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Aguilar Hernandez, G.A.; Hoof, B. van; Mtimde, N.; Kahhat, R.; Talwar, S.

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COMMENT

Circular Economy in the Global South: Co-creating a research agenda from the Industrial Ecology Society

Glenn A. Aguilar-Hernandez[1,2] · Bart van Hoof[3] · Nobantu Mtimde[4,5] · Ramzy Kahhat[6] · Simran Talwar[7]

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Abstract

The Global South faces unique sustainability challenges especially around the use and management of resources, providing a timely opportunity to understand and adapt Circular Economy (CE) approaches and initiatives, to chart a research agenda for these regions. During the 12th International Conference on Industrial Ecology (IE), ISIE Singapore 2025, we hosted the first special session to unpack the variety of research and key issues related to CE in the Global South. The session aimed to create shared learning and co-creation of a research agenda to prioritize the necessary elements for an effective, inclusive, and just CE transition. A total of 24 participants contributed to the session, representing 16 nationalities. In this paper, we discuss the key outcomes from the session, focusing on the most pressing research gaps, desirable characteristics of a comprehensive CE research agenda, and enablers needed to ensure alignment with both global priorities and local realities. Three core areas emerged as priorities for the IE community's CE research agenda in the Global South: (1) improving data integrity and availability, especially addressing data collection methodologies for uncovering blind-spots such as those related to the informal economy; (2) combining quantitative IE tools with qualitative, transdisciplinary approaches to better address complex circular challenges; and (3) recognizing and integrating cultural practices and ancestral knowledge drawing on CE principles. By articulating these priorities, our IE society can support more grounded, context-sensitive, and inclusive CE research practices that respond to the specific needs and contributions of the Global South.

Keywords Circular economy · Global South · Stakeholder engagement · Research gaps · Industrial ecology

1 Introduction

The Global South—as a region of developing countries mainly located in Africa, Asia, Latin America and the Caribbean, as well as parts of Oceania (UNCTAD, 2018)—faces distinct sustainability and resource challenges that demand urgent and context-specific research. Likewise, the Global South is crucial for achieving sustainable development and the energy transition, as it contains approximately 73% of the world's biodiversity hotspots (Marchese, 2015), 70% of the global solar and wind potential, and 50% of cleantech minerals (Singh & Bond, 2024). Other differences reflect in the unequal structure of global material consumption between the Global North and South (Hansen et al., 2018). For instance, high-income countries, with only 17% of the world's population, consume 25% of materials and generate 43% of greenhouse gas emissions, while low-income countries, with nearly half of the population and differentiated consumption patterns, barely reach 5 tons per capita per year—below the sustainable threshold of 8 tons per

✉ Glenn A. Aguilar-Hernandez
g.a.aguilar.hernandez@cml.leidenuniv.nl

1 Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands

2 Academia de Centroamérica, San José, Costa Rica

3 School of Management, Universidad de los Andes, Bogotá, Colombia

4 Makwande Auctioneers (Pty) Ltd, Hartbeespoort, South Africa

5 University of South Africa, Pretoria, South Africa

6 Peruvian LCA and Industrial Ecology Network, Department of Engineering, Pontificia Universidad Católica del Perú, Lima, Perú

7 Institute for Sustainable Futures, University of Technology Sydney, Sydney, Australia

capita (Circle Economy, 2025). This asymmetry is sustained through an ecologically unequal exchange, where the North appropriates resources from the South without ensuring the satisfaction of basic needs (Hickel et al., 2022).

While Circular Economy (CE) has gained global traction as a model for sustainability that maximizes the value of resources for economic development and job creation, most academic and policy debates are dominated by Global North perspectives (Halog & Anieke, 2021; Muchangos, 2022). However, a growing development of CE initiatives have been established in policy and research agendas across Africa (Nijman-Ross et al., 2023), Latin America and the Caribbean (Samaniego et al., 2022) and Asian-Pacific (Herrador & Van, 2024) regions.

For the Industrial Ecology (IE) community to remain inclusive, impactful, and relevant, it is essential to understand how CE research in the Global South can reflect local realities, needs, and strengths. Industrial Ecology, as a scientific field, can contribute methodological developments, tools for decision-making, and science-based evidence to challenge the current state of the art and move beyond the status quo (Kirchherr & Hartley, 2025). Within this motivation, a special session was hosted at the 12th International Conference on Industrial Ecology, ISIE Singapore 2025, to co-develop a shared research agenda for CE in the Global South from the IE community.

