Global J. Environ. Sci. Manage. 10(2): 907-938, Spring 2024, Serial #38

Global Journal of Environmental Science and Management
(GJESM)

Homepage: https://www.gjesm.net/

Podcasts

REVIEW PAPER

Life cycle assessment of agricultural waste recycling for sustainable environmental impact

S. Sumiyati[1*], B.P. Samadikun[1], A. Widiyanti[2], M.A. Budihardjo[1], S. Al Qadar[2], A.S. Puspita[3]

[1] *Department of Environmental Engineering, Universitas Diponegoro, Jl. Professor Sudarto SH., Semarang, Indonesia*

[2] *Environmental Science Department, University of Mataram, Jl Majapahit, Mataram, Indonesia*

[3] *Environmental Sustainability Research Group, Universitas Diponegoro, Jl. Professor Sudarto Sudarto SH., Semarang, Indonesia*

ARTICLE INFO

Article History:
Received 09 September 2023
Revised 11 November 2023
Accepted 24 July 2024

Keywords:
Agricultural Waste
Environmental impact
Life cycle assessment
Sustainable farming

ABSTRACT

Agricultural waste recycling is crucial for sustainable farming operations and farming practices. Life cycle assessment has emerged as an innovative and comprehensive viewpoint that considers the entire recycling process to evaluate the potential and true implications of agricultural waste recycling. This study considered methods for recycling different agricultural waste streams, such as crop waste, animal manure, pruning materials, and by-products and subsequent uses. Furthermore, the life cycle assessment method was used to investigate the process of handling agricultural waste, from collection and recycling to final usage in the agricultural system. Environmental impact categories, including greenhouse gas emissions, energy usage, eutrophication, acidification, and land use, were evaluated to determine their potential effects on climate change, resource depletion, and ecosystem health. The results were compared with those of 31 studies that analyzed the potential environmental impacts of agricultural waste management. Various methods initially developed and implemented for agricultural waste landfilling methods have now changed to energy-generating sources, such as biochar, biogas, briquettes, and various energy production methods. Furthermore, composting, a popular method of recycling agricultural waste, significantly lowers greenhouse gas emissions and energy use compared to traditional waste disposal techniques. The study also examines cutting-edge technologies, such as anaerobic digestion and biomass-to-energy conversion, highlighting their potential to manage agricultural waste and being a sustainable energy source. These findings indicate potential environmental advantages in terms of decreased greenhouse gas emissions and fossil fuel consumption, leading to a circular economic approach for agriculture. When integrating agricultural waste, including composting, anaerobic digestion, and pyrolysis, biochar is highlighted as a waste recycling method that is promising for sustainable waste management. In addition to efficiently managing agricultural waste, these technologies help generate electricity and sequester carbon, thereby advancing the objectives of climate change mitigation and circular economy. Although life cycle assessment has been used to analyze several waste management strategies, including those specific to agricultural waste, certain significant gaps and discoveries still require attention for a more thorough analysis. It might be challenging to gather complete and accurate data to assess the entire lifecycle of agricultural waste management technology. The direct environmental effects of waste management are frequently the focus of life cycle assessment studies, but they may overlook secondary effects such as indirect land use change, habitat damage, and biodiversity effects. It is crucial to consider these secondary effects in a more comprehensive analysis.

DOI: 10.22034/gjesm.2024.02.30

This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

NUMBER OF REFERENCES
120

NUMBER OF FIGURES
11

NUMBER OF TABLES
1

*Corresponding Author:
Email: *srisumiyati@lecturer.undip.ac.id*
ORCID: 0000-0002-1256-3076

Note: Discussion period for this manuscript open until July 1, 2024 on GJESM website at the “Show Article”.

INTRODUCTION

Pursuing sustainable practices has become essential across industries due to escalating environmental problems. As a foundational element of civilization, agriculture significantly impacts the planet's future fate. However, given that traditional agricultural methods adversely affect the environment, it is important to look for alternatives that balance agricultural output and environmental stewardship (Eyhorn *et al.*, 2019). A paradigm shift in approaching agricultural operations is necessary in light of the world's expanding population, climate change, and loss of natural resources. Conventional approaches caused detrimental environmental effects such as soil erosion, water pollution, and greenhouse gas (GHG) emissions, frequently accompanied by ineffective waste management (Sharma *et al.*, 2023). Sustainable agriculture can potentially help create a more sustainable and resilient global future. There is a growing understanding that recycling and circular economy strategies may transform waste into valuable resources (Kurniawan *et al.*, 2022). An innovative and comprehensive perspective that considers the complete life cycle of these recycling processes is required to evaluate the potential and implications of recycling agricultural waste. The method, known as "Life Cycle Thinking," explains the extensive environmental effects of recycling agricultural waste and provides insights into sustainable practices (Dahiya *et al.*, 2020; Zeug *et al.*, 2023). The core idea of "sustainability" is life cycle thinking, an original and comprehensive strategy that goes beyond conventional linear evaluations. Life Cycle Thinking provides a thorough understanding of the environmental impact at every stage by considering the entire life cycle of agricultural waste from its origin through final recycling or disposal (Hauschild *et al.*, 2020; Puspita *et al.*, 2023), and it helps create transformational opportunities to reduce unfavorable effects and improve sustainable behaviors. Furthermore, Life Cycle Thinking gives a precise and comprehensive assessment by considering the entire life cycle of trash from its initial generation through its eventual reuse or disposal. Recycling techniques using this strategy are suitable for the environment but have uncovered potential trade-offs (Wahyono *et al.*, 2023; Wu *et al.*, 2021). Additionally, Life Cycle Thinking ensures that decision-makers are aware of the long-term effects of their decisions, promoting the development of intelligent policies and practices. Waste can be diverted from conventional disposal procedures and reused to reduce environmental harm and improve the circular flow of resources within agricultural systems. Recycling agricultural waste is a practical method that balances environmental protection with human advancement, paving the way for a resilient and regenerative planet. Life-cycle assessment (LCA) is a robust framework that directs research and has an ambitious purpose and clear objectives. The LCA technique analyzes the entire life cycle of agricultural waste recycling (Gilani *et al.*, 2023). While various studies have analyzed the potential environmental impacts of various agricultural waste management methods, no studies have analyzed and compared each method completely in Asian nations. Therefore, this study's results can help Asian countries consider adding agricultural waste management methods and assess the environmental effects of each stage, revealing vital information that guides sustainable decision-making. Furthermore, this study aims to enable readers to holistically analyze the implications of recycling agricultural waste, noting its broader environmental effects. Moreover, this study aims to uncover the potential for sustainable practices, promote circular economy principles, educate policy decisions, increase stakeholder engagement, and contribute to global sustainable development goals using LCA methodology. Finally, this study aims to promote and help implement sustainable agricultural waste recycling procedures to encourage a more peaceful coexistence between agriculture and the environment. This study was conducted in an Asian country in 2023.

METHODOLOGY

State of the art and challenges for agricultural waste management LCA in answering sustainable concept

Agricultural land use produces significant agricultural waste, such as crop leftovers, animal manure, and trash from food processing (Rani *et al.*, 2023). Improper agricultural waste management can have adverse environmental effects, including soil, water, and air pollution, as well as land degradation; therefore, effective agricultural waste management is crucial (Koul *et al.*, 2022). Regarding agricultural waste management, sustainability refers to balancing human needs and preserving and protecting the

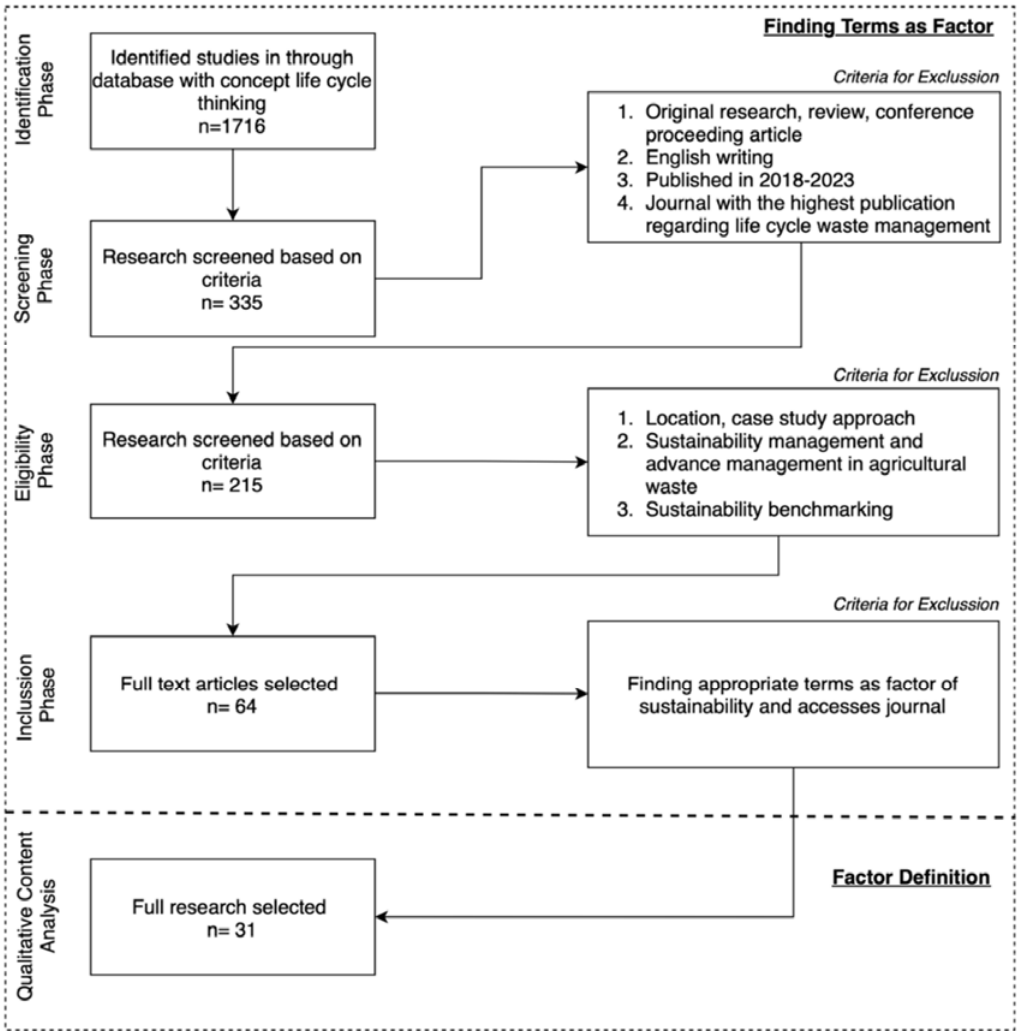

Fig. 1: Steps to find, identify, and define agricultural waste management with a sustainable concept

environment. This entails techniques that enhance the social and economic well-being of farmers and communities around them and reduce harmful environmental effects (Nigussie *et al.*, 2021). The LCA method is crucial for determining the environmental impact of a process or product from the perspective of production to final disposal. Regarding managing agricultural waste, LCA makes it possible to thoroughly assess the environmental effects of alternative waste treatment choices, including creating new treatment techniques and discovering potential enhancements in environmental performance (Llorach-Massana *et al.*, 2023). A life-cycle thinking strategy is related to LCA and is advocated for managing agricultural waste. Life cycle gas emissions conserve natural resources such as land and water and boost soil fertility (Adekomaya and Majozi, 2022; Mondal and Palit, 2022). It is possible to develop efficient and sustainable policies and activities to address sustainability in managing agricultural waste by incorporating life-cycle thinking and LCA.

Selection criteria of research LCA review

This study focuses on LCA studies on the management of agricultural waste produced from each agricultural process in Fig. 1. This study utilizes SCOPUS and Google

Table 1: Traditional agricultural waste management

Research Study	Functional unit (FU), method, model & Waste type	Agriculture waste management	Impact assessment result of parameter	Critical findings	Sources
Qatar	FU: 1 ton Method: CML 2 baseline 2000 Model: Simapro Waste type: agriculture general waste	S1: WC S2: AD S3: WC, AD	1. AD p 2. G WP 3. OD 4. HT 5. PO 6. AP 7. EP	In terms of overall impact, the use of fossil fuels for transportation accounts for around 60 percent (%) of the emissions produced. Composting follows with 40% of the emissions produced, particularly in terms of possible global warming.	Al-Rumaihi *et al.,* 2020)
China	FU: 1 Mt Method: Ecoinvent 3.2 Model: OpenLCA Waste type: Dairy manure	S1: AD S2: COMP S3: SS-AD, COMP	1. AD p 2. G WP 3. EP 4. RD	The combined GWP of solid-state AD and composting, which is -2900 kg CO_2 eq/t of dairy manure, was the lowest. This figure is almost 14.8 times lower than that of the current status, which is liquid AD of dairy manure.	Li *et al.,* 2018)
Turkey	FU: 1 ton Method: Edip 2003 Model: Gabi 5 Waste type: Agriculture and organic fertilizer	S1: AD S2: GS S3: LF	1. AP 2. AE 3. G WP 4. PO F 5. SO D	By removing it from the region's traditional landfilling waste management system, the sustainability of energy production from agricultural and farm waste, via AD, was further strengthened.	Nayal *et al.,* 2016)
China	FU: 1 ton Method: CML 2000 Model: Simapro Waste type: Pig Manure	S1: AD S2: BS S3: Ds	1. G WP 2. AP 3. EP 4. HT 5. AD p 6. OD	The findings imply that comprehensive digestate reuse and biogas use (heating, lighting, and fuel) from AD are equally important in the system's overall energy production and play a significant role in systemic greenhouse gas reduction.	Chen *et al.,* 2012)
Beijing	FU: 1 ton Method: IPCC, CML, Ecoinvent Model: Simapro Waste type: Mixed manure	S1: BS	1. GH G	Hopefully, by improving fermentation efficiency and coordinating the operation of biogas digesters, the linked system can be maximized.	Chen and Chen, 2013)
Vietnam	FU: 1 ton, 100 kg Method: Recipe 2008 Model: Simapro Waste type: liquid manure, solid manure	S1: BS	1. G WP 2. FD 3. FE 4. M AE	Biogas digesters could help to mitigate the effects of global warming if methane emissions are kept to a minimum, according to a sensitivity study.	Vu *et al.,* 2015)
China	FU: 1 ton Method: Ecoinvent, Eco-indicator 99, IPCC 2007 Model: Simapro Waste type: agricultural waste	S1: BS	1. G WP 2. OD 3. AD 4. EP	According to the findings, the production of biogas has a positive impact on artificial environments while having a negative impact on GWPs. With time, its detrimental effects on GWPs become more pronounced.	Wang *et al.,* 2016)
Singapore	FU: 1000 ton Method: NA Mode: Gabi Waste type: NA	S1: INC S2: AD	1. AD 2. EP 3. G WP 4. HT 5. M AE 6. OD	The sensitivity study also showed that by reducing water use, reducing gas engine emissions, and diverting as much FW from incineration plants to AD plants as possible, better environmental profiles might be attained.	Tong *et al.,* 2018)

