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# The role of agricultural extension services on supporting circular bioeconomy in Indonesia

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The global pursuit of sustainable development has highlighted the Circular Bioeconomy (CBE) as a key framework for resilience and sustainability. CBE, which focuses on regenerating natural resources and minimizing waste, encompasses sectors like agriculture, waste management, and renewable energy. Agricultural Extension Services (AES) play a pivotal role within this paradigm, serving as conduits for disseminating knowledge, providing training, and fostering innovation in the agricultural sector. Indonesia, with its rich agricultural heritage and diverse natural resources, stands as a key player in the global agricultural landscape. However, the country faces challenges such as land degradation, deforestation, and climate change impacts, necessitating a shift toward sustainable agricultural practices. This article examines the potential of CBE in Indonesia, particularly the role of AES in its adoption. AES bridge the gap between research, policy, and implementation, equipping farmers with the necessary tools and information for transitioning to CBE models. Despite challenges such as limited awareness, technological barriers, and policy constraints, strategic interventions and collaborative efforts can pave the way for effective CBE implementation in Indonesia. Strengthening collaboration, enhancing capacity-building efforts, advocating for supportive policies, mobilizing financial resources, and fostering public awareness are key strategies in this endeavor. In conclusion, successful CBE adoption in Indonesia depends on the active involvement of AES. Through embracing CBE principles and leveraging AES capabilities, Indonesia can achieve a sustainable and prosperous future, fostering resilience, economic growth, and environmental integrity.

## KEYWORDS

circular bioeconomy, agricultural extension services, agriculture, economy, sustainability

## 1 Introduction

The global shift toward sustainable development has brought increased attention to the concept of circular bioeconomy (CBE), which presents a promising pathway for achieving a more sustainable and resilient future (Duan et al., 2020; Stegmann et al., 2020; Mpofu et al., 2021; Ncube et al., 2022). CBE offers a comprehensive framework to achieve these objectives by promoting the regeneration of natural resources, minimizing waste generation, and maximizing value creation across the agricultural value chain (Carus and Dammer, 2018; Giampietro, 2019; Tan and Lamers, 2021). CBE practices encompass various aspects, including sustainable agriculture, waste management, renewable energy generation, and the development

of bio-based products (Muscat et al., 2021; Klein et al., 2022; Ansari et al., 2023). Through transitioning from a linear “take-make-dispose” model to circular approach that can focus on reducing waste, optimizing resource use, and promoting sustainable agricultural practices (Tan and Lamers, 2021; Ansari et al., 2023; Holden et al., 2023). Within this context, the role of agricultural extension services (AES) in supporting CBE practices has gained significant importance. AES serve as crucial intermediaries between researchers, policymakers, and farmers, bridging the gap between scientific knowledge and on-ground implementation (Anderson and Feder, 2004; Klerkx, 2022). They play a pivotal role in disseminating information, providing training and technical assistance, and fostering innovation in the agricultural sector (Altalib et al., 2015; Msuya et al., 2017).

In Indonesia, a country known for its rich agricultural heritage and diverse natural resources, the potential for CBE is immense (Ansari et al., 2021, 2023). The nation’s agricultural sector has long been a pillar of its economy, providing employment opportunities for millions of people and contributing significantly to its GDP (Quincieu, 2015; Ansari et al., 2023). With a rapidly growing population and increasing pressures on land, water, and ecosystems, it is essential to transform agricultural practices toward sustainability and resource efficiency (Maat, 2016; Ansari et al., 2019; Mukhtar et al., 2023). However, realizing the full potential of CBE in Indonesia requires a comprehensive understanding of its principles, challenges, and opportunities. The complexity of implementing CBE practices necessitates a multi-faceted approach that involves various stakeholders, including policymakers, researchers, industry players, and most importantly, AES (Muscat et al., 2021; Tan and Lamers, 2021; Holden et al., 2023). These extension services act as critical conduits for knowledge and innovation, providing farmers with the necessary information, training, and resources to adopt sustainable and circular practices (Anderson and Feder, 2004; Rusliyadi et al., 2018). The AES act as intermediaries between research institutions, policymakers, and the farming community, disseminating knowledge and innovative techniques that contribute to sustainable agricultural practices (Rusliyadi et al., 2018; Sabir et al., 2019). Through bridging the gap between theory and application, AES empower farmers with the tools and information necessary to transition toward circular bioeconomy models. This involves educating farmers about resource-efficient farming methods, waste reduction strategies, and the integration of bio-based products, ultimately enhancing the overall resilience and sustainability of agricultural systems (Albore, 2018; Baruwadi et al., 2020; Nataliningsih et al., 2020).