The special session aimed to stimulate collective reflection and collaboration among IE researchers working on or interested in advancing CE research in the Global South. During the session, we explored the necessary components of an effective, inclusive, and just CE research agenda, ensuring that diverse voices inform the direction of future CE research from the IE community. The session focused not only on identifying key research gaps but also on considering enablers and a shared vision of what a meaningful CE research agenda should look like for the Global South.

This special session was the first of its kind for the IE society. The workshop was co-organized by active ISIE members, including regions of Africa, Asia–Pacific, Latin America and the Caribbean. It brought together 24 participants from 16 nationalities, most of whom were researchers with lived experience in the Global South and active involvement in CE research and practice. Through structured group discussions and interactive brainstorming exercises, participants identified the most pressing research gaps, defined the ideal components of a CE research agenda, and shared strategies to enable such an agenda. The discussion was guided through three core questions:

1. What are the most urgent research gaps for Circular Economy in the Global South?
2. What does an inclusive and comprehensive CE research agenda look like for the Global South?
3. As members of the IE community, how can we enable the society to co-create a comprehensive CE research agenda in alignment with global priorities and local realities?

In this paper, we discuss the key outcomes of the session, focusing on the most pressing research gaps, desirable characteristics of a comprehensive CE research agenda, and enablers for alignment between global priorities and local realities in the Global South.

2 Research gaps for Circular Economy in the Global South

During the session, four major gaps were noted to hinder the advancement of CE research in the Global South: 1) data and methods, 2) informal economy, 3) stakeholder engagement and institutional capacity, and 4) recognition of sociocultural context.

2.1 Data and method gaps

A main challenge was the lack of robust, context-specific disaggregated data. Many countries in the Global South do not have reliable public data inventories which inhibits the use of tools such as Life Cycle Assessment (LCA) or Material Flow Analysis (MFA). For example, data gaps are shown in applying Global North conceived indicators such as Circularity Gap metrics, which report for the Latin American region less than 1% of circular use of waste materials (Circle Economy, 2023), and similar scores for the African country of Ghana (Ahenkan et al., 2024). These low scores identify at most the lack of reliable information, instead of limited existence of implementation of circular practices.

The availability of data is closely linked to the broader socio-economic and policy contexts of each country, which shape both the demand for and the feasibility of applying IE tools. For instance, in countries such as Indonesia, Malaysia, the Philippines, Thailand, and Vietnam, motivations for resource efficiency and MFA application differ significantly across the region, and reliance on imported metals and industrial minerals underscores the importance of 3R strategies and MFA-related applications despite the lack of concrete resource efficiency policies (Aoki-Suzuki, 2016). To deal with alternative data collection methods in Global South context, researchers often resort to bottom-up approaches—such as direct engagement with companies and communities such as reported by Olguín et al., (2025) and van Hoof et al., (2024). As mentioned by the workshop's participants, the challenges relate to "accessing holistic data that is fully representative of a community", and "building

databases in various sectors from the bottom up" beyond, often deficient, publicly available databases.

Since most CE literature in the Global South is geared towards waste management and recycling (see, for example, Gallego-Schmid et al., 2024; Kuah & Wang, 2020; Nijman-Ross et al., 2023; Priyadarshini & Abhilash, 2020), this presents additional gaps in research areas that are relevant for the IE community. Although there are rich qualitative insights, such efforts remain fragmented, time-and labor-intensive. Furthermore, existing IE methods can be adapted to consider local realities, such as high levels of informality in waste management, resource extractive economic needs, export dependence and the variability in regulation and enforcement. Without methodological innovation, these tools risk producing insights that fail to resonate with regional dynamics.

Thus, the research agenda should prioritize data and method gaps by addressing context-specific, disaggregated data and suitable methodological approaches. These require innovation in IE methods that can accommodate diverse data sources and integrate them into traditional analytical models. For example, during the workshop, participants brought examples of research projects such as the Materials-GRoWL project (CORDIS, 2023), which uses innovative data science, remote sensing, and machine learning to track, predict, and analyze construction material flows across Africa, Asia, and Latin America. As an indication of progress in overcoming data and method gaps, the community could track the number of emerging projects focused on data and method development linked to Global South, and establish a repository for both data—for example, building on initiatives such as the IE Data Commons (IEF, 2025)—and methods applied in Global South contexts.