Continued Table 1: Traditional agricultural waste management

Research Study	Functional unit (FU), method, model & Waste type	Agriculture waste management	Impact assessment result of parameter	Critical findings	Sources
Indonesia	FU: 1 ton Method: IPCC 2013, Impact 2002+ Model: Simapro Waste type: Animal manure	S1: COMP S2: BS S3: COLT-BS (A)	1. G WP 2. AP 3. EP 4. HT	The findings given here suggest that the GWP was the most important factor in the environmental impact evaluation of the POME. COLT-Biogas A combined with communication posting was found to be more environmentally beneficial than the other combinations in terms of GWP.	Nasution *et al.,* 2018)
Malaysia	FU: 1 ton Method: CML 2001 Model: Simapro Waste type: Agro residue	S1: COMP S2: LF	1. OD 2. G WP 3. AP 4. EP 5. EC t	The completed compost is demonstrated to satisfy Malaysia's requirements for organic fertilizer, proving the viability of this affordable method.	Keng *et al.,* 2020)
India	FU: 1 ton Method: CML 2001 Model: Simapro Waste type: Agro residue	S1: PRs S2: Ln S3: Cs	1. G WP	The development of biofuel processing, however, has a number of challenges in addition to the advantages mentioned above, such as scientific, technological, economic, environmental, safety, depository, policy, and so on. Therefore, thorough R&D is required to overcome these obstacles. However, these negative effects can be lessened by technological development and careful planning.	Rahimi *et al.,* 2022)
Vietnam	FU: 1 ton Method: Recipe Model: Gabi Waste type: Organic manure, corn waste	S1: PRs S2: Br	1. GH G	Due to its low cost, high efficiency, simplicity of usage, ecological integrity, and reliability in terms of public safety, biochar made from agricultural waste biomass may be a suitable replacement for managing pollutants.	Nguyen *et al.* , 2019)
China	FU: 1 ton Method: Gabi Model: NA Waste type: Oil palm kernel shell and empty fruit bunches	S1: Co- PRs	1. G WP 2. HT 3. TE TP 4. AP	In summary, these studies can serve as a resource and simple methodology for persons who are interested in advocating the use of co-pyrolysis of agricultural waste and promoting product industrialization.	Mo *et al.,* 2022)
Indonesia	FU: 1 ton Method: Gabi Model: CML-2001 Waste type: Coconut shells	S1: AC	1. G WP 2. HT 3. AP	The analysis of alternative scenarios suggests that by reducing the electrical energy consumptions in the process units of crushing and tumbling as well as by using electrical energy from renewable sources, such as biomass, the sustainability of activated carbon production in Indonesia could be greatly improved, reducing the contribution to global warming and local human toxicity. This would contribute to a reduction of 80% in global warming and a 60% decrease in the local impact to human toxicity.	Arena *et al.,* 2016)

Continued Table 1: Traditional agricultural waste management

Research Study	Functional unit (FU), method, model & Waste type	Agriculture waste management	Impact assessment result of parameter	Critical findings	Sources
North Vietnam	FU: 1 ton Method: Simapro Model: IPCC 2006 Waste type: Rice straw and husk	S1: OB S2: Br	1. CF	The findings suggest that the climate consequences of these double rice cropping systems in Vietnam can be reduced by stopping the burning of crop leftover in the field and using residues to generate biochar for application to soils.	Mohammadi *et al.,* 2016)
Vietnam	FU: 1 Mt Method: Simapro Model: IPCC 2006 Waste type: Rice husk	S1: PRs, Br S2: Br, COMP	1. G WP	The findings of this LCA analysis suggest that, in comparison to open burning of rice husks during both the spring and summer rice cropping seasons, using rice husks for biochar in biochar-compost (COMBI) systems can improve climate change and health effects.	Mohammadi *et al.,* 2017)
China	FU: 1 Mt Method: Na Model: MUIO-LCA model Waste type: Feedstock	S1: Cr S2: Cr, Br S3: Cr, Dfp S4: Cr, Bb	1. GH G	The outcomes showed that Cr-Bb outperformed the other two technologies in terms of energy generation and air pollution reduction. Efficiency in energy conversion was proposed as a crucial variable in assessing the possibility for producing bioenergy and enhancing the environment.	Dai *et al.,* 2020)
Japan	FU: 1,34 ton Method: NA Model: NA Waste type: Manure	S1: COMP	1. GH G	On farmland on livestock farms, liquid materials (wastewater or slurry) could be applied.	Haga, 2021)
Indonesia	FU: 1 ton Method: NA Model: NA Waste type: General agricultural waste	S1: AF	1. So cial 2. Ec onomy	Using alternative agricultural waste as animal feed, it is possible to minimize agricultural waste, which has not previously been widely employed, and provide animal feed for the following six months in just 27 days.	Mufti and Fathurahman , 2022)

Scholar and the keywords "evaluation of the life cycle of agricultural waste management," publications for 31 LCA studies on agricultural management systems since 2012-2023 were obtained. The processing grouping is divided into two as described in Tables 1 and 2 namely traditional and advanced management using technology. Agricultural management is centered on one traditional management method that is analyzed and the use of new technology with a combination of traditional management, aims to compare the most efficient method of agricultural management. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method as a qualitative systematic review and science mapping as a quantitative and qualitative technique were used in literature studies to define and explore the aspects that influence sustainability in agricultural waste management. Fig. 1 depicts the approach used in the current investigation as a flowchart with PRISMA method. Data was gathered and examined utilizing a qualitative content analysis methodology, which offers insight into the circumstances surrounding the phenomenon under study and permits flexibility in research through the collection of descriptive and

Table 2: Advance agricultural waste management

Research Study	Functional unit (FU), method, model & Waste type	Agriculture waste management	Impact assessment result of parameter	Critical findings	Sources
Bangladesh	FU: 1 kg Method: NA Model: NA Waste type: General agricultural waste	S1: AD S2: COMP S3; LF S4: INC S5: GS	1. Social 2. Economy 3. Politic	This study simply aims to increase understanding of the waste-related issues that have arisen in Bangladesh from various sources, and it then suggests a feasible model that may be used to achieve a zero-waste policy. The findings of this study are nevertheless intended to be applied by academics, scholars, researchers, policymakers, and practitioners to future endeavors to support the proposed model prior to the adoption of the zero-waste policy to attain sustainable development goals.	Ahmed *et al.,* 2023)
Indonesia	FU: 1 ton Method: Ecoinvent 3.1, Recipe Model: NA Waste type: Feedstock collection	S1: Br S2: Brq	1. GHG 2. Pm10 3. Social 4. Economy	In this instance, the benefits of carbon sequestration in the soil and the economic worth of improved agricultural production outweigh the drawbacks of biochar production for the environment and the expenditures associated with it.	Sparrevik *et al.,* 2014)
Philipines	FU: 1 kg Method: Ecoinvent 3.1 Model: Gabi Waste type: Rice straw, rice husk, coconut husk, coconut shell, cattle manure	S1: Cs S2: Gs S3: AD	1. GHG 2. ME 3. HTP 4. TETP 5. POF	The findings indicate that AD is generally the most environmentally friendly alternative, exceeding the competition in 14 of the 18 impact categories. Nearly all of the effects of AD are net-negative, indicating that they should be avoided. This is because manure is used more effectively than when it is dumped in water or left on the ground. The global warming potential of AD can range from 170% lower to 41% higher than that of the diesel generator, depending on the feedstock.	Aberilla *et al.,* 2019)
Thailand	FU: 1 ton Method: IPCC Model: Simapro Waste type: date palm waste	S1: Br	1. GWP	When the adsorption capacities of the two adsorbents were evaluated, it was discovered that biochar performs on par with activated carbon.	Shaheen *et al.,* 2022)

Continued Table 2: Advance agricultural waste management

Research Study	Functional unit (FU), method, model & Waste type	Agriculture waste management	Impact assessment result of parameter	Critical findings	Sources
China	FU: 2,1 Mt Method: IPCC 2007 Model: OpenLCA Waste type: Straw	S1: PRs S2: Gs S3: Br S4: Brq	1. GW P	However indirect carbon abatement processes arising from biochar application could significantly improve the carbon abatement potential of the pyrolysis scenario. Likewise, increasing the agronomic value of biochar is essential for the pyrolysis scenario to compete as an economically viable, cost-effective mitigation technology.	Clare *et al.,* 2015)
China	FU: 1 ton Method: CML-2000 Model: Simapro Waste type: Agricultural straw	S1: Br S2: PRs	1. GW P 2. AD 3. AP 4. EP	A careful investigation revealed that the GWP categories are significantly impacted by the uncertainties of energy usage and agricultural straw yield.	Yang *et al.,* 2020)
Malaysia	FU: 1 ton Method: Recipe Model: Gabi Waste type: Organic manure, corn waste	S1: Gs S2: Ln S3: PRs S4: BS S5: Cs	1. GW P	Nevertheless, ongoing research is being done to address the gaps in the state-of-the-art technologies and boost their effectiveness and profitability.	Lee *et al.,* 2019)
Indonesia	FU: 1 ton Method: EASETECH Model: NA Waste type: Empty fruit bunch	S1: PRs	1. CF	For instance, some of the benefits of emissions reduction may be countered by the deforestation and land-use changes associated with oil palm farming. To maintain the overall sustainability of the biochar export program, it is critical to take into account and mitigate these negative effects.	Robb and Dargusch, 2018)
Thailand	FU: 1 ton Method: IPCC Model: Simapro Waste type: Manure and general agricultural waste	S1: BS	1. GW P 2. HT 3. FE 4. TE	Biomethane has the lowest well-to-wheel GHG emissions of all the biofuels (by less than one third).	Koido *et al.,* 2018)
Malaysia	FU: 1 ton Method: ReciPe Model:Simapro Waste type: Agricultural waste general	S2: LSS	1. GW P 2. HT	The production and milling of fresh fruit bunches for palm biodiesel and large-scale solar installations (electrical installation) aretwo environmental hotspots that have the potential to cause environmental burdens of up to 15–51% in terms of human non-carcinogenic toxicity, human carcinogenic toxicity, global warming, marine ecotoxicity, water	Phuang *et al.,* 2022)

Continued Table 2: Advance agricultural waste management

Research Study	Functional unit (FU), method, model & Waste type	Agriculture waste management	Impact assessment result of parameter	Critical findings	Sources
				consumption, and the scarcity of fossil fuels.	
China	FU: 1 ton Method: ReciPe Model: Simapro Waste type: Agro residue	S1: PRs S2: AD S3: GS S4: Cs S5: Ln	1. AP 2. EP 3. GWP	A popular management technique for reaching carbon neutrality in a circular economy, addressing both environmental and social problems, is to pyrolyze agricultural leftovers into biochar.	Zhu *et al.*, 2022)
China	FU: 2136 ton Method: Weighthing Model: Gabi Waste type: manure	S1: AD S2: GS S3: LBP	1. GWP 2. EP 3. AP 4. HT	According to the LCA, both large-scale (LBP) and BS plants demonstrated good environmental sustainability in terms of reducing pollutant emissions and producing clean energy.	Wang *et al.*, 2018)

visual data. The authors used the operator to search the SCOPUS database to find a suitable database covering the environmental effects of processing agricultural waste using the LCA approach. "TITLE-ABS-KEY (Agricultural Waste AND Agricultural Waste Recycle AND Life cycle assessment AND Asian)." The study was evaluated based on the following criteria: i) study area; ii) functional unit; iii) system boundary; iv) sensitivity analysis; v) environmental impact category; vii) potential comparison waste management strategy; and viii) key gaps and findings. Conference evaluations lack the requisite peer review to be recognized as a reliable source of information because they are not held to the same standards as journal articles. viii) Old conference evaluations: Conference reviews made before 2012-2023 may be regarded as out of date because more recent research has been undertaken. After reading the title, citation details, abstract, keywords, and the complete content, the author undertakes a thorough study analysis to establish credibility, dependability, and trustworthiness.

Review scheme

Critical evaluations focused on the fundamental elements of LCA for managing agricultural waste, such as the definition of objectives and scope, functional units, assumptions, selection of effect categories, and essential parameters/factors. Several LCA studies focusing on Asian nations have led to the discovery of these components. A logical ranking of the best technologies/policies was developed after categorizing the studies according to their distinctive nature and the treatment strategy used. Recommendations and the consequences of the best waste management techniques are provided based on numerous technological, environmental, and socioeconomic issues. This study is limited to agricultural waste, such as animal waste; agricultural wastewater, such as animal urine; and various plant residues (leaves, stems, and other plant parts remaining after harvest) with a gate-gate system (agricultural waste management). This selection aimed to ensure consistency in the life cycle analysis methodology. This includes selecting relevant inputs and outputs as well as modeling environmental impacts. This consistency supports the accuracy and sharpness of the research results. Therefore, collection and transportation are beyond the scope of this study.