Indonesia, with its diverse agroecological zones and rich biodiversity, stands as a key player in the global agricultural landscape (Ansari et al., 2021, 2023). However, challenges such as land degradation, deforestation, and the impact of climate change have underscored the need for a paradigm shift toward sustainable agricultural practices (Ansari et al., 2023). This article explores the specific role of agricultural extension services in Indonesia in catalyzing the transition toward a CBE. Examining the unique challenges and opportunities within the Indonesian agricultural sector, we delve into how the integration of CBE principles can lead to improved productivity, environmental conservation, and enhanced socio-economic outcomes for farmers. This perspective article aims to explore the role of AES in supporting CBE in Indonesia and provide insights into the necessary strategies and actions for maximizing its benefit. It is crucial to recognize and leverage the potential of AES as

catalysts for change in promoting CBE practices and ensuring their effective adoption at the grassroots level. Through collaborative efforts, innovative approaches, and targeted investments, Indonesia can pave the way for a transformative agricultural sector that embraces the principles of CBE, leading to sustainable development and a greener future.

## 2 Understanding circular bioeconomy and its application in Indonesia

CBE represents a paradigm shift in economic models, blending the principles of circular economy with sustainable practices in the utilization of biological resources (Carus and Dammer, 2018; Stegmann et al., 2020; Tan and Lamers, 2021; Ansari et al., 2023). At its essence, CBE aims to establish a closed-loop system that minimizes waste, optimizes resource utilization, and emphasizes the restoration of natural ecosystems (MacArthur, 2013; Del Borghi et al., 2020; Ansari et al., 2023). Its foundational principles encompass resource efficiency, valorization of biomass, establishment of circular supply chains, regeneration of ecosystems, and the cultivation of innovation and collaboration (Carus and Dammer, 2018; Schögl et al., 2020; Tan and Lamers, 2021; Ncube et al., 2022). This holistic approach holds significant promise for Indonesia across multiple fronts (Ansari et al., 2023). Notably, sustainable resource management emerges as a pivotal advantage, facilitating the optimization of natural resources and addressing pressing environmental concerns such as deforestation, soil degradation, and water scarcity (Tan and Lamers, 2021; Klein et al., 2022; Holden et al., 2023; Kumar Sarangi et al., 2023). Furthermore, the adoption of CBE principles offers opportunities for economic diversification, reducing dependence on traditional sectors and fostering avenues for innovation and economic growth (Chodkowska-Miszczuk et al., 2021; Koysoumpa et al., 2021; Ncube et al., 2022). In addition to these economic and environmental benefits, CBE plays a crucial role in climate change mitigation, job creation, rural development, and enhancing Indonesia’s global competitiveness by aligning with international sustainability standards (Neogi et al., 2022; Sharma and Malaviya, 2023).

Moreover, the transition to CBE in Indonesia offers far-reaching societal benefits by promoting sustainable practices and resource-efficient technologies. CBE initiatives have the potential to generate employment opportunities, particularly in rural areas (Sutomo, 2022; Mulyani et al., 2024). This not only addresses issues of unemployment but also fosters inclusive economic growth and social development (Suhartini et al., 2022). Additionally, the emphasis on ecosystem regeneration and sustainable land management practices promotes biodiversity conservation and safeguards ecosystem services crucial for human well-being (Nattasha et al., 2020; Sutomo, 2022; Latif et al., 2023). CBE initiatives also contribute to building resilient communities by enhancing food security, reducing vulnerability to environmental shocks, and fostering adaptive capacities in the face of climate change (Suhartini et al., 2022). Furthermore, by embracing CBE principles, Indonesia can strengthen its position in the global marketplace, attracting investment, fostering international partnerships, and enhancing its reputation as a leader in sustainable development (Kusumowardani et al., 2022; Suhartini et al., 2022; Perdana et al., 2023). In summary, the adoption of CBE principles presents Indonesia with a unique opportunity to achieve synergistic outcomes across

economic, environmental, and social dimensions, ultimately leading toward a more sustainable and prosperous future for the nation and its people.