2.2 Informal economy

The role of the informal sector on CE research is acknowledged but not well-articulated or considered in providing solutions. In the Global South, informal economy is a vital component of the socioeconomic structure, accounting for approximately 34% of the global GDP (Torkington, 2024) and employing more than half of the labor force (ILO, 2025). Likewise, regions such as Sub-Saharan Africa and Latin America and the Caribbean are among the highest globally in terms of informality (Elgin et al., 2021). These systems—encompassing activities such as street vending, domestic work, construction, agriculture, and solid waste management—are organized as decentralized, small-scale, flexible, and adaptive networks that operate both within and outside institutional frameworks (Choueiri et al., 2025). Their growth in the Global South stems from economic instability and bureaucratic barriers that restrict access to formal employment, serving as a livelihood for large segments of the population, particularly women, migrants, and youth (Souza Piao et al., 2023).

As an important part of the Circular Economy, informal systems play a central role in the functioning of many circular systems in these regions—such as waste picking and repairing activities (Latin America & Caribbean Circular Economy Coalition, 2022; UNDP, 2023). Ignoring these intricacies results in the dominance of Global North narratives and strategies, limiting CE adoption.

Therefore, priorities for a research agenda include developing clear approaches to evaluate the contribution of the informal economy, strengthening the scientific understanding of how informal systems operate, and identifying ways to support these systems without undermining their existing functions. One participant highlighted the importance of "how to engage the informal sector in a professional and fair way", emphasizing the need for research that respects and integrates informal actors rather than attempts to replace them.

Furthermore, participants discussed how to approach the contribution of informal economy to CE by conducting system-level case studies that document informal practices in context, co-developing engagement strategies with informal workers, and generating analytical guidelines that help researchers interact with informal actors without disrupting their livelihoods. Participants mentioned examples such as the case of e-waste picker collectors in Mexicali (Kahhat et al., 2022), which highlights the need for a better understanding of informal systems and for clearer guidance based on scientific analysis. Indicators for reducing the informality research gaps would be the increased availability of publications—such as the facilitation of Special Issues on the topic (see, for example, IOP, 2025)—and methodological guidelines focused on quantifying and analyzing informal systems within CE research in the Global South.

2.3 Stakeholders and institutional capacity gaps

Weak engagement with key stakeholders limits the systemic impact of CE research. Political support remains fragmented, and partnerships between research institutions—particularly South–South collaborations—are underdeveloped. This is closely related to a weak institutional capacity across the Global South, which is marked by irregular elections, weak state capacity, and widespread clientelism and favoritism in public administration (Mazzuca & Munck, 2021). Such conditions undermine the development of professional bureaucracies, transparency in information systems, and hinder effective governance, reflecting a broader pattern of institutional fragility (Mazzuca & Munck, 2021) that affects long-term CE transition processes and demands specific conditions for CE research and implementation.

Additional constrains for data collection and methods consider limited infrastructure and inadequate funding mechanisms for CE research. For example, in 2019, the Europe Union invested about 530 billion of U.S. Purchasing Power Parity (PPP) dollars on research and development, whereas investments in South Asia, South America, and the African regions were 64, 48 and 25 billion of U.S. PPP dollars, respectively (NSF, 2025). Although collaborative efforts and international initiatives have emerged, the availability of adequate finance and investment remain a glaring issue. Furthermore, as mentioned by one participant, there is a lack of "capacity building in Global South universities to do IE/CE research and application", which limits opportunities for IE professionals across the Global South. While some strong academic nodes exist in Latin America, Africa, and Asia, the need for broader institutional support and regional coherence persists. Within this context, governments and policymakers should prioritize and support the development of CE policies, strategies, and initiatives (Passaro et al., 2021). Expanding the number and diversity of Global South researchers involved in CE research is essential. Moreover, engaging all relevant stakeholders and integrating insights from behavioral science is key to designing inclusive strategies that cultivate societal motivation and institutional change (Kujala et al., 2023).

Thus, priorities for addressing stakeholder and institutional capacity gaps—from a viewpoint of an agenda for the IE community—include strengthening capacity building for CE and IE research in Global South institutions, enhancing collaboration between researchers and non-academic stakeholders, and expanding both North–South and South–South partnerships. Participants emphasized that without stronger institutional support and more inclusive participation, CE research risks remaining fragmented and disconnected from local realities. Moreover, participants discussed the importance of developing regional research projects and network groups within the ISIE community, creating structured opportunities for collaboration across countries, and building platforms that facilitate ongoing engagement with policymakers, practitioners, and community actors. For example, some participants highlighted the experience of the ISIE Island Section (ISIE, 2025a), which actively engages stakeholders to foster more inclusive resource-use patterns on islands, and connects through broader networks such as Metabolism of Islands (MoI, 2025)—demonstrating how a consolidated platform can connect researchers working on CE-related topics worldwide. An indicator for the stakeholder and institutional capacity priority would be the growth of sustained regional collaboration, evidenced by an increasing number of joint Global South–led CE research initiatives, network activities, and partnerships involving both academic and non-academic stakeholders.

2.4 Recognition of socio-cultural contexts

Another identified gap lies in the insufficient recognition of socio-cultural contexts. Across Latin America, Africa, and Asia, community-based and ancestral practices—many of which underpin CE thinking—remain under-represented in mainstream research. Participants mentioned that there is a "disconnect between knowledge and experience of the Global North vs realities on the ground in Global South countries", and it is crucial to "customize and localize CE concepts and practices", and "acknowledging existing knowledge and practices and continuing what already works well". These include long-standing traditions of reuse, repair, and waste valorization.

It is important to note that these CE traditional practices are not exclusive to the Global South. 19th-century Northern contexts also embodied strong repair cultures, localized production systems and material cycles, which turned into greater linearity as part of industrialization and mass production processes (Aggeri, 2021). However, within the contemporary CE narrative in the Global North, these historical CE practices are rarely framed as a major aspect (see, for example, Kirchherr et al., 2018), largely because current economic developments and consumer behaviors differ substantially from those in the Global South. Regardless of regional origin, acknowledging these historical trajectories emphasizes that CE practices have long existed across societies. Recognizing and valuing such long-standing traditions provides an important foundation for integrating socio-cultural knowledge into CE research agendas. Moreover, indigenous practices present in modern societies in Global South, provide visible examples of ancient knowledge currently applied in circular economy models (Breidlid, 2009; Jackson & Warren, 2005; Mistry, 2009).

Considering traditional CE practices, the role of indigenous knowledge systems in adaptive CE strategies, as well as the potential for replicating these strategies elsewhere, has been increasingly recognized as highly relevant (Dewick et al., 2022). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) defines indigenous and local knowledge system as "social and ecological knowledge practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments", providing knowledge, methodological tools, theoretical perspectives, and practical guidance for the sustainable management of ecosystems (IPBES, 2025). Participants referred to "appreciation and valorization of local resources, culture, geographies, etc.", and "drawing on indigenous knowledge and practices that have been ongoing for generations".

Within the CE research agenda, it is therefore relevant to examine how local, indigenous and ancestral knowledge can be acknowledged and integrated into modern scientific

developments in a rigorous and non-romanticized manner. This requires structured approaches to identify, validate, and incorporate such knowledge into contemporary CE practices, ensuring that it complements rather than replaces evidence-based methods. Although this issue is not unique to Global South regions, its importance was strongly emphasized during the workshop as one of the most significant gaps to be addressed in shaping a CE research agenda that is locally grounded and contextually responsive.

Thus, key priorities for addressing the recognition of socio-cultural context gaps include advancing the systematic integration of local and ancestral knowledge into CE research, clarifying the forms and degrees of integration appropriate for the IE community, and ensuring that such integration is conducted ethically and transparently. Participants emphasized that without explicit guidance, efforts to incorporate indigenous and community-based knowledge risk becoming superficial or extractive. For advancing this integration, a range of actions can be considered from co-reviewing traditional CE practices with community members and formally acknowledging them in scientific outputs, to more participatory and collaborative research designs in which local and indigenous communities engage directly in the scientific process. For example, emerging engineering projects in Colombia employ decolonial participatory design approaches with Amazonian communities (Kambunga et al., 2023), moving beyond Westernized knowledge-production frameworks and enabling alternative epistemologies that inform new ways of understanding and applying knowledge (Kambunga et al., 2023). Such approaches create opportunities to integrate CE practices rooted in indigenous cultures while respecting cultural heritage and providing tangible benefits to the participating communities and researchers.