Classification of LCA studied on basis economy analysis

In this subcategory of LCA studies, the environmental and economic impacts and various agricultural waste

treatment solutions were compared. To determine the most effective and sustainable approach for handling agricultural waste in certain situations, researchers examined the lifecycle effects of various waste treatment techniques. This study was evaluated and classified based on technology and economics. It starts by classifying the technology, where the LCA study concentrates on assessing the technological aspects of agricultural waste management. This requires an evaluation of the effectiveness, performance, and environmental impact of various waste treatment systems, including waste-to-energy processes, anaerobic digestion, and composting. Furthermore, the economic aspects and evaluation of available alternative agricultural waste management methods are the main focus of LCA research in this category, requiring cost evaluations associated with various waste management approaches, comparing the financial feasibility of different treatment technologies, and exploring the potential savings or benefits of adopting more sustainable and affordable waste management techniques. Fig. 2 illustrates those various countries, from low- to high-income countries, have substantial differences in agricultural waste produced per person yearly, which also impacts the management costs. The average total agricultural spending per farm in the US in 2020 was $182,130, an increase of 2.6% over the average of $177,564 in 2019 (Smith *et al.*, 2020). Although these statistics cover many farm operations, a sizeable amount of these expenses may be devoted to waste management activities. Additionally, food waste is predicted to cost the US restaurant industry $162 billion annually (Blum, 2020; Read and Muth, 2021). The financial impact of the food industry's waste, which is closely tied to agricultural waste even though this figure is not solely devoted to managing agricultural waste, is apparent. Leaders in the recycling sector are investing in waste management strategies, indicating that money is being invested to create and implement effective waste management systems.

Mapping of the study area and evolution of LCA studies in Asia

Thirteen Asian countries meet the requirements for LCA analysis on agricultural waste management, and China is the most dominant country for agricultural waste management analysis. Despite China's tremendous industrial and technological developments, agriculture plays an important role in its economy. Waste management is a crucial issue that must be addressed because of the country's high dependence on agriculture. As a result, it also impacts a demanding environment where the

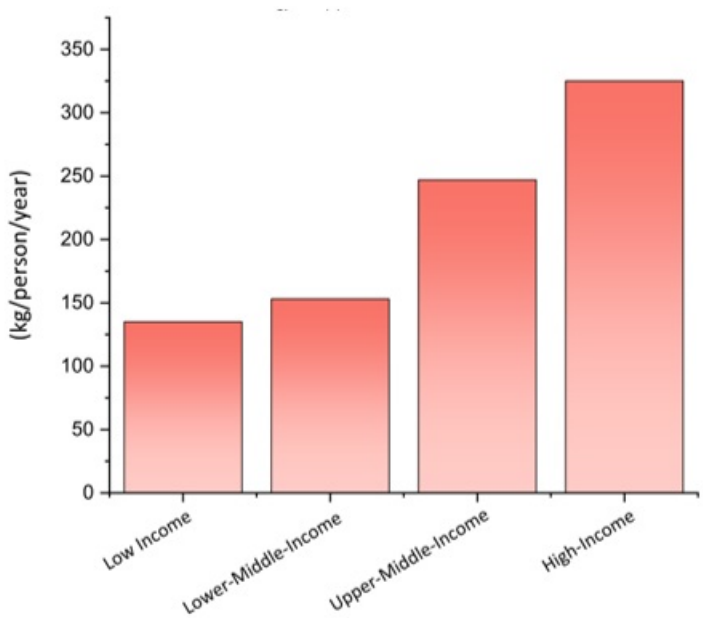

Fig. 2: Agricultural waste generation rate in different income group countries

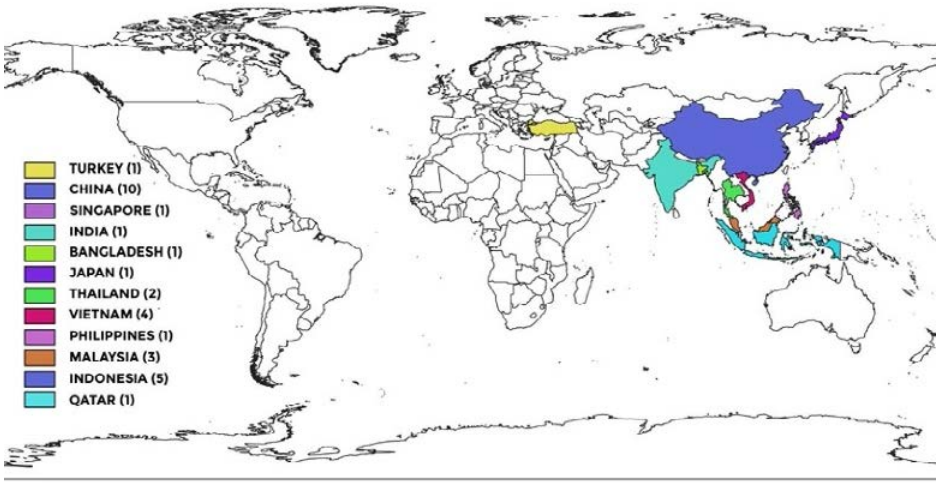

Fig. 3: Geographical distribution selected research

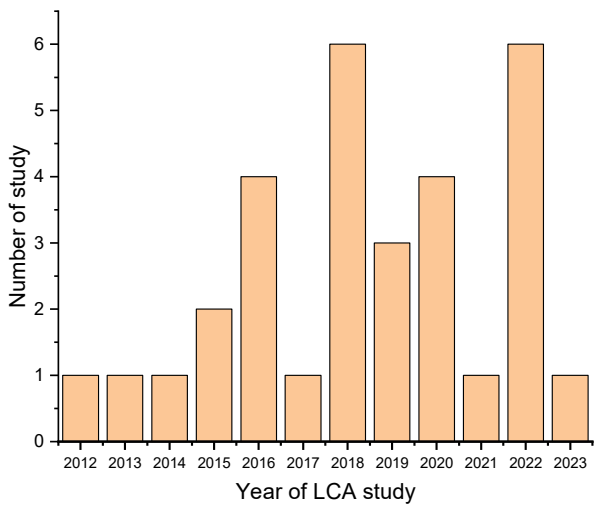

Fig. 4: Evolution time LCA studies (2012-2023)

handling of agricultural waste can negatively impact the environment, resulting in air and water pollution. China has stepped up its research efforts to identify sustainable solutions to this problem because of its growing awareness of environmental challenges. Fig. 3 shows the distribution of the LCA studies (shown in brackets) selected for evaluation in Qatar (1), China (9), Indonesia (5), Turkey (1), Beijing (1), Vietnam (4), Singapore (1), Thailand (2), Malaysia (3), India (1), Japan (1), Bangladesh (1), and Philippines (1). Most LCA were observed in 2020 and 2018, while the least LCA were observed between 2012-2014 and 2017, all of which had the same number of LCA, namely one study. The number of LCAs increased from 2016 to 2020, and the LCA studies identified in 2021 and 2023 were neither classified for analysis nor accessible. The number of LCAs is expected to increase in 2019 and 2022, as shown in Fig. 4. due to various factors such as the general public's understanding of environmental challenges, climate change, environmental degradation, and the scarcity of natural resources, which has grown over time. The need for LCA research is growing as more businesses, governments, and members of the public

recognize the importance of gauging how products and activities affect the environment. Furthermore, laws and guidelines are being presented, and more nations and regulatory bodies are beginning to enact stricter environmental regulations, which may include demands that LCA be conducted on specific products. This motivates businesses and industries to conduct LCA research as part of their regulatory compliance and identify areas where their environmental performance can be enhanced. For the second Focus on Sustainability, throughout 2018–2020, sustainability rose to the top of the priority list for many organizations and industrial sectors. To make operations more sustainable, businesses are utilizing LCA as a valuable tool for assessing and controlling how human activities affect the environment.

Changes in the LCA can be attributed to waste-related issues in specific years, the amount of engagement in the scientific community, and the availability of functional units for projects involving municipal solid waste (MSW) management (Budihardjo *et al.*, 2023b; Yadav and Samadder, 2018). This trend highlights the significance of utilizing LCA to evaluate the environmental impacts of MSW management. The global uptake of LCA studies and the ISO 14044:2006 standard for LCA methodology are growing (Khandelwal *et al.*, 2019). Moreover, research, regulatory changes, and adoption of ISO standards have improved LCA implementation (Laurent *et al.*, 2020).

This review focuses on the main elements of LCA for MSW management, such as the definition of objectives and scope, functional units, assumptions, choice of effect categories, and critical parameters/factors. Several LCA investigations conducted in Asia led to the discovery of these components. A logical ranking of the best technologies/policies was developed after categorizing the research according to their distinctive characteristics and treatment methods. Recommendations and consequences of the best waste management techniques are based on numerous technological, environmental, and socioeconomic concerns.

Scope definition analysis

This section analyzes the vital aspects of the research results that have been collected, such as functional units, system limitations, the models used, the path categories analyzed, sensitive parameters, and the reasons for implementing the technology.

Functional unit

LCA includes functional units (FU) as fundamental vital points that require attention. The measured performance of the production system was used as a reference for the output produced (McAuliffe *et al.*, 2020; Haumahu *et al.*, 2023). The included LCA comparisons usually had the same FU to obtain fair results for each comparison of the technologies used. Limiting and having the same FU as a whole provides a general understanding of current waste management issues, necessary developments, processes that can be replaced with raw materials, and the replacement of fossil energy with natural energy, such as solar energy, so that it has an impact on sustainability, reduces management costs, and reduces emissions from an economic and environmental standpoint (Chen *et al.*, 2021; Saravanan *et al.*, 2021). Fig. 5 shows the FU for the cited agricultural waste management practices. The functional unit used in the studies cited in general was 1 ton (23 of 31 studies). Some used 1 Mt and more than 1 Mt (3 of 31 studies) and <1 ton and >1 ton for the remainder.

To accurately reflect the true intent of LCA and enable fair comparisons between various goods or services, the choice of a FU must be carefully considered (Corominas *et al.*, 2020). One ton is one of the most popular FU alternatives in LCA due to: i) industry standard: in certain industries or sectors, one ton is a commonly used measure of production or performance. For example, ton is the standard unit to report production quantities in industrially produced materials such as steel, cement, and paper; ii) Practical and easy to measure: Using ton as the FU can result in easier calculations and easier to perform in LCA analysis because it is easier to measure and compare; iii) Consistency: using ton as the FU allows for consistency in LCA analysis because different products or services can be compared on a similar scale with the same weight (ISO 14040, 2006; ISO 14044:2006). It is crucial to remember that FU selection should consider specific LCA objectives and encompass the entire extent of the goods or services being assessed (Marmiroli *et al.*, 2021). Depending on the goal and setting of the LCA, another FU may occasionally be more suitable. It is also important to understand the dynamic nature of the study, which means that over time, the procedures and methods

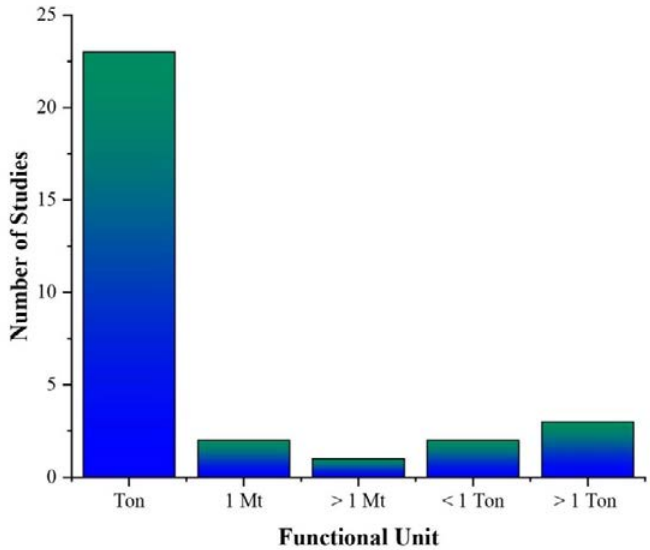

Fig. 5: Research on the use of functional units are distributed

employed in LCA may also change (Mio *et al.*, 2022). Consequently, a different set of FU may be chosen for each LCA instead of one ton.

System boundaries and use LCA methods

System constraints, commonly called "analytical constraints," are important for the LCA method's early phase. System boundaries are crucial factors affecting the overall results of an analysis (Bonilla-Alicea and Fu, 2019; Kajtaz, 2019). This is defined as the processing/management stage, which depends on what is being analyzed, including the operation phase, inputs, outputs, and operating time options for agricultural waste management (Sharma *et al.*, 2023). System boundaries determine the entry and exit of process units or component variables from the analysis performed (Abbasi *et al.*, 2022). This stage must consider the duration, scope, and study objectives, and the decision to exclude input/output processes must be explained (Onat and Kucukvar, 2022). System constraints should ensure that all relevant processes and the possibility of realizing their environments are considered in the evaluation. A proper definition of system boundaries carries the risk of offloading from one phase of the life cycle to another. Furthermore, the software or model used is a computer-based tool for collecting, organizing, and analyzing data, simulating systems from life cycle flows, and analyzing the impacts that will occur (Kenett *et al.*, 2023). Furthermore, LCA of various activities can be performed without the help of software. However, the experts greatly assisted in their work, such as obtaining, compiling, and analyzing various inventories. Common tools often used in LCA analysis, such as Simapro and Gabi, which have complete facilities as well as adequate choices for LCA analysis, such as characterizing and evaluating environmental impacts to examine life paths, such as urban waste management and agricultural waste, and can be accessed or subscribed to obtain unlimited premium services (Budihardjo *et al.*, 2023b). Other software has been developed specifically for LCA waste management, such as the Environmental Assessment System for Environmental Technologies (EASETECH), Integrated Waste Management, and Open LCA, and other newer experimental software programs, such as the MUIO-LCA model. Comprehensive data collection is required for LCA in all aspects of agricultural management, including the production of raw materials and the handling, processing, and disposal of waste (Trummer *et al.*, 2022). The general LCA analysis steps are as follows: i) Goal and scope determination: The program user determines the objectives of the analysis and specifies the parameters for the solid waste management system assessment and review;

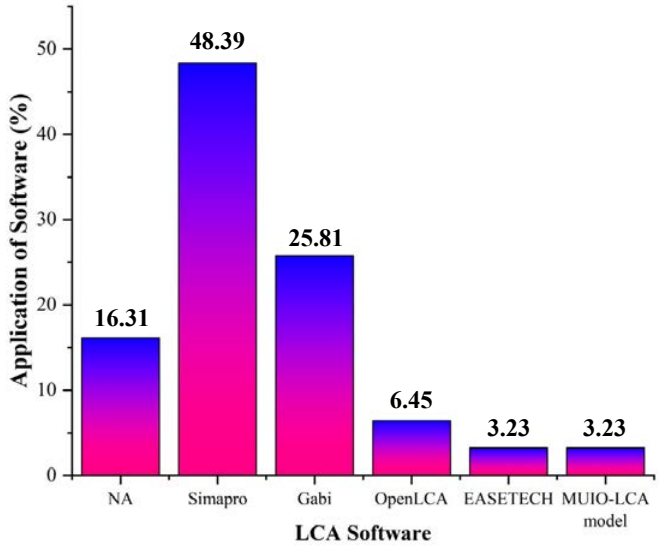

Fig. 6: Analysis of LCA research and growth

ii) Lifecycle inventory: Information on inputs and outputs is compiled and entered into a program. It contains information on the amount and type of energy consumed, raw material quantities and types, emissions, and other characteristics of each process; iii) Characterization of the environmental impact: The collected data explain how each phase of the waste management system affects the environment; and (iv) Interpreting the results: To understand the relative contributions of each stage of the waste management system to the overall environmental impact, the LCA results were assessed (ISO 14040, 2006 ; ISO 14044:2006). The software used in the cited research that will be compared and examined is shown in Fig. 6. To satisfy low-cost and environmentally friendly economic sectors, all LCA analyses seek to streamline agricultural waste management. With rates of 25.81%, 6.45%, and 48.39% for Gabi, Open LCA, and SimaPro, respectively, two studies that used the EASETECH and MUIO-LCA software also saw usage. However, in 16% of the studies, using software for analyzing environmental effects was left unexplained. Furthermore, 16% of studies did not employ any software for their environmental impact analyses for the following reasons: i) financial restrictions, licensed LCA software can be fairly priced, and research resources might not be enough to cover purchasing costs. Researchers may employ a manual approach or straightforward tools, such as spreadsheets or self-programming code, in such situations; ii) Flexibility and control. Under certain circumstances, it may be desirable to have complete control over the entire LCA process, including the figures and techniques employed. Researchers may feel constrained by their ability to alter or modify the existing software to meet their study objectives; and iii) Creation of a special methodology: In some cases, researchers may be motivated to create a unique LCA approach that has not yet been implemented in the software. Under such circumstances, they may have to create a special computational tool to match their study goals

The LCA software selection depends on the research objectives, equipment acquisition costs, the data held, and program usage (Manco *et al.*, 2023; Petrillo *et al.*, 2022). LCA software is also often used in the implementation of environmental management systems as it has many benefits beyond environmental impact analysis, such as economic analysis, weak-point assistance, opportunities for improvement at a stage that has a high impact, and opportunities to replace cheaper or environmentally

friendly fuels (Deepak *et al.*, 2022). Therefore, the LCA method could accurately identify stages with poor impact and performance. Moreover, the LCA method provides decision-makers with a tool for making complex choices and providing relevant and accountable information for reporting (Torkayesh *et al.*, 2022). By providing actual data and scientific analyses regarding the impact of agricultural waste management environmental systems, LCA ensures that each approach is evidence-based and sustainable. The LCA method can also help decision-makers contribute to reducing economic impacts and developing an effective waste management system so that an environmental management system can be developed

Impact categories selection

The selection of impact categories is one of the objectives for determining whether the selected application is in accordance with the desired target; however, if the impact category analyzed is broader, it will provide a more detailed analysis to achieve a sustainable system (Khanali *et al.*, 2022). Fig. 7 shows the number of impact categories most often used to meet technology goals. The Global Warming Potential (GWP) impact category is used most commonly, at 80–94%, because it covers climate change issues and is required to consider potential environmental implications. This is in line with the research by Pratibha *et al.* (2019), where the main indicators of sustainability cover technologies with low GHG emissions were classified as GWP. In the context of GWP, key stages in the life cycle contributing to GWP, such as raw material extraction, production, transportation, use, and end-of-life disposal, should be identified to reduce GWP. When these are met, the potential trade-offs between environmental impacts will help decision-making for more sustainable alternatives. Therefore, evaluating the reduction in methane emissions caused by the breakdown of agricultural waste can be reduced when suitable management techniques, such as composting or anaerobic digestion, are used. Furthermore, the second impact analysis is the potential for human toxicity and ozone depletion of 30-45%, while the analysis of other impacts such as social, economic, ozone depletion, and photochemical ozone formation. An LCA can reveal the type and amount of toxic substances released during the life cycle of a product. These findings highlight the life cycle stages that contribute significantly to the impact of toxicity in humans. For example, the use of pesticides or other chemicals in agriculture may contribute to human toxicity, highlighting the importance of sustainable practices and using alternative ingredients. Moreover, ozone depletion in a city reveals the extent to which a product or process contributes to ozone layer depletion, highlighting certain substances or

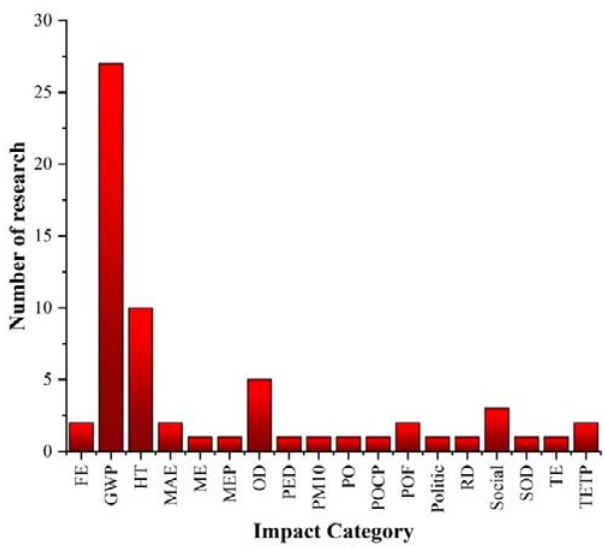

Fig. 7: Impact category analysis

manufacturing processes with high ozone depletion potential. Sustainable alternatives that minimize or eliminate the use of ozone-depleting substances can be identified, thereby contributing to more environmentally friendly practices. Sustainability outcomes depend on the balance between various environmental impacts. For example, a product or process may have a lower ozone depletion potential but a higher toxicity in humans, or vice versa. LCA should consider these trade-offs and help identify strategies to minimize negative impacts while maximizing positive ones. Agricultural waste management significantly affects climate change, resource depletion, and ecosystem health. Burning agricultural residues or neglecting trash may release methane and exacerbate global warming. When agricultural waste is not recycled, soil erosion and synthetic fertilizer use deplete resources (Khanali *et al.*, 2022). This method reduces soil fertility and agricultural production. Water contamination and habitat degradation due to improper waste management threaten ecosystem health (McAuliffe *et al.*, 2020). Sustainable waste management, such as composting and anaerobic digestion, is beneficial. Renewable energy from waste biogas reduces gas emissions from glasshouses. Recycling agricultural waste improves soil organic matter, lowers synthetic fertilizer use, and supports sustainable farming. The rest of the analysis, which is rarely used, can potentially help further studies to suggest substituting materials, raw materials, fuels, and the development of tools for managing agricultural waste to achieve a sustainable solution (Budihardjo *et al.*, 2023b). This is because, when measuring the total energy used in each life cycle of the technology used, high energy use can significantly impact natural resources and GHG emissions.

Furthermore, for the economic sector, such cost cuts are expected by analyzing potential cost savings from effectively managing agricultural waste, considering opportunities for waste-based goods, and decreasing disposal costs (Chepeliev *et al.*, 2022). Resource recovery evaluates the financial value of materials recovered from trash, such as compost, that can be used to produce bioenergy or improve soil (Haque *et al.*, 2023). Market development, which measures the market expansion of waste-derived goods, stimulates economic opportunities in the agricultural waste management sector followed by health and safety (D'Agaro *et al.*, 2022). Analyzing how well waste management decreases health risks for farmers, employees, and people in the area by minimizing exposure to dangerous substances is required (Mehmood *et al.*, 2022). This sector is also covered by community engagement, which assesses the potential to create new employment opportunities and generate income through waste management practices and value-added products by examining local community involvement and awareness of waste management initiatives, encouraging a sense of responsibility and ownership and improving livelihoods. Support for conformity with laws and regulations is required for systematic application, and legal compliance assesses how well agricultural waste management operations adhere to current waste and environmental rules and whether policies are well-aligned. It also analyzes how national and international policies, such as pledges to the environment and sustainable development goals, connect with waste management initiatives. By considering these impact categories, stakeholders may build thorough plans for efficient agricultural waste management that address environmental, economic, and social concerns while fostering sustainability and resilience in agriculture.

Key sensitives parameters

Sensitivity analysis is used to determine how various characteristics or variables affect the results of agricultural waste management. This section discusses agricultural waste management and its effects on environmental, economic, and social issues. However, these studies typically include additional criteria (Awasthi *et al.,* 2022). The amount of agricultural waste produced substantially impacts the total waste management plan, and some studies indicate a waste generation rate of 30–55%, as this is a widespread issue (Karić *et al.,* 2022). The scalability of the waste management system can be evaluated, and the critical point at which alternative waste treatment methods are required can be identified by analyzing the sensitivity to changes in the rate of waste formation (Sabet *et al.,* 2023). Agrochemical containers, crop residues, animal dung, and other waste products are produced by diverse agricultural activities in addition to the composition of agricultural waste. The most important waste streams can be identified by analyzing their sensitivity to changes

in waste composition, and their management can then be based on the potential for resource recovery and environmental impact (Ganesan and Valderrama, 2022). Additionally, selecting from a range of processing technologies, such as anaerobic digestion, incineration, composting, and other cutting-edge technologies, as shown in Fig. 8 is the most widely discussed topic. The compatibility of these technologies in multiple situations can be determined using sensitivity analysis, which considers energy efficiency, GHG emissions, nutrient recovery, and economic viability (Zoppi *et al.,* 2023). Sensitivity analysis can evaluate the impact of changes in the market prices of agricultural and waste-derived products (such as bioenergy and biological fertilizers), which is another factor that is rarely considered (Bhatt *et al.,* 2023). This analysis can determine prospective revenue sources and impact the economic viability of waste management solutions. Government laws and regulations can significantly impact how agricultural waste is managed; however, there is a lack of sensitivity analysis. Different policy scenarios, such as financial incentives for garbage recycling or fines for improper waste disposal, can be designed using sensitivity analysis to determine their impact on waste management decisions (Ma *et al.,* 2023). The last and most debated component is social acceptance, which overlaps with existing conditions, the workplace, and stakeholders' willingness to engage. Sensitivity analysis can help with the adoption of sustainable waste management, which can be influenced by public perception and engagement.

Important sensitive criteria for agricultural waste management

Identifying and prioritizing sensitive criteria are essential in agricultural waste management to ensure efficient and long-lasting waste treatment procedures. These criteria are crucial because they significantly impact the development of waste management methods. The following are some delicate factors for managing agricultural waste, listed in order of importance: i) Waste Composition: It is crucial to comprehend the makeup of agricultural waste. The viability and efficacy of various waste management strategies can be affected by variations in nutrient content, moisture levels, and the ratio of organic to inorganic elements; ii) Resource Recovery Potential: It is important to evaluate the possibility of recovering resources and energy from agricultural waste. Technologies that effectively transform trash into useful goods, such as compost for soil improvement or biogas from anaerobic digestion, are widely desired; iii) Environmental impacts: The effects of agricultural waste management systems on the environment should be carefully considered. Minimizing emissions, reducing GHG emissions, and avoiding soil and water pollution are important factors to consider when choosing the best waste management techniques; iv) It is important to consider the applicability, compatibility, and ability of the technology to handle particular forms of agricultural waste. To achieve the best outcomes, the technology should be chosen considering the waste composition and regional context; v)

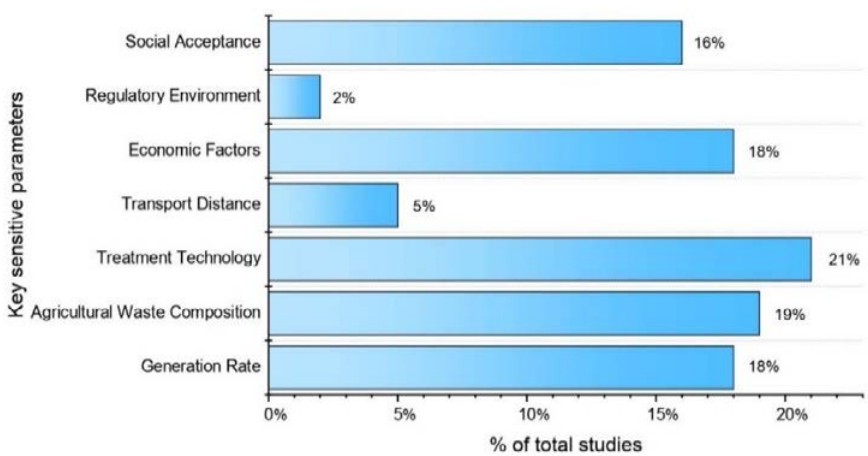

Fig. 8. Key sensitive parameters, sensitivity analysis has been used in research to identify and completely detail critical sensitive parameters that have a major impact on the outcomes

Economic Viability: Agricultural waste management strategies must be economically viable. The long-term sustainability of waste management projects is significantly influenced by their cost-effectiveness and potential for resource recovery to generate income; vi) Local Context and Socioeconomic Factors: Successful implementation and community involvement in waste management programs depends on taking into account the local context, involving social acceptance, existing infrastructure, and economic conditions; vii) Energy Restoration: To maximize the advantages of energy generation, the efficiency of energy recovery systems such as biogas yield from anaerobic digestion should be adequately analyzed; viii) Market Demand and Supply: A successful circular economy must consider the supply and demand dynamics of items made from recycled agricultural waste. Compost, biochar, or other recycled goods are used properly when viable markets are identified; ix) Transportation distance: Reducing travel distances between waste-generation sites and management facilities lowers carbon emissions and transportation expenses; x) Life Cycle Assessment: Carrying out a thorough LCA enables a holistic assessment of the environmental effects linked to various waste management solutions, facilitating well-informed decision-making. Agricultural waste management strategies can be created and implemented to maximize resource recovery and environmental consequences and fit with each region's distinctive characteristics by prioritizing these delicate criteria and considering how they interact.

Guideline best practices for recycle agricultural waste management

The best handbook for managing agricultural waste offers a thorough overview of important factors that must be considered (Bureau and Antón, 2022). It addresses several crucial topics, such as waste classification, resource recovery, sustainability, public awareness, and regulatory considerations (Tseng *et al.*, 2022). Although the recommendations contain insightful advice, several areas should be strengthened and elaborated, and the type and volume of agricultural waste produced on agricultural land must be carefully evaluated (Budihardjo *et al.*, 2023a). This process aids in identifying waste-management issues and growth prospects. Subsequently, waste stream characteristics were grouped according to their composition, biodegradability, and possibility of recycling or reuse. The stage of "Reduce and Prevent Waste Generation" needs to be given more attention because it can motivate farmers to use precision farming methods to maximize resource use and decrease overproduction, which then results in reduced waste production (Starek-Wójcicka *et al.*, 2022). It can also encourage the implementation of effective irrigation techniques, pest control strategies, and nutrition management strategies to reduce agricultural by-products (Tedesco *et al.*, 2023). If the phases cannot be shortened owing to strong demand, another option is to reduce waste in the livestock industry by encouraging people to compost organic waste products, such as agricultural residues, manure, and kitchen scraps, to produce nutrient-rich soil amendments. Encouraging farmers to use a zero-waste strategy, such as recycling agricultural packaging or switching to bioenergy generation from waste, is necessary. To support this, it is necessary to dispose of trash responsibly (Qin *et al.*, 2022). Agricultural waste should not be burned in an open environment as it releases dangerous air pollutants. Promoting controlled combustion or looking into different disposal options, such as anaerobic digestion is required. To avoid pollution, one must ensure that the waste disposal sites are far from vulnerable ecosystems and water bodies (Pantusa *et al.*, 2023). Recycling and resource recovery, which promote the recycling and reuse of agricultural waste, such as converting crop residues into animal feed or biofuel production, and exploring the potential to create value-added products from agricultural by-products, such as biodegradable packaging materials or natural fertilizers, continue to implement sustainable concepts (Koul *et al.*, 2022; Kumar Sarangi *et al.*, 2023). Collaboration and education are necessary for executing sustainable ideas. Cooperation should be encouraged among farmers, scientists, government organizations, and waste management professionals to create better approaches for managing agricultural waste (Farooq *et al.*, 2022). Additionally, it is necessary to conduct workshops, training sessions, and awareness campaigns to inform farmers about the significance of sustainable waste management techniques. Compliance with the regulations is required for their application. Ensuring that all agricultural waste management techniques adhere to applicable local, regional, and federal laws

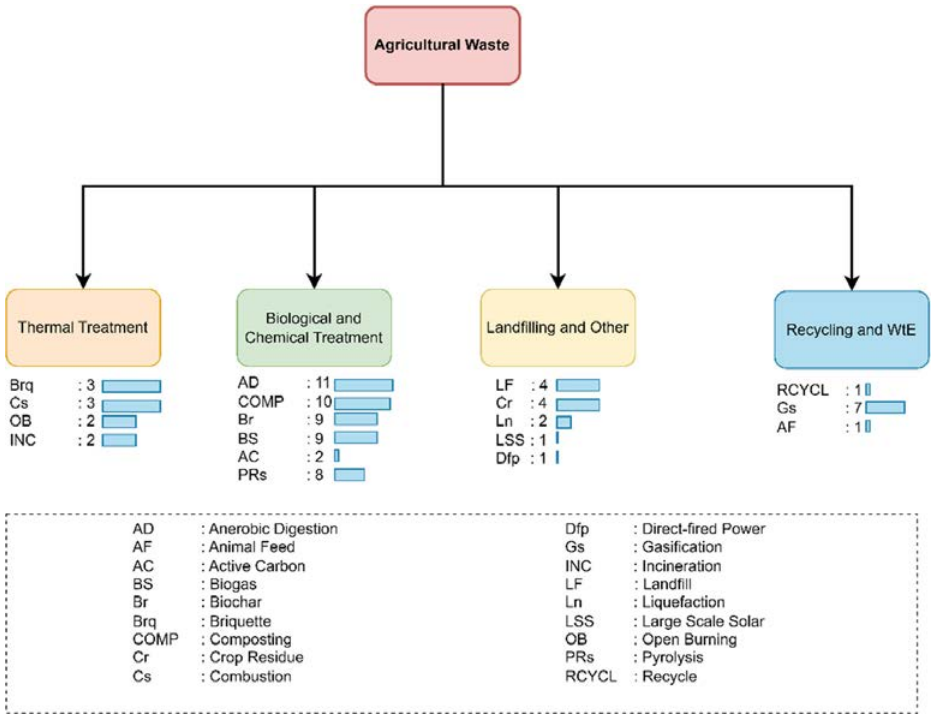

Fig. 9: Types and quantities of agricultural treatment technologies under evaluation

and regulations is necessary (Hemidat *et al.*, 2022). Farmers should be encouraged to adopt effective waste management practices by adhering to any changes in waste management regulations. Finally, monitoring and assessments are required to ensure that this concept is feasible. Installing mechanisms to monitor waste production and disposal methods can help with the success of waste management plans. Regularly evaluating the effects of waste management projects on agricultural productivity, environmental safety, and long-term economic viability is important. Agricultural waste management is a crucial component of sustainable agriculture. As per these recommendations, farmers can effectively manage their waste, reduce their adverse environmental effects, and convert it into useful resources. Adopting effective agricultural waste management methods benefits individual farms and helps develop a robust and environmentally conscious agricultural industry.

Reviewed technology

The existing conditions and advanced technologies have diversified the technologies used for agricultural waste management. The various types of technologies and quantities frequently used in these studies are shown in Fig. 9. Various methods that have been developed and implemented for agricultural waste have changed significantly from landfilling methods to becoming energy sources, such as biochar, biogas, briquettes, and various methods that produce energy, such as solar and electricity. However, several methods lack technology, such as animal feed. Many methods still use thermal scenarios such as gasification, pyrolysis, and combustion. Overall, these results have a variety of methods with various approaches, from traditional to advanced, which are analyzed by LCA experts to assess potential environmental impacts.

Suggested agricultural waste management technologies/facilities

This section summarizes the various methods for managing traditional and advanced agricultural waste in Asia, as shown in Figs. 10 and 11, apart from those analyzed, because they do not meet the criteria. Asia has many traditional practices because

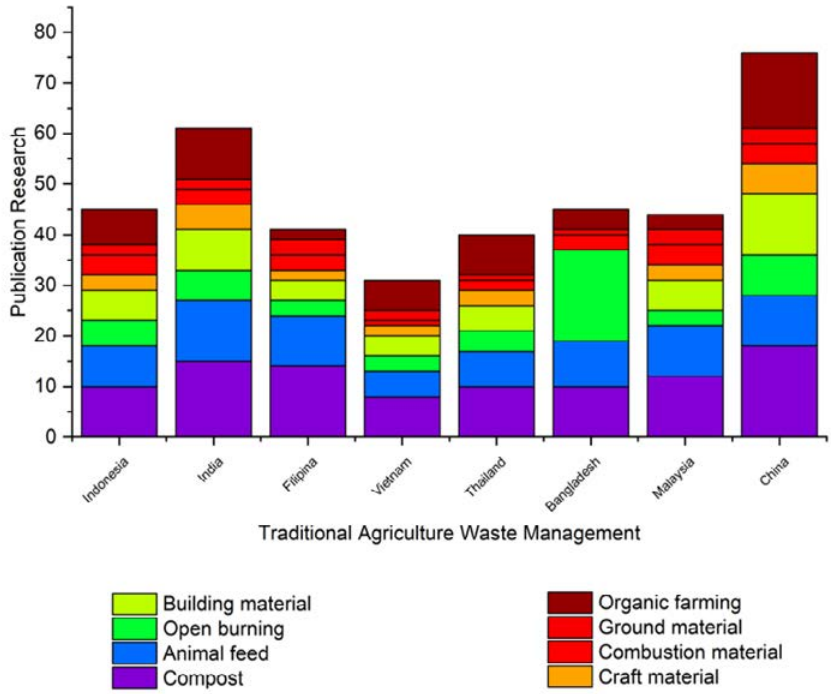

Fig. 10: Traditional agricultural waste management

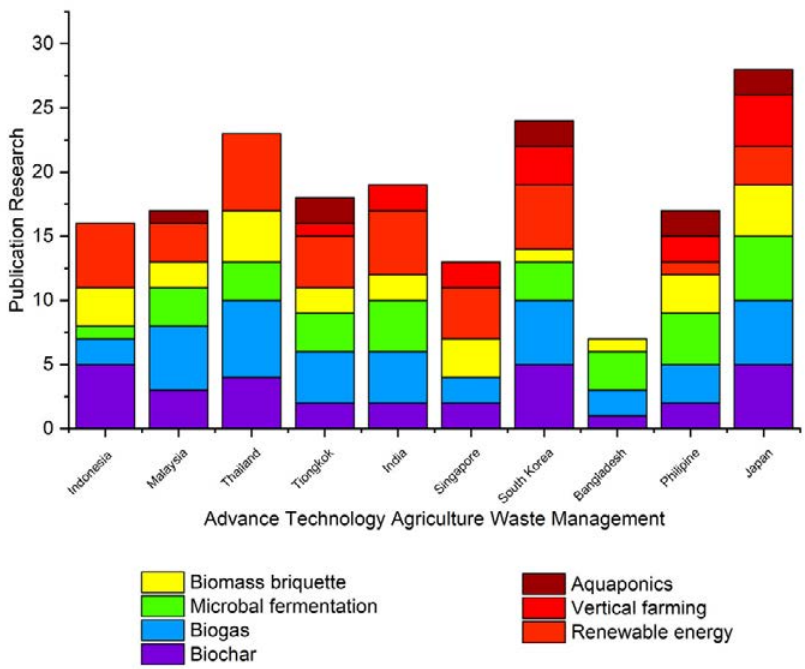

Fig. 11: Advance technology agriculture waste management

farmers often do not have access to resources, machinery, and contemporary technologies (Chaudhary *et al.*, 2023). Traditional farming techniques are usually more practical for small-scale farmers with limited resources because they are more accessible and affordable (Mizik, 2023). Traditional agricultural practices have changed over time to accommodate certain local factors, such as climate, soil type, and resource availability, which is another reason why many traditional methods are still in use (Chimi *et al.*, 2022; Samela *et al.*, 2022). These techniques frequently fit the particular needs and challenges of a region (Ezugwu *et al.*, 2022). Traditional agricultural methods are frequently taught and passed down from parents to younger generations in farming families or communities because of the lack of knowledge and skill transfer. This information transfer ensured the continuation of customary practices. There is also a connection between nature and sustainability, as traditional agriculture frequently emphasizes both concepts. By improving soil fertility, water conservation, and organic pest management, these techniques can support long-term ecological equilibrium (Vasseghian *et al.*, 2022). Moreover, cultural identity and food security have emerged. Local cuisine may be influenced by traditional crops and farming methods, which may be culturally important (Baldi *et al.*, 2022). Maintaining traditional agricultural practices helps preserve cultural identity and food security. Although traditional agricultural management has numerous advantages, it is crucial to understand how sustainable and current agricultural innovations can improve and supplement conventional approaches (Muhie, 2022). An integrated approach incorporating conventional knowledge with contemporary technologies is necessary to increase productivity, efficiency, and environmental sustainability in Asian agriculture (Kannan *et al.*, 2023). Governments, researchers, and organizations can play significant roles in assisting farmers in adopting sustainable and cutting-edge agriculture, while respecting and protecting traditional knowledge.

play a significant role in assisting farmers in adopting sustainable and cutting-edge agricultural.

Owing to several factors, such as the frequent need for considerable initial outlay and ongoing expenses, there are few advanced technologies in Asia. It may be difficult for small-scale farmers and rural populations across Asia, who constitute a significant portion of the agricultural sector, to afford this technology. Apart from technological matters, there is also the understanding that all agricultural waste will decompose by itself. The adoption process is impeded by upfront costs (Shaikh *et al.*, 2022). Lack of Awareness and Knowledge: Many farmers and other rural stakeholders may be unaware of the advantages of cutting-edge agricultural waste management systems (Fielke *et al.*, 2022). To persuade farmers with more expansive agricultural holdings to directly utilize crop waste, animal manure, and pruning materials instead of synthetic fertilizers, it is necessary to emphasize the advantageous outcomes regarding economics, the environment, and agriculture. On-farm organic resource utilization can substantially reduce input expenses for producers with larger farmland holdings. Alternatives to purchasing synthetic fertilizers that are frequently available on-site, sourced locally at reduced or non-existent expenses, and consist of crop refuse, animal manure, and pruning materials. In contrast to synthetic fertilizers, which may provide instantaneous nutrient availability but have the potential to deteriorate soil health gradually, organic materials impart long-term fertility to the soil through direct application. This method generates organic matter and ensures sustainable long-term productivity. Understanding how these technologies enhance waste management procedures is hampered by a lack of informational and educational resources. Technology and regional context adaptation: many cutting-edge waste management systems have been created outside Asia, and it may be difficult to adapt them to the particular requirements and conditions of Asian agricultural settings (Shokri and Fard, 2023). Although this can take time, localizing and modifying technology to meet regional demands is necessary. Cultural and traditional elements: the culture and heritage of many Asian communities are firmly rooted in traditional agricultural methods. Traditional approaches may have to be abandoned when a new technology is implemented, leading to resistance or skepticism. Furthermore, it is known that organic waste, including agricultural waste, naturally decomposes; however, recycling amplifies this organic process and derives multiple benefits from the waste. Composting is a prevalent recycling technique that involves the intentional decomposition

of organic agricultural waste in a controlled environment, generating a nutrient-dense compost that functions exceptionally well as an organic fertilizer. Compost enhances soil structure, optimizes water retention, and supplies vital nutrients to plants, thereby improving soil fertility and the overall health of crops. Implementing anaerobic digestion and composting as methods for recycling agricultural waste contributes to mitigating glasshouse gas emissions that would otherwise accumulate in landfills during natural decomposition. Methane, a highly potent glasshouse gas, is produced under landfill-like anaerobic conditions. Diverting organic waste from landfills by recycling reduces emissions and alleviates the adverse effects of climate change. Furthermore, agricultural waste recycling promotes sustainable agricultural practices by mitigating environmental impacts, reducing dependence on synthetic fertilizers, and enhancing soil health, enhancing the productivity and long-term resilience of agricultural systems. Governments, research institutes, the commercial sector, and non-governmental organizations must collaborate to address this challenge. Accelerating the adoption of cutting-edge technology for agricultural waste management in Asian nations would require stimulating public-private partnerships, developing awareness campaigns, offering financial support, and promoting information exchange (Kountios *et al.*, 2023). By removing these obstacles and encouraging environmentally friendly technologies, Asian countries can utilize cutting-edge waste management techniques to build a more resilient and sustainable agricultural industry (Iwuozor *et al.*, 2022). Effective agricultural waste management is essential for resource conservation, environmental preservation, and sustainable farming (Kharola *et al.*, 2022). The most effective technologies and facilities for managing agricultural waste emphasize resource efficiency, environmental sustainability, and a circular economy (Onyeaka *et al.*, 2023). Farmers and waste management stakeholders can dramatically reduce waste, produce renewable energy, increase soil fertility, and contribute to a more sustainable and robust agricultural sector using these technologies. Fostering cooperation among the public, corporate, and academic sectors can also promote innovation and the adoption of cutting-edge waste management techniques. Implementing a waste management system that integrates several waste processing methods, such as recycling, composting, biochar, and biogas production from anaerobic digestion, is necessary. By incorporating recycling, composting, biogas production from anaerobic digestion, and biochar production, an integrated approach to agricultural waste management was established, focusing on establishing a circular and sustainable system within the agricultural domain. Recycling entails repurposing by-products, including animal manure and crop residues, thereby decreasing dependence on external inputs and minimizing the environmental impact. Composting transforms organic waste into compost abundant in nutrients, thereby completing the nutrient cycle and improving the overall health of the soil. Biochar production is achieved by pyrolyzing organic materials, enhancing nutrient availability, water retention, and soil quality, thereby contributing to sustainable agriculture. Concurrently, biogas generation through anaerobic digestion serves the dual purpose of organic waste treatment and renewable energy provision for on-farm utilization, thereby adhering to the tenets of self-reliance and a diminished ecological footprint. The aforementioned integrated approach prioritizes waste valorization, establishment of closed nutrient cycles, and a holistic strategy that tackles the dual challenges of waste disposal and resource efficiency in the agricultural system. Using a biotechnological process called anaerobic digestion, organic wastes such as agricultural residues, animal manure, and food scraps are transformed into digestate and nutrient-rich biogas (Manikandan *et al.*, 2023). Although the digestate can be used as a natural fertilizer, biogas can also be used to generate heat and electricity from renewable sources. Anaerobic digestion is an eco-friendly method of waste management because it reduces waste volume and GHG emissions, with studies showing a net saving in GWP emissions of −31.6 kg CO_2 (Budihardjo *et al.*, 2023b). Composting is the second approach that is widely utilized and sustainable and has an impact of less than -2900 kg CO2 eq/t when combined with anaerobic digestion (Li *et al.*, 2018). Composting is a biological process that converts organic waste into nutrient-rich humus. Composting facilities make it easier for agricultural waste to decompose under controlled conditions and produce high-quality compost (Badawi, 2023). Compost can be used to

improve soil quality, retain water, and increase nutritional content. Compost is produced effectively and safely owing to large-scale composting facilities. Biomass and bioenergy crops, which use agricultural waste, such as crop residues and wood chips, as raw materials for bioenergy production, are widely used in the cited research (Rashedi *et al.*, 2022). Biomass waste is transformed into biofuels, such as bioethanol or bio-oil, and syngas by gasification or pyrolysis. Biofuels have the potential to replace fossil fuels, reduce GHG emissions, and support a circular economy (Kovacs *et al.*, 2022). Biochar manufacturing facilities employ pyrolysis to create biochar, a stable form of carbon, from agricultural waste. Mohammadi *et al.* (2017) showed little environmental impact in reducing the carbon footprint of spring and summer rice by 26% and 14%, respectively. Biochar is a soil additive that improves soil fertility, water retention, and nutrient availability. Additionally, long-term carbon sequestration in the soil helps slow climate change. Plants process agricultural waste and other types of garbage, transforming it into energy, often electricity and heat, using the waste-to-energy (WTE) strategy (Rani *et al.*, 2023). Modern WTE techniques, such as incineration with energy recovery, guarantee the effective and safe disposal of trash while also capturing energy from the burning process and having less impact on the environment with a GWP of −5 kg CO2 eq/t (Tong *et al.,* 2018; Priyambada *et al.*, 2023). Recycling facilities for agricultural waste focus on removing and processing recyclable components from waste streams such as plastics, metals, and paper. Additionally, recycling facilities are looking into novel ways to transform agricultural waste into value-added goods, such as composite materials or biodegradable packaging (Mujtaba *et al.*, 2023). However, many technologies will be ineffective without integrated farming systems that employ a comprehensive approach to waste management and use agricultural waste on-site to promote soil health, boost livestock feed, and produce renewable energy. For instance, animal excrement can be nutrient-rich, and plant residues can be used as animal feed. Decentralized waste management is required to support various approaches and the ensuing environmental effects. Waste management systems promote waste processing at the farm or local level. This approach lowers the cost of transportation, shortens the distances across which waste must be transported, and makes it easier to recycle and reuse the waste locally. Finally, smart technologies such as sensors and the Internet of Things (IoT) should be adopted for effective waste management. These technologies can be incorporated into waste management systems for waste collection, monitoring of composting or anaerobic digestion processes, and ensuring effective resource use. Minimizing agricultural waste at source is imperative for fostering sustainable and resource-efficient farming practices. Farmers can optimize inputs, such as water, fertilizers, and pesticides, by utilizing precision farming technologies, including sensors and GPS-guided equipment, thereby mitigating the risk of environmental damage and over-application. Incorporating biological control methods such as Integrated Pest Management (IPM) practices reduces the dependence on chemical pesticides, thereby decreasing the environmental impact of agriculture. Diversification and crop rotation disrupt the cycle of pests and diseases, improve soil fertility, and reduce the need for excessive chemical inputs. By optimizing harvesting practices, including selective and opportune harvesting, the risk of postharvest spoilage and over-ripening-related losses is reduced to that of mature and healthy harvested crops. Furthermore, implementing cold chain management for perishable produce, establishing adequate storage facilities, and investigating on-farm processing alternatives all contribute to the reduction of postharvest waste.

Gaps and critical findings in implementation

A useful approach for assessing the environmental effects of agricultural waste management systems and facilities is LCA. Although LCA has been used to analyze several waste management strategies, including those specific to agricultural waste, certain significant gaps and discoveries still require attention for a more thorough analysis. It might be challenging to gather complete and accurate data for the entire lifecycle of agricultural waste management technology. Information gaps exist in areas such as trash collection, transportation, treatment, and disposal. The LCA findings may be inaccurate because of missing or conflicting data. Agricultural practices differ significantly based on geography, crop type, and management strategies. This variability must be considered in LCA studies of agricultural waste management to reflect the

environmental effects of various waste management solutions appropriately. Limited Attention to Secondary Effects: The direct environmental effects of waste management are frequently the focus of LCA studies, but they may overlook secondary effects such as indirect land-use change, habitat damage, and biodiversity effects. It is crucial to consider these secondary effects in a more comprehensive analysis. The impact assessment approach is the final step, frequently leading to gaps. In LCA, picking an appropriate impact assessment methodology is crucial for an LCA. To achieve consistency and comparability among studies, designing specialized impact assessment procedures for agricultural waste management is necessary. In LCA studies emphasizing the significance of source segregation and pretreatment of agricultural wastes, separating sources and pretreatment has been one of the criteria for a crucial comparison. The quality of recycled materials or energy recovered from trash can be improved through proper source segregation, which enables more effective waste management procedures. The possibilities of energy recovery are as follows: Anaerobic digestion, biochar, and pyrolysis are the most common agricultural waste management techniques and have shown substantial promise for energy recovery through LCA. Using this technology, farms can generate biogas, charcoal, or bioenergy that can be used on-site or fed into a grid. Recycling nutrients and improving soil quality: Agricultural waste can be recycled back into the soil as organic amendments, boosting soil fertility and lowering the demand for fertilizers. Examples of such wastes include crop residue and animal manure. The relevance of nutrient recycling and its beneficial effects on soil health have been emphasized in LCA studies, but this has not been covered in depth in the aforementioned research. To achieve sustainability, a circular economic strategy to manage agricultural waste can result in more sustainable procedures. LCA studies have shown the possibility of reducing overall environmental effects and resource consumption by reusing and recycling waste materials. To promote sustainable waste management and aid in the transition to a more resource- and environment-friendly agricultural sector, it is important to fill the identified gaps and consider the major findings of the LCA study for agricultural waste management.

RECOMMENDATION

Asian nations can address the issues with managing agricultural waste while creating a more resilient and sustainable agriculture industry by incorporating interactive and sustainable solutions. Governments, communities, and other stakeholders must work together if they are to manage agricultural waste appropriately over the long term. Encourage farmers, local communities, researchers, and policymakers to work together actively to discover regionally unique problems with agricultural waste management and create specialized solutions. Participation from the community encourages a sense of responsibility, which results in more efficient and sustainable waste management techniques. Invest in programs that develop the capacity of waste management stakeholders and educate farmers about sustainable waste management techniques. Training sessions may concentrate on appropriate waste segregation, composting methods, anaerobic digestion, and other cutting-edge agricultural technologies appropriate for Asia. Implementing an integrated waste management system that includes recycling, composting, biochar, and anaerobic digestion biogas production. Recycle, compost, biogas from anaerobic digestion, and biochar synthesis create an integrated approach to agricultural waste management that promotes a circular and sustainable system. By recycling byproducts like animal manure and crop leftovers, dependence on external inputs and environmental effect are reduced. Making nutrient-rich compost from organic waste completes the nutrient cycle and improves soil health. Pyrolyzing organic materials produces biochar, which improves soil quality, water retention, and nutrient availability for sustainable agriculture. Self-reliance and reduced environmental impact are achieved by generating biogas from anaerobic digestion of organic waste and providing renewable energy for on-farm use. The integrated method prioritizes waste valorization, closed nutrient cycles, and a holistic approach to agricultural waste management and resource efficiency. The holistic approach guarantees effective management of various waste streams and maximizes resource recovery. Promoting the use of biogas production methods that generate the fuel from agricultural waste, such as plant leftovers and animal dung. A renewable energy source for rural communities, biogas can be electricity, heating, and cooking. Promotes on-farm

composting and composting of agricultural waste as a natural, inexpensive way to recycle organic matter. Vermicomposting and Composting. As a result, the soil is more fertile, fewer chemical fertilizers are needed, and fewer greenhouse gas emissions are produced. To encourage farmers and waste management facilities to adopt sustainable practices, offer financial incentives and policy support. Environmentally friendly waste management systems can be adopted more quickly if the government offers subsidies, tax breaks, and favorable legislation. Can encourage the successful implementation of waste management practices by facilitating technology transfer and knowledge sharing across Asian nations. The adoption of sustainable solutions can be accelerated by regional cooperation. The circular economy's concepts should also be included into strategies for managing agricultural waste, with a focus on waste reduction, reuse, and recycling. Encouraging the creation of agricultural waste-derived value-added goods including biochar, bio-based materials, and biodegradable packaging. Spend money on research and development to create and enhance agricultural waste management methods. Accept cutting-edge waste-to-energy techniques, intelligent waste collection systems, and other developing technology. The importance of sustainable agricultural waste management and its benefits for the environment, human health, and rural livelihoods should be made more widely known. Campaigns for proper waste management can be promoted through education and behavior change.

CONCLUSION

Life cycle thinking has emerged as an innovative and comprehensive viewpoint that considers the entire recycling process to evaluate the potential and true implications of agricultural waste recycling. The core idea of "sustainable" is life cycle thinking, an original and comprehensive strategy that goes beyond conventional linear evaluations. This study demonstrated the significance of context-specific techniques in recycling agricultural waste. Adapting waste management solutions to local conditions and resource availability is essential because agricultural practices vary between locations. Identifying and prioritizing sensitive criteria are essential when choosing agricultural waste management to ensure efficient and long-lasting waste treatment procedures. Various methods developed and implemented for agricultural waste have changed significantly from landfilling methods to becoming energy sources, such as biochar, biogas, briquettes, and various methods that produce energy, such as solar and electricity. This review provides insights into how recycling agricultural waste can dramatically lower GHG emissions, conserve resources, and improve soil fertility. Composting, anaerobic digestion, and pyrolysis are used to create biochar, a waste recycling method that holds promise for sustainable waste management. In addition to efficiently managing agricultural waste, these technologies help generate electricity and sequester carbon, thereby advancing the objectives of climate change mitigation and circular economy. Widespread adoption of sustainable waste management techniques can be facilitated by integrating community involvement, capacity building, and policy assistance, allowing farmers and local communities to participate actively. Environmentally friendly waste management systems can be adopted more quickly if the government offers subsidies, tax breaks, and favorable legislation. This can encourage the successful implementation of waste management practices by facilitating technology transfer and knowledge sharing across Asian nations. Regional cooperation can accelerate the adoption of sustainable solutions. Although LCA has been used to analyze several waste management strategies, including those specific to agricultural waste, certain significant gaps and discoveries still require attention for a more thorough analysis. It might be difficult to gather complete and accurate data for the entire lifecycle of agricultural waste management technology. Limited Attention to Secondary Effects: The direct environmental effects of waste management are frequently the focus of LCA studies, but they may overlook secondary effects such as indirect land-use change, habitat damage, and biodiversity effects. It is crucial to consider these secondary effects in a more comprehensive analysis. To promote sustainable waste management and aid in the transition to a more resource- and environment-friendly agricultural sector, it is important to fill the gaps that have been identified and consider the major findings of the LCA study for agricultural waste management.

AUTHOR CONTRIBUTIONS

S. Sumiyati is responsible for making whole

concept. B.P Samadikun is responsible for finding out the outline of each manuscript analyzed in managing agricultural waste, determining searches, compiling concepts, reviewing all manuscripts. A. Widiyanti is responsible for finding out the outline of each manuscript analyzed in managing agricultural waste, determining searches, compiling concepts, reviewing all manuscripts. S. Al Qadar reviewed the final report. A.S. Puspita is responsible for preparing drafts, journal analysis sources and reviewing the entire manuscript.

ACKNOWLEDGEMENT

This work was supported by the Directorate of Research, Technology and Community Service (DRPM), the Directorate General of Higher Education, Research and Technology (DIKTI), the Ministry of Education, Culture, Research, and Technology (KEMENDIKBUD) with Grant Number [449A-55/UN.7. D2/PP/VI/2023].

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

OPEN ACCESS

©2024 The author(s). This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit: http://creativecommons.org/licenses/by/4.0/

PUBLISHER NOTE

GJESM Publisher remains neutral concerning jurisdictional claims in published maps and institutional affiliations.

ABBREVIATIONS

%	*Per cent*
AC	*Active carbom*
AD	*Anaerobic digestion*
Adp	*Abiotic depletion*
AF	*Animal Feed*
AP	*Acidification potential*
Br	*Biochar*
Brq	*Briquette*
Bs	*Biogas*
CF	*Carbon footprint*
COMP	*Composting*
Cr	*Crop residue*
Cs	*Combustion*
Dfp	*Direct-fired power*
DRPM	*Directorate of Research, Technology and Community Service*
DIKTI	*Directorate General of Higher Education, Research and Technology*
Ds	*Digestate*
Ect	*Ecotoxicity*
EP	*Eutrophication potential*
FD	*Fossil depletion*
FE	*Freshwater eutrophication*
FW	*Food waste*
GHG	*Greenhouse gasses*
Gs	*Gasification*
GWP	*Global warming potential*
HT	*Human toxicity*
INC	*Incineration*
IPM	*Integrated pest management*
KEMENDIKBUD	*Ministry of Education, Culture, Research, and Technology*

kg CO_2	kilogram of carbon dioxide
kg CO_2 eq/t	kilogram of carbon dioxide equivalent per ton
IoT	Internet of Things
LBP	*Large biogas scale production*
LCA	*Life cycle assessment*
LF	*Landfill*
Ln	*Liquefaction*
LSS	*Large scale solar*
MAE	*Marine Aquatic Ecotoxicity*
MEP	*Marine eutrophication potential*
Mt	*Metric ton*
OB	*Open burning*
OD	*Ozone Depletion*
pm10	*Particulate matter 10nm*
PO	*photochemical oxidation*
POCP	*Photochemical ozone creation potential*
POF	*Photochemical ozone formation*
PRISMA	*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*
PRs	*Pyrolysis*
RCYCL	*Recycle*
RD	*Resource depletion*
SOD	*Stratospheric ozone depletion*
TE	*Terrestrial ecotoxicity*
TETP	*Terrestrial ecotoxicity potential*

REFERENCES

Abbasi, R.; Martinez, P.; Ahmad, R., (2022). The digitization of agricultural industry–a systematic

literature review on agriculture 4.0. Smart Agric. Technol., 100042: 1-24 **(24 Pages)**.

Aberilla, J.M.; Gallego-Schmid, A.; Azapagic, A., (2019). Environmental sustainability of small-scale biomass power technologies for agricultural communities in developing countries. Renewable Energy. 141: 493-506 **(14 Pages)**.

Adekomaya, O.; Majozi, T., (2022). Promoting natural cycle and environmental resilience: A pathway toward sustainable development. S. Afr. J. Chem. Eng., 42: 229-240 **(12 Pages)**.

Ahmed, F.; Hasan, S.; Rana, M.; Sharmin, N., (2023). A conceptual framework for zero waste management in Bangladesh. Int. J. Environ. Sci. Technol., 20(2): 1887-1904 **(18 Pages)**.

Al-Rumaihi, A.; McKay, G.; Mackey, H.R.; Al-Ansari, T., (2020). Environmental impact assessment of food waste management using two composting techniques. Sustainability. 12(4): 1-23 **(23 Pages)**.

Arena, N.; Lee, J.; Clift, R., (2016). Life Cycle Assessment of activated carbon production from coconut shells. J. Cleaner Prod., 125: 68-77 **(10 Pages)**.

Awasthi, M.K.; Sindhu, R.; Sirohi, R.; Kumar, V.; Ahluwalia, V.; Binod, P.; Juneja, A.; Kumar, D.; Yan, B.; Sarsaiya, S., (2022). Agricultural waste biorefinery development towards circular bioeconomy. Renewable Sustainable Energy Rev., 112122: 1-17 **(17 Pages)**.

Badawi, M.A., (2023). Composting farm waste for production of high quality organic fertilizers and sustainable development. Integrated Waste Management: The Circular Economy, United Kingdom **(196 Pages)**.

Baldi, A.; Bruschi, P.; Campeggi, S.; Egea, T.; Rivera, D.; Obón, C.; Lenzi, A., (2022). The renaissance of wild food plants: Insights from Tuscany (Italy). Foods. 11(3): 1-28 **(28 Pages)**.

Bhatt, A.H.; Zhang, Y.; Milbrandt, A.; Newes, E.; Moriarty, K.; Klein, B.; Tao, L., (2023). Evaluation of performance variables to accelerate the deployment of sustainable aviation fuels at a regional scale. Energy Convers. Manage., 275: 1-16 **(16 Pages)**.

Blum, D., (2020). Ways to reduce restaurant industry food waste costsInt. J. Appl. Sci. Technol., 19(1): 1-12 **(12 Pages)**.

Bonilla-Alicea, R.J.; Fu, K., (2019). Systematic map of the social impact assessment field. Sustainability. 11(15): 1-30 **(30 Pages)**.

Budihardjo,M.A.; Huboyo, H.S.; Puspita, A.S.; Hutagaol, J.D.C., (2023a). Utilization of Bokashi Composting and Animal Feed Silage for Sustainable Agricultural Waste Management and Environmental Impact Analysis. Glob.Nest J., 25: 1-10 **(10 Pages)**.

Budihardjo, M.A.; Priyambada, I.B.; Chegenizadeh, A.; Al Qadar, S.; Puspita, A.S., (2023b). Environmental impact technology for life cycle assessment in municipal solid waste management. Global J. Environ. Sci. Manage., 9(SI): 145-172 **(28 Pages)**.

Bureau, J.C.; Antón, J., (2022). Agricultural Total factor productivity and the environment: A guide to emerging best practices in measurement. 1-42 **(42 Pages)**.

Chaudhary, A.; Timsina, P.; Karki, E.; Sharma, A.; Suri, B.; Sharma, R.; Brown, B., (2023). Contextual realities and poverty traps: why South Asian smallholder farmers negatively evaluate conservation agriculture. Renewable Agric. Food Syst., 38: 1-10 **(10 Pages)**.

Chen, B.; Chen, S., (2013). Life cycle assessment of coupling household biogas production to agricultural industry: A case study of biogas-linked persimmon cultivation and processing system. Energy Policy. 62: 707-716 **(10 Pages)**.

Chen, H.L.; Nath, T.K.; Chong, S.; Foo, V.; Gibbins, C.; Lechner,

A.M., (2021). The plastic waste problem in Malaysia: management, recycling and disposal of local and global plastic waste. SN Appl. Sci., 3: 1-15 **(15 Pages)**.

Chen, S.; Chen, B.; Song, D., (2012). Life-cycle energy production and emissions mitigation by comprehensive biogas–digestate utilization. Bioresour. Technol., 114: 357-364 **(8 Pages)**.

Chepeliev, M.; Hertel, T.W.; van der Mensbrugghe, D., (2022). Cutting Russia's fossil fuel exports: Short-term pain for long-term gain. SSRN, 1-30 **(30 Pages)**.

Chimi, P.M.; Mala, W.A.; Fobane, J.L.; Essouma, F.M.; Mbom II, J.A.; Funwi, F.P.; Bell, J.M., (2022). Climate change perception and local adaptation of natural resource management in a farming community of Cameroon: A case study. Environ. Challenges. 100539: 1-10 **(10 Pages)**.

Clare, A.; Shackley, S.; Joseph, S.; Hammond, J.; Pan, G.; Bloom, A., (2015). Competing uses for China's straw: the economic and carbon abatement potential of biochar. Gcb Bioenergy. 7(6): 1272-1282 **(11 Pages)**.

Corominas, L.; Byrne, D.M.; Guest, J.S.; Hospido, A.; Roux, P.; Shaw, A., Short, M.D., (2020). The application of life cycle assessment (LCA) to wastewater treatment: A best practice guide and critical review. WaterRes., 184: 1-18 **(18 Pages)**.

D'Agaro, E.; Gibertoni, P.; Esposito, S., (2022). Recent trends and economic aspects in the rainbow trout (Oncorhynchus mykiss) sector. Appl. Sci., 12(17): 1-19 **(19 Pages)**.

Dahiya, S.; Katakojwala, R.; Ramakrishna, S.; Mohan, S.V., (2020). Biobased products and life cycle assessment in the context of circular economy and sustainability. Mater. Circ. Econ., 2: 1-28 **(28 Pages)**.

Dai, Y.; Zheng, H.; Jiang, Z.; Xing, B., (2020). Comparison of different crop residue-based technologies for their energy production and air pollutant emission. Sci. Total Environ., 136122: 1-10 **(10 Pages)**.

Deepak, A.; Sharma, V.; Kumar, D., (2022). Life cycle assessment of biomedical waste management for reduced environmental impacts. J. Cleaner Prod., 131376: 1-14 **(14 Pages)**.

Eyhorn, F.; Muller, A.; Reganold, J.P.; Frison, E.; Herren, H.R.; Luttikholt, L.; Mueller, A.; Sanders, J.; Scialabba, N.E.-H.; Seufert, V., (2019). Sustainability in global agriculture driven by organic farming. Nat. Sustainability. 2(4): 253-255 **(3 Pages)**.

Ezugwu, A.E.; Ikotun, A.M.; Oyelade, O.O.; Abualigah, L.; Agushaka, J.O.; Eke, C.I.; Akinyelu, A.A., (2022). A comprehensive survey of clustering algorithms: State-of-the-art machine learning applications, taxonomy, challenges, and future research prospects. Eng. Appl. Artif. Intell., 104743: 1-43 **(43 Pages)**.

Farooq, M.; Cheng, J.; Khan, N.U.; Saufi, R.A.; Kanwal, N.; Bazkiaei, H.A., (2022). Sustainable waste management companies with innovative smart Solutions: A Systematic Review and Conceptual Model. Sustainability. 14(20): 1-19 **(19 Pages)**.

Fielke, S.; Taylor, B.M.; Coggan, A.; Jakku, E.; Davis, A.M.; Thorburn, P.J.; Webster, A.J.; Smart, J.C., (2022). Understanding power, social capital and trust alongside near real-time water quality monitoring and technological development collaboration. J. Rural Stud., 92: 120-131 **(12 Pages)**.

Ganesan, K.; Valderrama, C., (2022). Anticipatory life cycle analysis framework for sustainable management of end-of-life crystalline silicon photovoltaic panels. Energy. 123207: 1-13 **(13 Pages)**.

Gilani, H.R.; Ibrik, K.; Sanchez, D.L., (2023). Techno-economic and policy analysis of hydrogen and gasoline production from forest biomass, agricultural residues and municipal solid waste in C alifornia. Biofuels, Bioprod. Biorefin. 1-16 **(16 Pages)**.

Haga, K., (2021). Sustainable recycling of livestock wastes by composting and environmentally friendly control of wastewater and odors. J. Environ. Eng. Sci., 10: 163-178 **(16 Pages)**.

Haque, F.; Fan, C.; Lee, Y.-y., (2023). From waste to value: Addressing the relevance of waste recovery to agricultural sector in line with circular economy. J. Cleaner Prod., 137873: 1-12 **(12 pages)**.

Haumahu, S.A.Q.; Budihardjo, M.A.; Priyambada, I.B.; Puspita, A.S., (2023). Review of Household Waste Management Technology for a Greener Solution to Accomplish Circular Economy in Salatiga, Indonesia. Ecol. Eng. Environ. Technol., 9: 1-14 **(14 Pages)**.

Hauschild, M.Z.; Kara, S.; Røpke, I., (2020). Absolute sustainability: Challenges to life cycle engineering. CIRP Ann., 69(2): 533-553 **(21 Pages)**.

Hemidat, S.; Achouri, O.; El Fels, L.; Elagroudy, S.; Hafidi, M.; Chaouki, B.; Ahmed, M.; Hodgkinson, I.; Guo, J., (2022). Solid waste management in the context of a circular economy in the MENA region. Sustainability. 14(1): 1-24 **(24 Pages)**.

ISO 14040., (2006). Environmental management. Life cycle assessment principles and framework. International Standard International Organization for Standardization.

ISO 14044., (2006). Environmental management. Life cycle assessment requirements and guidlines. International Standard International Organization for Standardization.

Iwuozor, K.O.; Emenike, E.C.; Ighalo, J.O.; Eshiemogie, S.; Omuku, P.E.; Adeniyi, A.G., (2022). Valorization of sugar industry's by-products: a perspective. Sugar Tech., 24(4): 1052-1078 **(27 Pages).**

Kajtaz, M., (2019). Unconstrained shape optimisation of a lightweight side door reinforcing crossbar for passenger vehicles using a comparative evaluation method. Int. J. Automot. Technol., 20: 157-168 **(12 Pages)**.

Kannan, M.; Bojan, N.; Swaminathan, J.; Zicarelli, G.; Hemalatha, D.; Zhang, Y.; Ramesh, M., Faggio, C., (2023). Nanopesticides in agricultural pest management and their environmental risks: A review. Int. J. Environ. Sci. Technol., 20: 10507-10532 **(26 Pages)**.

Karić, N.; Maia, A.S.; Teodorović, A.; Atanasova, N.; Langergraber, G.; Crini, G.; Ribeiro, A.R.; Đolić, M., (2022). Bio-waste valorisation: Agricultural wastes as biosorbents for removal of (in) organic pollutants in wastewater treatment.

Chem. Eng. J. Adv., 100239: 1-17 **(17 Pages)**.

Kenett, R.S.; Zacks, S.; Gedeck, P., (2023). Industrial statistics: A computer-based approach with Python. Springer, Nature. 1-471 **(471 Pages)**.

Keng, Z.X.; Chong, S.; Ng, C.G.; Ridzuan, N.I.; Hanson, S.; Pan, G.-T.; Lau, P.L.; Supramaniam, C.V.; Singh, A.; Chin, C.F., (2020). Community-scale composting for food waste: A life-cycle assessment-supported case study. J. Cleaner Prod., 121220: 1-11 **(11 Pages)**.

Khanali, M.; Ghasemi-Mobtaker, H.; Varmazyar, H.; Mohammadkashi, N.; Chau, K.-w.; Nabavi-Pelesaraei, A., (2022). Applying novel eco-exergoenvironmental toxicity index to select the best irrigation system of sunflower production. Energy. 123822: 1-15 **(15 Pages)**.

Khandelwal, H.; Dhar, H.; Thalla, A.K.; Kumar, S., (2019). Application of life cycle assessment in municipal solid waste management: A worldwide critical review. J. Cleaner Prod., 209: 630-654 **(25 Pages)**.

Kharola, S.; Ram, M.; Mangla, S.K.; Goyal, N.; Nautiyal, O.; Pant, D.; Kazancoglu, Y., (2022). Exploring the green waste management problem in food supply chains: A circular economy context. J. Cleaner Prod., 131355: 1-14 **(14 Pages)**.

Koido, K.; Takeuchi, H.; Hasegawa, T., (2018). Life cycle environmental and economic analysis of regional-scale food-waste biogas production with digestate nutrient management for fig fertilisation. J. Cleaner Prod., 190: 552-562 **(11 Pages)**.

Koul, B.; Yakoob, M.; Shah, M.P., (2022). Agricultural waste management strategies for environmental sustainability. Environ. Res., 112285: 1-16 **(16 Pages)**.

Kountios, G.; Konstantinidis, C.; Antoniadis, I., (2023). Can the adoption of ICT and advisory services be considered as a tool of competitive advantage in agricultural holdings? A literature review. Agronomy, 13(2): 1-20 **(20 Pages)**.

Kovacs, E.; Hoaghia, M.-A.; Senila, L.; Scurtu, D.A.; Varaticeanu, C.; Roman, C.; Dumitras, D.E., (2022). Life cycle assessment of biofuels production processes in viticulture in the context of circular economy. Agronomy. 12(6): 1-15 **(15 Pages)**.

Kumar Sarangi, P.; Subudhi, S.; Bhatia, L.; Saha, K.; Mudgil, D.; Prasad Shadangi, K.; Srivastava, R.K.; Pattnaik, B.; Arya, R.K., (2023). Utilization of agricultural waste biomass and recycling toward circular bioeconomy. Environ. Sci. Pollut. Res., 30(4): 8526-8539 **(14 Pages)**.

Kurniawan, T.A.; Othman, M.H.D.; Hwang, G.H.; Gikas, P., (2022). Unlocking digital technologies for waste recycling in Industry 4.0 era: A transformation towards a digitalization-based circular economy in Indonesia. J. Cleaner Prod., 131911: 1-16 **(16 Pages)**.

Laurent, A.; Weidema, B.P.; Bare, J.; Liao, X.; Maia de Souza, D.; Pizzol, M.; Sala, S.; Schreiber, H.; Thonemann, N.; Verones, F., (2020). Methodological review and detailed guidance for the life cycle interpretation phase. J. Ind. Ecol., 24(5): 986-1003 **(18 Pages)**.

Lee, S.Y.; Sankaran, R.; Chew, K.W.; Tan, C.H.; Krishnamoorthy, R.; Chu, D.-T.; Show, P.-L., (2019). Waste to bioenergy: a review on the recent conversion technologies. BMC Energy. 1(1): 1-22 **(22 Pages)**.

Li, Y.; Manandhar, A.; Li, G.; Shah, A., (2018). Life cycle assessment of integrated solid state anaerobic digestion and composting for on-farm organic residues treatment. Waste Manage., 76: 294-305 **(12 Pages)**.

Llorach-Massana, P.; Cirrincione, L.; Sierra-Perez, J.; Scaccianoce, G.; La Gennusa, M.; Peña, J.; Rieradevall, J., (2023). Environmental assessment of a new building envelope material derived from urban agriculture wastes: the case of the tomato plants stems. Int J Life Cycle Assess., 28: 813-827 **(15 Pages)**.

Ma, H.; Li, M.; Tong, X.; Dong, P., (2023). Community-Level household waste disposal behavior simulation and visualization under multiple incentive policies—An agent-based modelling approach. Sustainability. 15(13): 1-15 **(15 Pages)**.

Manco, P.; Caterino, M.; Rinaldi, M.; Fera, M., (2023). Additive manufacturing in green supply chains: A parametric model for life cycle assessment and cost. Sustainable Prod. Consumption. 36: 463-478 **(16 Pages)**.

Manikandan, S.; Vickram, S.; Sirohi, R.; Subbaiya, R.; Krishnan, R.Y.; Karmegam, N.; Sumathijones, C.; Rajagopal, R.; Chang, S.W.; Ravindran, B., (2023). Critical review of biochemical pathways to transformation of waste and biomass into bioenergy. Bioresour. Technol., 128679: 1-20 **(20 Pages)**.

Marmiroli, B.; Rigamonti, L.; Brito-Parada, P.R., (2021). Life cycle assessment in mineral processing–a review of the role of flotation. Int J Life Cycle Assess., 27: 62-81 **(20 Pages)**.

Mazzi, A., 2020. Introduction. Life cycle thinking. in: Life cycle sustainability assessment for decision-making, Elsevier. 1-19 **(19 Pages)**.

McAuliffe, G.A.; Takahashi, T.; Lee, M.R., (2020). Applications of nutritional functional units in commodity-level life cycle assessment (LCA) of agri-food systems. Int. J. Life Cycle Assess., 25: 208-221 **(14 Pages)**.

Mehmood, Y.; Arshad, M.; Kächele, H., (2022). Effects of wastewater reuse on perceived health risks of farmers in Pakistan: Application of the zero-inflated poisson regression model. J. Cleaner Prod., 133430: 1-11 **(11 Pages)**.

Mio, A.; Fermeglia, M.; Favi, C., (2022). A critical review and normalization of the life cycle assessment outcomes in the naval sector. Articles description. J. Cleaner Prod., 133476: 1-22 **(22 Pages)**.

Mizik, T., (2023). How can precision farming work on a small scale? A systematic literature review. Precis. Agric., 24(1): 384-406 **(23 Pages)**.

Mo, W.; Xiong, Z.; Leong, H.; Gong, X.; Jiang, L.; Xu, J.; Su, S.; Hu, S.; Wang, Y.; Xiang, J., (2022). Processes simulation and environmental evaluation of biofuel production via Co-pyrolysis of tropical agricultural waste. Energy. 123016: 1-13 **(13 Pages)**.

Mohammadi, A.; Cowie, A.; Anh Mai, T.L.; de la Rosa, R.A.; Kristiansen, P.; Brandão, M.; Joseph, S., (2016). Biochar use for climate-change mitigation in rice cropping systems. J. Cleaner Prod., 116: 61-70 **(10 Pages)**.

Mohammadi, A.; Cowie, A.L.; Anh Mai, T.L.; Brandão, M.; Anaya

de la Rosa, R.; Kristiansen, P.; Joseph, S., (2017). Climate-change and health effects of using rice husk for biochar-compost: Comparing three pyrolysis systems J. Cleaner Prod., 162: 260-272 **(13 Pages)**.

Mondal, S.; Palit, D. (2022). Challenges in natural resource management for ecological sustainability. in: Natural resources conservation and advances for sustainability, Elsevier. 29-59 **(31 Pages)**.

Mufti, M.; Fathurahman, M.R., (2022). Penyuluhan pemanfaatan limbah pertanian untuk pakan ternak alternatif menggunakan mesin pencacah rumput multifungsi dengan proses amoniase pada kelompok ternak makmur Desa Kebondalem, Jombang. Sarwahita. 19: 583-594 **(12 Pages)**.

Muhie, S.H., (2022). Novel approaches and practices to sustainable agriculture. J. Agric. Food Res., 100446: 1-11 **(11 Pages)**.

Mujtaba, M.; Fraceto, L.; Fazeli, M.; Mukherjee, S.; Savassa, S.M.; de Medeiros, G.A.; Santo Pereira, A.d.E.; Mancini, S.D.; Lipponen, J.; Vilaplana, F., (2023). Lignocellulosic biomass from agricultural waste to the circular economy: A review with focus on biofuels, biocomposites and bioplastics. J. Cleaner Prod., 136815: 1-23 **(23 Pages)**.

Nasution, M.A.; Wibawa, D.S.; Ahamed, T.; Noguchi, R., (2018). Comparative environmental impact evaluation of palm oil mill effluent treatment using a life cycle assessment approach: A case study based on composting and a combination for biogas technologies in North Sumatera of Indonesia. J. Cleaner Prod., 184: 1028-1040 **(13 Pages)**.

Nayal, F.S.; Mammadov, A.; Ciliz, N., (2016). Environmental assessment of energy generation from agricultural and farm waste through anaerobic digestion. J. Environ. Manage., 184: 389-399 **(11 Pages)**.

Nguyen, T.D.P.; Le, T.V.A.; Show, P.L.; Nguyen, T.T.; Tran, M.H.; Tran, T.N.T.; Lee, S.Y., (2019). Bioflocculation formation of microalgae-bacteria in enhancing microalgae harvesting and nutrient removal from wastewater effluent. Bioresour. Technol., 272: 34-39 **(6 Pages)**.

Nigussie, Z.; Tsunekawa, A.; Haregeweyn, N.; Tsubo, M.; Adgo, E.; Ayalew, Z.; Abele, S., (2021). The impacts of Acacia decurrens plantations on livelihoods in rural Ethiopia. Land Use Policy., 104928: 1-12 **(12 Pages)**.

Onat, N.C.; Kucukvar, M., (2022). A systematic review on sustainability assessment of electric vehicles: Knowledge gaps and future perspectives. Environ. Impact Assess. Rev., 106867: 1-13 **(13 Pages)**.

Onyeaka, H.; Tamasiga, P.; Nwauzoma, U.M.; Miri, T.; Juliet, U.C.; Nwaiwu, O.; Akinsemolu, A.A., (2023). Using artificial intelligence to tackle food waste and enhance the circular economy: maximising resource efficiency and minimising environmental impact: A Review. Sustainability. 15(13): 1-20 **(20 Pages)**.

Pantusa, D.; Saponieri, A.; Tomasicchio, G.R., (2023). Assessment of coastal vulnerability to land-based sources of pollution and its application in Apulia, Italy. Sci. Total Environ. , 163754: 1-12 **(12 Pages)**.

Petrillo, A.; Colangelo, F.; Farina, I.; Travaglioni, M.; Salzano, C.; Cioffi, R., (2022). Multi-criteria analysis for Life Cycle Assessment and Life Cycle Costing of lightweight artificial aggregates from industrial waste by double-step cold bonding palletization. J. Cleaner Prod.,131395: 1-14 **(14 Pages)**.

Phuang, Z.X.; Lin, Z.; Liew, P.Y.; Hanafiah, M.M.; Woon, K.S., (2022). The dilemma in energy transition in Malaysia: A comparative life cycle assessment of large scale solar and biodiesel production from palm oil. J. Cleaner Prod., 131475: 1-13 **(13 Pages)**.

Pratibha, G.; Srinivas, I.; V. Rao, K.; M.K. Raju, B.; Shanker, A.K.; Jha, A.; Uday Kumar, M.; Srinivasa Rao, K.; Sammi Reddy, K., (2019). Identification of environment friendly tillage implement as a strategy for energy efficiency and mitigation of climate change in semiarid rainfed agro ecosystems. J. Cleaner Prod., 214: 524-535 **(12 Pages)**.

Priyambada, I.; Budihardjo, M.; Al Qadar, S.; Puspita, A., (2023). Bibliometric analysis for sustainable food waste using multicriteria decision. Global J. Environ. Sci. Manage., 9(SI): 271-300 **(30 Pages)**.

Puspita, A.S.; Budihardjo, M.A.; Samadikun, B.P., (2023). Evaluating coconut fiber and fly ash composites for use in landfill retention layers. Global Nest J., 25(4): 1-7 **(7 Pages)**.

Qin, T.; She, L.; Wang, Z.; Chen, L.; Xu, W.; Jiang, G.; Zhang, Z., (2022). The Practical Experience of "Zero Waste City" Construction in Foshan City Condenses the Chinese Solution to the Sustainable Development Goals. Sustainability. 14(19): 1-16 **(16 Pages)**.

Rahimi, Z.; Anand, A.; Gautam, S., (2022). An overview on thermochemical conversion and potential evaluation of biofuels derived from agricultural wastes. Energy Nexus, 100125: 1-30 **(30 Pages)**.

Rani, G.M.; Pathania, D.; Umapathi, R.; Rustagi, S.; Huh, Y.S.; Gupta, V.K.; Kaushik, A.; Chaudhary, V., (2023). Agro-waste to sustainable energy: A green strategy of converting agricultural waste to nano-enabled energy applications. Sci. Total Environ., 162667: 1-28 **(28 Pages)**.

Rashedi, A.; Gul, N.; Hussain, M.; Hadi, R.; Khan, N.; Nadeem, S.G.; Khanam, T.; Asyraf, M.; Kumar, V., (2022). Life cycle environmental sustainability and cumulative energy assessment of biomass pellets biofuel derived from agroforest residues. PLoS One, 17(10): 1-18 **(18 Pages)**.

Read, Q.D.; Muth, M.K., (2021). Cost-effectiveness of four food waste interventions: Is food waste reduction a "win–win?". Resour. Conserv. Recycl., 105448: 1-10 **(10 Pages)**.

Robb, S.; Dargusch, P., (2018). A financial analysis and life-cycle carbon emissions assessment of oil palm waste biochar exports from Indonesia for use in Australian broad-acre agriculture. Carbon Manage., 9(2): 105-114 **(10 Pages)**.

Sabet, H.; Moghaddam, S.S.; Ehteshami, M., (2023). A comparative life cycle assessment (LCA) analysis of innovative methods employing cutting-edge technology to improve sludge reduction directly in wastewater handling units. J. Water Process Eng., 103354: 1-13 **(13 Pages)**.

Samela, C.; Imbrenda, V.; Coluzzi, R.; Pace, L.; Simoniello, T.; Lanfredi, M., (2022). Multi-decadal assessment of soil loss

in a Mediterranean region characterized by contrasting local climates. Land. 11(7): 1-25 **(25 Pages)**.

Saravanan, A.; Kumar, P.S.; Jeevanantham, S.; Karishma, S.; Tajsabreen, B.; Yaashikaa, P.; Reshma, B., (2021). Effective water/wastewater treatment methodologies for toxic pollutants removal: Processes and applications towards sustainable development. Chemosphere. 130595: 1-15 **(15 Pages)**.

Shaheen, J.; Fseha, Y.H.; Sizirici, B., (2022). