of study	Partially Accepted
H5	The relationship between GHRM and GI is moderated by statistical method	Rejected

that the choice of analytical technique does not systematically affect the magnitude of reported effects. Thus, H5 is not supported.

To clarify the structure and findings of our hypothesis testing, Table 9 summarizes all proposed hypotheses alongside their corresponding outcomes. The analysis confirms a strong positive association between GHRM and GI (H1) and further disaggregates the relative potency of specific HR practices, revealing that green compensation exerts a stronger influence than other GHRM components (H1a and H1b). Additionally, contextual moderators such as industry type (H2) and study year (H4) demonstrated varying levels of significance, while others, such as country development level (H3) and statistical method (H5), did not yield consistent moderating effects.

5 Discussion and conclusions

This meta-analysis consolidates evidence from 52 studies across diverse sectors and regions to rigorously examine the relationship between GHRM and GI. The pooled estimate reveals a moderate and statistically significant effect size ($r = 0.465$, $p < 0.001$), with a 95% confidence interval of [0.383, 0.539]. This confirms Hypothesis 1 (H1), affirming the critical role of GHRM as a strategic organizational lever for promoting sustainability-oriented innovation. The findings strongly support theoretical perspectives such as the RBV and the AMO framework. These theories posit that human capital, when strategically aligned with green objectives through enabling HR systems, becomes a source of competitive advantage by fostering eco-responsiveness and innovation capabilities.

Beyond the overall association, this study probes the differential effectiveness of specific GHRM practices using RVE. The results show that green compensation mechanisms exert the strongest and most significant influence on GI ($r = 0.318$, $p < 0.001$). This underscores the primacy of motivation in driving green behaviors, as predicted by AMO theory. In contrast, green recruitment and training practices showed weaker and statistically non-significant effects compared to green compensation, suggesting that capability-building alone may not translate into innovation outcomes unless reinforced by incentive structures. These findings align with field evidence from [22, 45], and also recent work by [56], which reveals that eco-incentive schemes consistently trigger innovation, whereas training alone may fall short without complementary organizational climates or performance management frameworks.

The moderator analysis provides important insights into when and where GHRM most effectively promotes green innovation. Industry type emerged as a significant moderator, supporting Hypothesis 2 (H2). Subgroup analysis and meta-regression both confirmed that large manufacturing ($r = 0.479$), multisector ($r = 0.605$), and service firms ($r = 0.449$) exhibit stronger GHRM–GI associations than hospitality firms ($r = 0.287$). This likely reflects differences in structural capacity and environmental exposure. Large and multisectoral firms often possess more formalized HR systems, greater resources, and are subject to stricter environmental scrutiny, creating conducive environments for green HR practices to translate into innovation. In contrast, the hospitality sector's high staff turnover and decentralized structures may hinder the institutionalization of green routines, though exceptions exist as shown by successful cases in the UAE and Turkey. These patterns echo sectoral insights found by [65], who observed that absorptive capacity and stakeholder influence vary by sector and condition the effectiveness of GHRM in achieving environmental outcomes.

Country development status, tested under Hypothesis 3 (H3), revealed no statistically significant difference in meta-regression ($\beta = 0.013$, $p = 0.853$), although subgroup means indicated that developed economies ($r = 0.490$) had slightly stronger associations than developing ones ($r = 0.461$). While not significant, this difference may be due to contextual enablers such as mature regulatory frameworks, robust green infrastructure, and established ESG norms in developed contexts. These conditions may amplify the institutional support for GHRM, even if firms in developing countries rely more heavily on internal levers to drive change amid institutional voids, as observed in studies from Ghana [35], Zimbabwe [37], and Indonesia [9]. Our findings are further supported by [69], who emphasize that although external institutions matter, well-structured internal HRM systems can significantly mitigate institutional weaknesses in developing contexts.