Establishing clear guidelines is essential to avoid exploitative practices in which knowledge is extracted from communities without meaningful recognition, reciprocity, or local benefit. Thus, an indicator of progress in overcoming the integration of local and ancestral knowledge gaps would be the development and adoption of IE community guidelines outlining rigorous, ethical, and culturally grounded methods for integrating local and ancestral knowledge into CE research.

3 Characteristics of Circular Economy research agenda for the Global South

During the special session, the participants emphasized that shaping a meaningful CE research agenda for the Global South requires moving beyond top-down frameworks and embracing a participatory, place-based approach in which geographical context is considered a fundamental aspect (Barca et al., 2012). The participants also pointed out that such an agenda should reflect the diversity of knowledge systems (e.g., from local communities), unique development challenges, and socio-economic realities across regions.

A key characteristic for a comprehensive CE research agenda is to provide a shift toward place-based approaches. Rather than applying standardized data and models, CE research in the Global South should engage with the complexity of local community settings within urban, regional, and rural contexts. This would allow for a better understanding of context-specific resources, infrastructures, socio-political structures, and cultural values. Local and lived experiences, especially those of unrepresented and vulnerable communities, should inform the design and implementation of CE initiatives.

The role of IE tools and methodologies remains critical, but these should be applied through a systems-thinking lens that incorporates social dimensions and measures social aspects. Despite the urgent need in developing countries for innovative approaches that reduce pollution and waste, enhance health and well-being, and support decent employment, these areas remain under-researched. Life cycle approaches should be complemented with insights from sociology, political science, and behavioral studies to unpack the dynamics of inclusion, power relations, and human motivations. Embedding humans in the CE perspective, understanding social structures, gender dynamics, and the role of unrepresented communities is key to ensuring that CE transitions are not only environmentally effective but also and human-centered and socially equitable (Schröder et al., 2020).

Equity and inclusion emerged as core pillars of the ideal research agenda. For instance, participants described that an ideal agenda should lead to "research reflecting of key stakeholders including informal sector and insights on the social dimensions of the issues from the view of gender, minorities", and "must be inclusive in terms of having many researchers actually affiliated in the Global South, but also must be gender and socially inclusive with vulnerable communities". Social dimensions—such as decent work, gender equality, community well-being, and fair relations across supply chains and between businesses and consumers—are well-recognized as fundamentals for a just and inclusive CE transition worldwide (see, for example, Schröder et al., 2020; Souza Piao et al., 2023). Within this context, CE research should explicitly examine who benefits from CE policies and technologies and, critically, who may be left behind (Aguilar-Hernandez, 2025). This calls for targeted assessments of the informal sector, exploration of pathways for professionalization, and the co-creation of strategies that support a just transition.

Furthermore, CE research should be reciprocal—contributing not only knowledge but also capacity, resources, and infrastructure back to the communities and institutions in the

Global South. Participants called for more impact-oriented research designs, driven by real-world challenges as defined by local stakeholders—community organizations, small and medium enterprises (SMEs), policymakers, and businesses. Research should be participatory in both process and intent, involving a diversity of actors across government, industry, academia, finance, and civil society. Engagement platforms, South–South and North–South collaborations (for example, GIZ, 2024; IDB, 2021), and representation in global discussions were identified as key aspect to ensuring that CE research is both relevant and inclusive.

The recognition and integration of diverse knowledge systems and perspectives is crucial—including indigenous and ancestral knowledge, community-led practices, and informal circular activities. However, there is a lack of inclusion of indigenous discourses from the Global South, even though these communities have been creating regenerative systems that sustain, restore, and respect ecosystems (Paes et al., 2021). These systems often operate in an interlinkage between formal and informal economic models (Williams et al., 2013), contributing to longstanding practices of repair, reuse, and sustainable resource use. Strengthening and valorizing these ongoing circular practices is essential for building locally grounded CE pathways, which can be prioritized in research agendas.