### 3 The role of agricultural extension services in implementing circular bioeconomy

AES refer to organized efforts aimed at providing farmers, rural communities, and other stakeholders with the necessary knowledge, skills, and information to enhance agricultural productivity, sustainability, and overall well-being (Anderson and Feder, 2004; Maiangwa et al., 2010). The primary purpose of AES is to bridge the gap between scientific research, government, technological advancements, and practical applications on the farm (Anderson and Feder, 2007; Altalb et al., 2015). They serve as facilitator for communication and knowledge transfer to empower farmers for adopting innovative and sustainable practices, improve crop yields, and address challenges related to agriculture and rural development (Anderson and Feder, 2007; Ali et al., 2012; Altalb et al., 2015). AES in Indonesia encompass organized initiatives designed to provide farmers, rural communities, and stakeholders with essential knowledge, skills, and information to enhance agricultural productivity, sustainability, and overall well-being (Rusliyadi et al., 2018; Yanfika et al., 2024).

In relation with CBE, AES contribute to CBE adoption by disseminating knowledge about its principles and benefits, organizing training programs to enhance farmers' skills, facilitating the transfer of innovative technologies related to CBE, advocating for supportive policies, and actively participating in the monitoring and evaluation of the impact of circular bioeconomy practices. The implementation of CBE practices in Indonesia relies significantly on the multifaceted role of AES. Firstly, these services serve as vital conduits for providing information and facilitating knowledge transfer on CBE practices. By disseminating the principles and benefits of CBE, extension officers empower farmers and stakeholders with the necessary insights to incorporate sustainable and regenerative practices into their agricultural activities. Secondly, AES play a pivotal role in training farmers and stakeholders on sustainable agriculture and waste management techniques. Through workshops, training programs, and advisory services, AES officers enhance the skills of the agricultural community, enabling them to adopt environmentally friendly practices that align with circular bioeconomy principles. This educational aspect is crucial in fostering a widespread understanding and implementation of sustainable agricultural methods. Thirdly, AES act as facilitators for technology adoption and innovation within the agricultural sector. Through staying abreast of the latest advancements and promoting the adoption of innovative technologies related to circular bioeconomy—such as efficient resource utilization, biomass valorization, and circular supply chain management—extension officers contribute to the sector's modernization and adherence to sustainable practices (Figure 1).