Temporal variation also moderated the observed relationships. Hypothesis 4 (H4) was partially supported, with studies from 2022 ($r = 0.527$) and 2024 ($r = 0.512$) reporting the highest effects, while 2025 studies reported a significantly lower and non-significant average ($r = 0.175$, $p = 0.331$). Meta-regression confirmed a significant negative deviation in 2025 from 2022 ($\beta = -0.239$, $p = 0.033$). This drop is most plausibly attributed to the limited number of studies published or indexed in 2025 at the time of analysis, rather than a substantive decline in the GHRM–GI linkage. It also highlights the importance of temporal context, as the post-COVID recovery period likely spurred renewed emphasis on sustainability, influencing 2022–2024 estimates.

The fifth moderator, analytical method, was tested under Hypothesis 5 (H5). Although subgroup analysis showed that regression-based studies ($r = 0.554$) reported slightly higher effect sizes than those using Structural Equation Modeling (SEM) ($r = 0.445$), the difference was not statistically significant in meta-regression ($\beta = 0.003$, $p = 0.970$). This suggests that methodological choices may not substantially bias effect magnitude. Nonetheless, the relatively lower estimates in SEM studies may reflect the model's multivariate control for confounding effects, as noted in prior meta-analyses [83], which can dampen coefficients compared to more parsimonious regression models. This underlines the need for methodological triangulation and transparency in effect size reporting.

Collectively, these findings validate three core insights. First, GHRM is a consistent and practical driver of green innovation across sectors, countries, and firm sizes. The average effect size is comparable to or greater than other strategic antecedents such as R&D intensity and innovation orientation, reinforcing its centrality in sustainability transitions. Second, not all HR practices contribute equally. Green compensation stands out as the most effective lever, affirming that motivation is critical to activating green behaviors. Training and recruitment, while necessary, appear insufficient unless embedded within broader, incentivized systems. Third, context matters deeply. Differences in industry structure, institutional quality, and time period all shape the strength of the GHRM–GI link. While the meta-regression did not yield statistically significant moderating effects for development status or method, the relative strength of estimates in developed countries and SEM-based studies suggests latent influences worth further exploration.

6 Implications, limitations and future research

6.1 Practical implications

This meta-analysis offers actionable guidance for managers aiming to integrate sustainability into the core operating model of their organizations through GHRM. The findings demonstrate that GHRM is not just a supportive function but a strategic enabler of GI. Among all HR practices analyzed, green-linked compensation emerged as the most influential, underscoring the power of performance-based incentives to drive environmental outcomes. Organizations should therefore institutionalize green performance metrics, such as energy savings, carbon footprint reduction, or waste minimization, into their appraisal systems and link 10–20% of variable pay to these targets. This direct alignment between incentives and sustainability outcomes creates stronger accountability, boosts employee motivation, and encourages eco-innovative behavior across all levels. Instead of disjointed green initiatives, firms should adopt an integrated GHRM bundle, where green recruitment, environmental training, sustainability-linked appraisals, and green rewards function as a coherent system. This holistic approach fosters a shared sustainability mindset and builds long-term environmental competencies.

Contextual customization is also vital. Manufacturing firms should prioritize recruitment of technically skilled personnel and provide problem-based training focused on clean technologies and process innovation. In contrast, hospitality and service sectors should empower frontline staff, leverage real-time feedback systems, and encourage guest participation in green experiences to co-create innovative solutions. In developing or resource-constrained settings, where regulatory enforcement may be weak, GHRM can compensate by creating internal structures that institutionalize sustainability. Managers should take the lead by building internal innovation capacity through environmental orientation in HR systems.

To support this shift, firms should invest in digital HR analytics platforms to monitor green KPIs, such as training attendance, idea submissions, project completions, and the recognition of sustainability champions, using the data to inform decisions and secure executive support. Dashboards and scorecards tied to green metrics can help managers track ROI on GHRM investments in real-time. Ultimately, GHRM must be seen as a core strategic function that strengthens both environmental and competitive positioning. Firms that embed GHRM deeply into their business strategy will not only meet regulatory expectations and stakeholder demands but also future-proof themselves against sustainability risks while unlocking new market opportunities through green innovation.

6.2 Theoretical implications

This meta-analysis makes robust theoretical contributions by reinforcing and extending key frameworks, namely the AMO model, the RBV, and the TPB, within the domain of

GHRM and GI. First, the findings solidify the AMO model's applicability to sustainability-driven HRM by showing that motivational mechanisms, particularly green-linked compensation, are the most potent predictors of green innovation. While ability-enhancing practices like training and recruitment are foundational, it is the motivational lever, specifically incentive alignment with environmental goals, that most strongly translates environmental awareness into behavior change. This calls for an enhanced AMO perspective, where motivation is treated as a catalytic driver, not just a complement, in triggering eco-innovation.

Second, the study reinforces the RBV by elevating GHRM as a dynamic, firm-specific resource that generates sustainable competitive advantage. Practices such as eco-aligned recruitment, green training, and sustainability-focused rewards create rare, valuable, and inimitable human capital, rooted in green knowledge, shared values, and innovation-oriented behaviors. This is particularly critical in SMEs and developing-economy firms, where external institutional support is weak and internal capabilities must compensate for regulatory and infrastructural gaps. GHRM thus becomes a core component of internal resource orchestration that enhances adaptive capacity and green innovation readiness.

Third, the study provides empirical validation for the TPB by illustrating how GHRM shapes key psychological precursors to pro-environmental behavior. Green training fosters favorable attitudes, eco-performance systems reinforce social norms, and participatory structures (like green task forces or idea platforms) enhance perceived behavioral control. Together, these dimensions create an enabling psychological environment that motivates employees to act in alignment with organizational sustainability goals. For instance, organizations that actively promote green suggestion schemes or recognize environmental champions cultivate stronger internal agency and commitment, echoing TPB's core assertions. Collectively, these insights extend the theoretical scope of GHRM by demonstrating how it bridges micro-level psychological mechanisms with macro-level innovation outcomes. This integration of behavioral and strategic lenses offers a more holistic view of how sustainability can be operationalized through human capital systems.

6.3 Policy implications

This meta-analysis reveals compelling policy implications for governments, regulatory bodies, and development agencies aiming to accelerate sustainable innovation. GHRM emerges as a strategic and cost-effective lever that complements traditional capital-intensive environmental policies by cultivating internal innovation capabilities. In contrast to subsidies for technology adoption alone, GHRM strengthens the human systems required to sustain and scale environmental progress. Governments, especially in developing and transitioning economies, should therefore prioritize HR-centered policy instruments. These include tax credits for firms implementing green HR systems, wage subsidies for eco-certified employees, and funding schemes for sustainability-focused training. Such interventions offer low-cost, high-impact pathways for building green competencies in the workforce and improving overall organizational readiness for eco-innovation.

In addition to financial incentives, embedding GHRM indicators into national ESG reporting frameworks and sustainability scorecards can institutionalize these practices across sectors. Standardized metrics such as the proportion of employees receiving green training, the percentage of variable compensation tied to environmental KPIs, and the frequency of employee-led sustainability initiatives can enhance corporate transparency and inform investor evaluations of long-term innovation potential. Public institutions can further catalyze progress by modeling GHRM integration themselves. Thailand's Lean–Agile–Green HR practices in the public health sector offer a compelling example of how government leadership can create benchmarks for private-sector emulation. Expanding such models to ministries in infrastructure, energy, and education would promote consistent sustainability integration across sectors and levels of government.

Moreover, sector-specific GHRM toolkits and certification mechanisms are essential for ensuring policy relevance and practical implementation. For example, ISO 14001-aligned HR standards can elevate compliance in manufacturing, while digital platforms, gamification techniques, and staff empowerment schemes may be more impactful in hospitality and service sectors. Finally, multilateral development banks, climate funds, and green finance institutions should consider requiring GHRM systems as a condition for concessional financing. This would guarantee that investments in green infrastructure are matched with the human capital needed to operationalize and sustain innovation. Elevating GHRM as a foundational element of environmental policy design will enhance regulatory effectiveness, support inclusive green growth, and directly contribute to several Sustainable Development Goals (SDGs), particularly SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

6.4 Limitations and future research directions

While this meta-analysis provides a comprehensive and statistically robust synthesis of the relationship between GHRM and GI, several limitations should be acknowledged. First, most of the included studies are cross-sectional and rely heavily on self-reported, single-source data. This methodological constraint limits the ability to infer causality or observe dynamic interactions over time. Additionally, variations in analytical techniques, particularly between regression-based and SEM approaches, suggest potential inconsistencies in effect size estimates, reflecting possible biases related to model specification and measurement precision. The review also identified inconsistent operationalizations of GHRM, with some studies evaluating bundled practices while others examined individual HR interventions, thereby complicating efforts to compare or generalize findings across contexts.

Second, there are limitations in terms of the geographic and institutional scope of the evidence base. The reviewed studies are disproportionately concentrated in Asia and Europe, with minimal representation from Sub-Saharan Africa, Latin America, and lower-middle-income economies. This uneven distribution limits the generalizability of the findings to underrepresented regions, particularly in resource-constrained environments where the implementation and impact of GHRM practices may differ significantly due to varying institutional pressures, infrastructural readiness, or organizational maturity. Furthermore, the scope of the meta-analysis was confined to peer-reviewed literature accessible through established academic databases. While rigorous, this approach may have inadvertently excluded relevant gray literature or studies published in non-indexed regional journals, which often report on local innovations or context-specific adaptations of GHRM. This introduces a potential source of omission bias that should be considered when interpreting the results.

Future research should address these limitations by adopting longitudinal and multi-source designs to reduce common method bias and reveal the temporal sequencing of green HR practices and innovation outcomes. There is a pressing need for studies that integrate GHRM with other internal environmental capabilities, such as Internal Environmental Management (IEM), to better understand how multiple internal levers work in concert to foster green innovation. Moreover, emerging technological factors such as Digital Orientation deserve greater attention as possible moderators that influence how internal practices translate into sustainable business performance. Expanding research in this direction, particularly among SMEs in underexplored institutional contexts, will deepen theoretical insights and offer more practical guidance for building sustainable, innovation-driven organizations in the face of growing environmental and digital pressures.

Author contribution

D.S.B. conceptualized the study, designed the methodology, conducted the meta-analysis, and drafted the original manuscript. S.A. contributed to the literature review, data extraction, and synthesis of empirical findings. E.K.T. provided overall supervision, refined the theoretical framework, and critically revised the manuscript. R.B. supported data validation, robustness testing, and contributed to the interpretation of findings and policy implications. All authors reviewed and approved the final version of the manuscript.

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Availability data and materials

The datasets generated and analyzed during the current study are not publicly available due to institutional and copyright restrictions but are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest

The authors declare no competing interests.

Consent to publish

Not applicable.

Consent to participate

Not applicable.

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References

1. Rockström J, Steffen W, Noone K, Persson Å, Chapin FS III, Lambin EF, et al. A safe operating space for humanity. Nature. 2009;461(7263):472–5.
2. Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM, et al. Planetary boundaries: guiding human development on a changing planet. Science. 2015;347(6223):1259855.
3. IFRS Foundation. IFRS S1 General requirements for disclosure of sustainability-related financial information and IFRS S2 Climate-related disclosures. London: International Sustainability Standards Board; 2023. Available from: https://www.ifrs.org
4. Renwick DWS, Redman T, Maguire S. Green human resource management: a review and research agenda*. Int J Manag Rev. 2013;15:1–14.
5. Veerasamy U, Joseph MS, Parayitam S. Green human resource management practices and employee green behavior. J Environ Planning Manage. 2024;67:2810–36.
6. Úbeda-García M, Marco-Lajara B, Zaragoza-Sáez PC, Manresa-Marhuenda E, Poveda-Pareja E. Green ambidexterity and environmental performance: the role of green human resources. Corp Soc Responsib Environ Manag. 2022;29:32–45.
7. Paillé P. Green human resource practices for individual environmental performance: a meta-review. Can J Adm Sci. 2024. https://doi.org/10.1002/cjas.1768.
8. Elshaer IA, Sobaih AEE, Aliedan M, Azzaz AMS. The effect of green human resource management on environmental performance in small tourism enterprises: mediating role of pro-environmental behaviors. Sustainability (Switzerland). 2021;13:1–17.