Finally, the research agenda should be created by and for the Global South. Some participants emphasized the importance of "co-create research agendas with Global South at the community level", and developing "research led by Global South researchers who understand the local context". Thus, an ideal research agenda should enable research led by scholars embedded in the region, supported by institutions that understand the local context, and responsive to the regions' unique material realities, political challenges, and aspirations. Rather than replicating Global North blueprints, CE research in the Global South should serve as a space for innovation—rooted in context, collaborative in practice, and transformative in outcome.

4 Enablers for advancing Circular Economy research in the Global South

To support the development of a contextually relevant CE research agenda in the Global South, the participants emphasized the need to focus on long-term enablers that can empower local actors, improve knowledge exchange, and build institutional resilience. These enablers refer to practical mechanisms such as multi-year funding commitments, regionally embedded research partnerships, accessible data infrastructures, and clear milestones for capacity building that can be coordinated by governments, universities, and professional networks such as the ISIE community. Enabling mechanisms are both technical or financial in nature, as well as social and collaborative-oriented, wherein the IE community can play an important role in creating venues for such enablers.

Strengthening local and regional research capacity emerged as a foundational step. This embraces investing in training, data development, and infrastructure to enable researchers, practitioners, and institutions in the Global South to lead CE efforts. Building such capacity requires meaningful engagement, and empower local actors to co-create their specific CE initiative, aligning research efforts with real-world needs. Participatory fieldwork and collaboration with communities and local stakeholders were identified as essential for anchoring research in real-world contexts.

Another core enabler is the creation of platforms and networks that facilitate peer learning, knowledge exchange, and visibility of Global South experiences. Participants highlighted the importance of "build up and strengthen local and regional capacity, and knowledge exchange networks" and "more functional and interrelated CE network that engages with different stakeholders in the different countries". These platforms should serve to showcase success stories, disseminate data, and foster collaborations across borders, while also bridging the disconnect between IE and other sustainability disciplines.

Many researchers in the Global South engage in work aligned with IE principles but may not identify with the terminology or community. As one participant pointed out: "Industrial Ecology as a term is a barrier to Global South researchers, as they don't recognize it", which means it is crucial to "connect and introduce the notion of IE to more researchers in the Global South who might be working on the field but do not call it so". Therefore, introducing IE tools and their contribution to CE research in more accessible ways—and in local languages—can help broaden engagement.

Institutional enablers also include more regionally located conferences, workshops, and professional networks. These spaces can amplify Global South voices, reduce accessibility barriers, and foster a sense of ownership and belonging within the global IE communities. Past efforts, such as ISIE regional conferences (ISIE, 2025b), demonstrate the potential of such spaces to catalyze collaboration and engagement.

5 Toward a shared Circular Economy research agenda for the Global South

The special session concluded with the formulation of three overarching priorities for a shared agenda from the IE community (see Fig. 1):