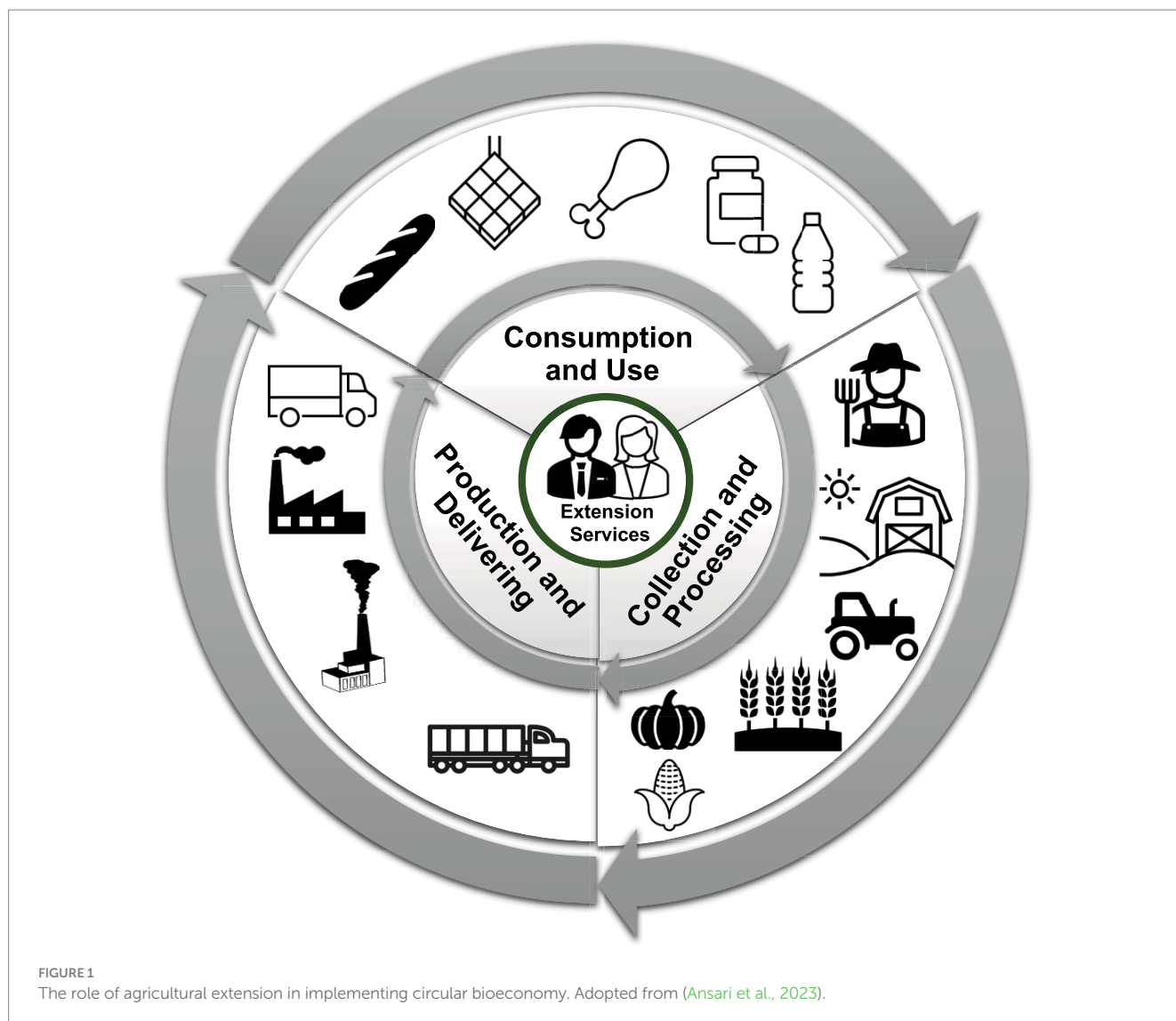
Moreover, AES encourage collaboration and networking among stakeholders by fostering partnerships between farmers, businesses, research institutions, and government bodies, extension services create a collaborative environment that enhances the effectiveness of circular bioeconomy initiatives. Collaboration becomes a catalyst for

shared resources, knowledge, and experiences, promoting a holistic approach to sustainable agricultural development. Finally, AES contribute significantly to the ongoing success of CBE initiatives by actively engaging in monitoring and evaluating their impact. Through systematic assessment, extension officers can identify areas of improvement, assess the effectiveness of implemented practices, and provide valuable feedback to refine strategies. This continuous evaluation ensures that CBE initiatives in Indonesia remain adaptive and responsive to the evolving needs and challenges within the agricultural sector. In summary, the comprehensive involvement of agricultural extension services across these key areas is instrumental in driving the successful adoption and integration of circular bioeconomy practices in Indonesia.

### 4 Challenges and recommendations

Implementing circular bioeconomy practices in Indonesia is not without challenges due to limited awareness and education present hurdles, requiring efforts to educate stakeholders, particularly farmers and businesses, about the benefits and methods involved (Tamsah and Yusriadi, 2022; Mardiharini et al., 2023) especially in remote areas which may impede progress because of limited infrastructure and technological barriers (Valerio et al., 2022). A primary challenge for agricultural extension services in supporting CBE is the limited awareness and understanding of its principles among farmers and stakeholders. This hinders effective communication about the benefits and practices associated with CBE. Additionally, technological barriers pose a significant obstacle, with inadequate access to advanced technologies and a lack of technical expertise limiting the capacity of extension workers to provide relevant guidance. The absence of supportive policies and regulations that incentivize CBE practices is another challenge, hindering the integration of sustainable initiatives into mainstream agricultural activities. Financial constraints further impede progress, as agricultural extension services may struggle to mobilize adequate resources for circular bioeconomy initiatives. Finally, limited collaboration and networking among extension services, farmers, businesses, and research institutions can hamper the synergistic efforts needed for successful CBE adoption.

To address these challenges, several strategies and recommendations can be implemented. Firstly, strengthening collaboration between agricultural extension services and other stakeholders is crucial. This can be achieved by establishing platforms for regular dialog, encouraging collaborative networks, and fostering partnerships to facilitate resource-sharing and joint initiatives (Klein et al., 2022). Secondly, enhancing the capacity and knowledge of extension workers is vital (Yanfika et al., 2024). Training programs and continuous learning opportunities through workshops and exposure visits can help them stay abreast of circular bioeconomy principles and technological advancements. Developing supportive policies and regulations is imperative, involving advocacy efforts and collaboration with policymakers to ensure alignment with the goals of sustainable agriculture (Anderson and Feder, 2007; Ragasa et al., 2016). Mobilizing financial resources requires strategic partnerships with governmental agencies, international organizations, and the private sector, exploring innovative financing mechanisms such as public-private partnerships (Van, 2000; Ali et al., 2012). Finally, fostering public awareness and engagement is essential. Educational campaigns



and various communication channels, including social media and community events, can raise awareness and encourage active participation in sustainable agricultural initiatives (Anderson and Feder, 2004; Ali et al., 2012; Ragasa et al., 2016; Rusliyadi et al., 2018; Yanfika et al., 2024). Through implementing these strategies, agricultural extension services can play a pivotal role in overcoming challenges and effectively supporting the integration of CBE practices in Indonesia.

## 5 Conclusion

In conclusion, the discourse presented herein underscores the pivotal role of AES in catalyzing the transition toward CBE in Indonesia. As articulated throughout the narrative, CBE offers a transformative framework that integrates principles of circular economy with sustainable practices in utilizing biological resources, promising a more resilient and sustainable future for the nation. Indonesia, endowed with rich agricultural heritage and diverse natural resources, stands poised to leverage the potential of CBE to address pressing environmental challenges, enhance economic prosperity, and

promote social development. The multifaceted role of AES in advancing CBE adoption is paramount. Acting as crucial intermediaries between researchers, policymakers, and farmers, AES play a pivotal role in disseminating knowledge, providing training, and fostering innovation in the agricultural sector. By bridging the gap between theory and application, AES empower farmers with the tools and information necessary to transition toward circular bioeconomy models. Moreover, AES contribute to building resilient communities by enhancing food security, promoting biodiversity conservation, and fostering adaptive capacities in the face of climate change. Through collaborative efforts, innovative approaches, and targeted investments, AES can serve as catalysts for change, driving the successful integration of CBE practices at the grassroots level. However, the journey toward realizing the full potential of CBE in Indonesia is not without challenges. Limited awareness, technological barriers, and inadequate policy support pose significant hurdles that must be addressed through strategic interventions and collaborative endeavors. By strengthening collaboration, enhancing capacity-building efforts, advocating for supportive policies, mobilizing financial resources, and fostering public awareness, AES can overcome these challenges and effectively support the integration of CBE practices in Indonesia. In essence, the successful

implementation of CBE principles in Indonesia hinges upon the comprehensive involvement of AES across various key areas. By embracing CBE principles and leveraging the transformative potential of AES, Indonesia can chart a course toward sustainable development, fostering a greener, more resilient, and prosperous future for generations to come.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

## Author contributions

HY: Conceptualization, Writing – original draft, Writing – review & editing. IE: Supervision, Writing – review & editing. Sumaryo: Writing – review & editing. AA: Conceptualization, Supervision, Writing – review & editing.

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**FIGURE 1 The role of agricultural extension in implementing circular bioeconomy**

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