9. Chau KY, Huang T, Moslehpour M, Khan W, Nisar QA, Haris M. Opening a new horizon in green HRM practices with big data analytics and its analogy to circular economy performance: an empirical evidence. Environ Dev Sustain. 2024;26:12133–62.
10. Kara E, Akbaba M, Yakut E, Çetinel MH, Pasli MM. The mediating effect of green human resources management on the relationship between organizational sustainability and innovative behavior: an application in Turkey. Sustainability (Switzerland). 2023. https://doi.org/10.3390/su15032068.
11. Kanan M, Taha B, Saleh Y, Alsayed M, Assaf R, Ben HM, Alshaibani E, Bakir A, Tunsi W. Green innovation as a mediator between green human resource management practices and sustainable performance in Palestinian manufacturing industries. Sustainability (Switzerland). 2023. https://doi.org/10.3390/su15021077.
12. Zhang M, Huang Z. The impact of digital transformation on ESG performance: the role of supply chain resilience. Sustainability. 2024;16:7621.
13. Yong JY, Yusliza MY, Ramayah T, Fawehinmi O. Nexus between green intellectual capital and green human resource management. J Clean Prod. 2019;215:364–74.
14. Al-Swidi AK, Al-Hakimi MA, Gelaidan HM, Al-Temimi SKAJ. How does consumer pressure affect green innovation of manufacturing SMEs in the presence of green human resource management and green values? A moderated mediation analysis. Bus Ethics Environ Responsib. 2022;31:1157–73.
15. Hassanein F, Daouk A, Yassine D, Bou Zakhem N, Elsayed R, Saleh A. Green human resource management and employee retention in the hotel industry of UAE: the mediating effect of green innovation. Sustainability (Switzerland). 2024. https://doi.org/10.3390/su16114668.
16. Meraj R, Nasir S, Shafqat A, Indrees S. Green human resource management (GHRM) and environmental performance in Pakistani Hotel Industry: the role of green perceived organizational support (POS), pro-environmental behavior and green innovative work behavior (GIWB). Pak J Humanit Soc Sci. 2023. https://doi.org/10.52131/pjhss.2023.1102.0403.
17. Appelbaum E, Bailey T, Berg P, Kalleberg AL. Do high performance work systems pay off? Res Soc Work. 2001;10:85–107.
18. Munawar S, Yousaf DHQ, Ahmed M, Rehman DS. Effects of green human resource management on green innovation through green human capital, environmental knowledge, and managerial environmental concern. J Hosp Tour Manag. 2022;52:141–50.
19. Meng J, Murad M, Li C, Bakhtawar A, Ashraf SF. Green lifestyle: a tie between green human resource management practices and green organizational citizenship behavior. Sustainability (Switzerland). 2023. https://doi.org/10.3390/su15010044.
20. Chen YS, Lai SB, Wen CT. The influence of green innovation performance on corporate advantage in Taiwan. J Bus Ethics. 2006;67:331–9.
21. Rennings K, Rammer C. The impact of regulation-driven environmental innovation on innovation success and firm performance. Ind Innov. 2011;18:255–83.
22. Martínez-Falcó J, Sánchez-García E, Marco-Lajara B, Zaragoza-Sáez P. Green human resource management and green ambidexterity innovation in the wine industry: exploring the role of green intellectual capital and top management environmental awareness. Discover Sustain. 2024. https://doi.org/10.1007/s43621-024-00333-z.
23. Mustafa F, Arshad S, Iqbal A, Khan SN. The influence of green HRM on environmental performance: the mediating effect of green innovation and moderating effect of environmental strategy. Int J Bus Econ Affairs. 2022. https://doi.org/10.24088/ijbea-2022-74003.
24. Fang L, Shi S, Gao J, Li X. The mediating role of green innovation and green culture in the relationship between green human resource management and environmental performance. PLoS ONE. 2022. https://doi.org/10.1371/journal.pone.0274820.
25. Bahmani S, Farmanesh P, Khademolomoom AH. Effects of green human resource management on innovation performance through green innovation: evidence from northern cyprus on small island universities. Sustainability (Switzerland). 2023. https://doi.org/10.3390/su15054158.
26. Yang P, Hao X, Wang L, Zhang S, Yang L. Moving toward sustainable development: the influence of digital transformation on corporate ESG performance. Kybernetes. 2024;53:669–87.
27. Alyahya M, Aliedan M, Agag G, Abdelmoety ZH. The Antecedents of hotels' green creativity: the role of green HRM, environmentally specific servant leadership, and psychological green climate. Sustainability (Switzerland). 2023. https://doi.org/10.3390/su15032629.
28. Lin Z, Gu H, Gillani KZ, Fahlevi M. Impact of green work-life balance and green human resource management practices on corporate sustainability performance and employee retention: mediation of green innovation and organisational culture. Sustainability (Switzerland). 2024. https://doi.org/10.3390/su16156621.
29. Liu J, Wang Q, Wei C. Unleashing green innovation in enterprises: the transformative power of digital technology application, green human resource, and digital innovation networks. Systems. 2024. https://doi.org/10.3390/systems12010011.
30. Afzal CM, Khan SN, Baig FJ, Ashraf MU. Impact of green human resource management on environmental performance: the mediating role of green innovation and environmental strategy in Pakistan. Rev Appl Manag Soc Sci. 2023;6:227–42.
31. Mustafa K, Hossain MB, Ahmad F, Ejaz F, Khan HGA, Dunay A. Green human resource management practices to accomplish green competitive advantage: a moderated mediation model. Heliyon. 2023. https://doi.org/10.1016/j.heliyon.2023.e21830.
32. Sobaih AEE, Hasanein A, Elshaer I. Influences of green human resources management on environmental performance in small lodging enterprises: the role of green innovation. Sustainability (Switzerland). 2020;12:1–19.
33. Correia AB, Farrukh Shahzad M, Moleiro Martins J, Baheer R. Impact of green human resource management towards sustainable performance in the healthcare sector: role of green innovation and risk management. Cogent Bus Manag. 2024. https://doi.org/10.1080/23311975.2024.2374625.
34. Gill AA, Ahmad B, Kazmi S. The effect of green human resource management on environmental performance: the mediating role of employee eco-friendly behavior. Manag Sci Lett. 2021;11:1725–36.
35. Ahakwa I, Yang J, Agba Tackie E, Asamany M. Green human resource management practices and environmental performance in Ghana: the role of green innovation. SEISENSE J Manag. 2021;4:100–19.
36. Aloqaily AN. The effects green human resource on employees' green voice behaviors towards green innovation. ABAC J. 2023. https://doi.org/10.59865/abacj.2023.62.

37. Makumbe W. Green human resources management and green performance: a mediation-moderation mechanism for green innovation and green knowledge sharing. Sustainability (Switzerland). 2024. https://doi.org/10.3390/su162410849.
38. Liu H, Jung JS. Impact of digital transformation on ESG management and corporate performance: focusing on the empirical comparison between Korea and China. Sustainability (Switzerland). 2024. https://doi.org/10.3390/su16072817.
39. Peng MYP, Zhang L, Lee MH, Hsu FY, Xu Y, He Y. The relationship between strategic human resource management, green innovation and environmental performance: a moderated-mediation model. Humanit Soc Sci Commun. 2024. https://doi.org/10.1057/s41599-024-02754-7.
40. Ortega-Lapiedra R, Marco-Fondevila M, Scarpellini S, Llena-Macarulla F. Measurement of the human capital applied to the business eco-innovation. Sustainability. 2019;11:3263.
41. Rana G, Arya V. Green human resource management and environmental performance: mediating role of green innovation—a study from an emerging country. Foresight. 2024;26:35–58.
42. Song W, Yu H, Xu H. Effects of green human resource management and managerial environmental concern on green innovation. Eur J Innov Manag. 2020;24:951–67.
43. Setyaningrum RP, Muafi M. Green human resources management on business performance: the mediating role of green product innovation and environmental commitment. Int J Sustain Dev Plan. 2023;18:209–20.
44. Zihan W, Makhbul ZKM. Green human resource management as a catalyst for sustainable performance: unveiling the role of green innovations. Sustainability (Switzerland). 2024. https://doi.org/10.3390/su16041453.
45. Awwad Al-Shammari AS, Alshammrei S, Nawaz N, Tayyab M. Green human resource management and sustainable performance with the mediating role of green innovation: a perspective of new technological era. Front Environ Sci. 2022. https://doi.org/10.3389/fenvs.2022.901235.
46. Carballo-Penela A, Ruzo-Sanmartín E, Álvarez-González P, Paillé P. How do GHRM practices influence firms' economic performance? A meta-analytic investigation of the role of GSCM and environmental performance. J Bus Res. 2023. https://doi.org/10.1016/j.jbusres.2023.113984.
47. Naderi L, Foukerdi A, Sanavifard R, Yazdani H. Green human resource management and green sustainable performance: a meta-analysis. J Clean Prod. 2024;421: 139865.
48. Miah M, Szabó-Szentgróti G, Walter V. A systematic literature review on green human resource management (GHRM): an organizational sustainability perspective. Cogent Bus Manag. 2024. https://doi.org/10.1080/23311975.2024.2371983.
49. Ajzen I. The theory of planned behavior. Organ Behav Hum Decis Process. 1991;50(2):179–211.
50. Song D, Bai Y, Wu H, Wang X. How does the perceived green human resource management impact employee's green innovative behavior?—From the perspective of theory of planned behavior. Front Psychol. 2023. https://doi.org/10.3389/fpsyg.2022.1106494.
51. Tran NKH. An empirical investigation on the impact of green human resources management and green leadership on green work engagement. Heliyon. 2023. https://doi.org/10.1016/j.heliyon.2023.e21018.
52. Zhou X, Firdaus HBR, Gazi MdAI, Omer AM, Al MA, Islam MM, Senathirajah RBS. Exploring the beneficial effects of green knowledge management on corporate sustainable development: the mediating roles of green innovation and green human resource management. Environ Res Commun. 2024. https://doi.org/10.1088/2515-7620/ada238.
53. Zhang S, Chen M, Tang G. How green human resource management can promote green competitive advantage: the role of green innovation. Bus Strategy Environ. 2024;33:4613–25.
54. Rawashdeh AM. The impact of green human resource management on organizational environmental performance in Jordanian health service organizations. Manag Sci Lett. 2018;8:1049–58.
55. Aftab J, Abid N, Cucari N, Savastano M. Green human resource management and environmental performance: the role of green innovation and environmental strategy in a developing country. Bus Strategy Environ. 2023;32:1782–98.
56. Makhloufi L, Vasa L, Rosak-Szyrocka J, Djermani F. Understanding the impact of big data analytics and knowledge management on green innovation practices and organizational performance: the moderating effect of government support. Sustainability (Switzerland). 2023. https://doi.org/10.3390/su15118456.
57. Tang J, Tang Z, Cowden BJ. Exploring the relationship between entrepreneurial orientation, CEO dual values, and SME performance in state-owned versus nonstate-owned enterprises in China. Entrep Theory Pract. 2017;41:883–908.
58. Sharma R, Jabbour CJC, de Sousa L, Jabbour AB. Sustainable manufacturing and industry 4.0: what we know and what we don't. J Enterp Inf Manag. 2020;34:230–66.
59. Barney J. Firm resources and sustained competitive advantage. J Manage. 1991;17(1):99–120.
60. Hart SL. A natural-resource-based view of the firm. Acad Manage Rev. 1995;20(4):986–1014.
61. Teece DJ, Pisano G, Shuen A. Dynamic capabilities and strategic management. Strateg Manag J. 1997;18:509–33.
62. Norton TA, Zacher H, Ashkanasy NM. Organisational sustainability policies and employee green behaviour: the mediating role of work climate perceptions. J Environ Psychol. 2014;38:49–54.
63. Rosenbusch N, Rauch A, Bausch A. The mediating role of entrepreneurial orientation in the task environment-performance relationship: a meta-analysis. J Manage. 2013;39:633–59.
64. Ali S, Ali AJ, Ashfaq K, Khalid J. Green human resource management and environmental innovativeness. Int J Sustain Dev Plan. 2021;16:1117–30.
65. Makhloufi L, Zhou J, Siddik AB. Why green absorptive capacity and managerial environmental concerns matter for corporate environmental entrepreneurship? Environ Sci Pollut Res. 2023;30:102295–312.
66. Alshuaibi MSI, Alhebri A, Khan SN, Sheikh AA. Big data analytics, GHRM practices, and green digital learning paving the way towards green innovation and sustainable firm performance. J Open Innov Technol Market Complex. 2024. https://doi.org/10.1016/j.joitmc.2024.100396.
67. Yang M, Li Z. The influence of green human resource management on employees' green innovation behavior: the role of green organizational commitment and knowledge sharing. Heliyon. 2023. https://doi.org/10.1016/j.heliyon.2023.e22161.
68. Hussain I, Nazir M, Khan Q, Shah S, Jammu A. Linking Green Human Resource Practices and Environmental Performance… Linking Green Human Resource Practices and Environmental Performance: The Role of Green Innovation as Mediator and Environmental Strategy as Moderator.
69. Makhloufi L, Laghouag AA, Meirun T, Belaid F. Impact of green entrepreneurship orientation on environmental performance: the natural resource-based view and environmental policy perspective. Bus Strategy Environ. 2022;31:425–44.
70. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Syst Rev. 2021. https://doi.org/10.1186/s13643-021-01626-4.

71. Oduro S. Eco-innovation and SMEs' sustainable performance: a meta-analysis. Eur J Innov Manag. 2024;27:248–79.
72. Kuzma E, Padilha LS, Sehnem S, Julkovski DJ, Roman DJ. The relationship between innovation and sustainability: a meta-analytic study. J Clean Prod. 2020. https://doi.org/10.1016/j.jclepro.2020.120745.
73. Sleesman DJ, Conlon DE, McNamara G, Miles JE. Cleaning Up the big muddy: a meta-analytic review of the determinants of escalation of commitment. Acad Manag J. 2012;55:541–62.
74. Duval S, Tweedie R. A nonparametric, "Trim and Fill" method of accounting for publication bias in meta-analysis. J Am Stat Assoc. 2000;95:89–98.
75. Borenstein M, Rothstein HR, Sutton AJ, Borenstein M. Publication Bias in Meta-analysis-Prevention, Assessment and Adjustments Edited. 2005.
76. Oduro S, Maccario G, De Nisco A. Green innovation: a multidomain systematic review. Eur J Innov Manag. 2022;25:567–91.
77. Liu R, Yue Z, Ijaz A, Lutfi A, Mao J. Sustainable business performance: examining the role of green HRM practices, green innovation and responsible leadership through the lens of pro-environmental behavior. Sustainability (Switzerland). 2023. https://doi.org/10.3390/su15097317.
78. Peterson RA, Brown SP. On the use of beta coefficients in meta-analysis. J Appl Psychol. 2005;90:175–81.
79. Rosenthal R, Dimatteo MR. META-ANALYSIS: recent developments in quantitative methods for literature reviews. Ann Rev Psychol. 2000;52:59–82.
80. Kirca AH, Jayachandran S, Bearden WO. Market orientation: a meta-analytic review and assessment of its antecedents and impact on performance. J Mark. 2005;69:24–41.
81. Roschk H, Loureiro SMC, Breitsohl J. Calibrating 30 years of experimental research: a meta-analysis of the atmospheric effects of music, scent, and color. J Retail. 2017;93:228–40.
82. Michael B, Hedges LV, Higgins JPT, Rothstein H. Introduction to meta-analysis. Hoboken: John Wiley & Sons Ltd.; 2011.
83. Oduro S, Umar RM, De Massis A, Haylemariam LG. Corporate social responsibility and family firm performance: a meta-analytic review. Corp Soc Responsib Environ Manag. 2024. https://doi.org/10.1002/csr.3004.

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