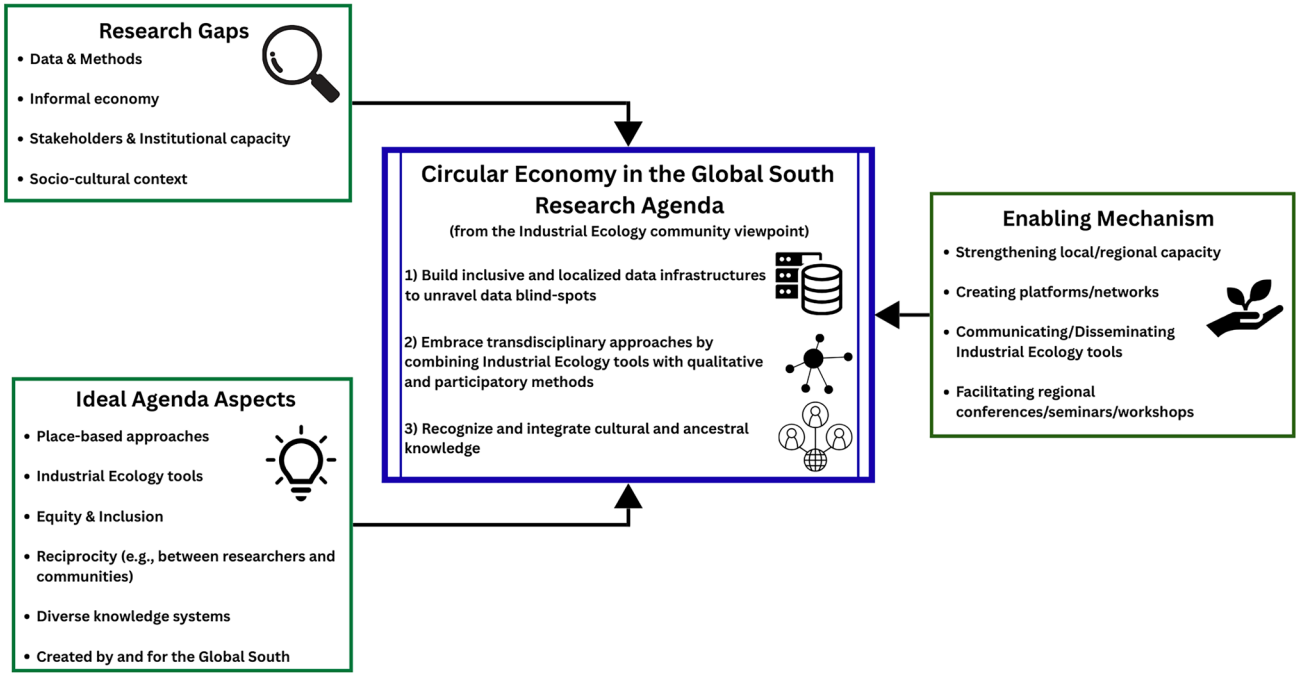

Fig. 1 Simplified research agenda for Circular Economy in the Global South from the Industrial Ecology community. The agenda summarizes the perspectives—including research gaps, ideal agenda characteristics, and enabling mechanisms—of 24 participants that contributed to the Special Session on the Circular Economy in Global South at the 12th International Conference on Industrial Ecology (IE), ISIE Singapore 2025

1. **Build inclusive and localized data infrastructures to unravel data blind-spots**: Data is essential for effective CE policymaking and tracking progress, but current data systems are often exclusionary and top-down. There is a need to develop data infrastructures that capture informal practices, and localized material flows. It is important to acknowledge that, in some countries, high-quality datasets can be found, but the accessibility through traditional data collection methods can be challenging as data is presented at different levels (e.g., internally within institutions or bottom-up from communities). Thus, adapted and participatory data collection can ensure that data for CE research can be retrieved, reflecting diverse realities in the Global South.
2. **Embrace transdisciplinary approaches by combining IE tools with qualitative and participatory methods**: Communities are increasingly being seen as key to realizing a CE transition. Therefore, a mixed-methods approach can bridge the gap between material analysis and lived experiences. Integrating IE tools with community-based research and participatory methods can help address transdisciplinary research questions and encourage mutual learning between academics and stakeholders.
3. **Recognize and integrate cultural and ancestral knowledge**: Circularity is not new in the Global South. Indigenous and local practices—such as repair culture, shared economies, and land stewardship—have embodied circular principles for generations. Future CE research should acknowledge these contributions, avoid extractive knowledge practices, and explore ways to learn from and strengthen these systems.

Together, these priorities offer a roadmap for CE research in the Global South that is grounded, inclusive, and action oriented. They invite the IE community to embrace regional cultures, promote equitable collaboration, and support transformative pathways toward circularity in unexplored regions. Different stakeholders coming together to collaborate towards CE interventions requires bringing together different experiences, including worldviews and different types of knowledge about the same system. The IE community plays a vital role in accelerating CE transition, however, defining priorities is only the first step.

To catalyze change, we must now ensure that our IE community builds upon this agenda by investing in the enablers that make such research possible. This includes strengthening regional capacities, fostering inclusive networks, and aligning CE research efforts with local needs. Expanding our knowledge and presence across Global South regions demands deliberate efforts—but it also offers an opportunity to reaffirm the spirit of collaboration and inclusiveness

that has characterized the International Society for Industrial Ecology since its beginnings.

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Author Contribution All the authors designed the workshop. G.A.A.H. collected the data, developed the initial analysis, and wrote the initial draft. All the authors reviewed and verified the analysis, contributed to the final manuscript, and approved the final version.

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Data Availability The data that supports the findings of this study are available in Supplementary Information SI1 of this article.

Declarations

Conflict of Interest The authors declare no competing interests.

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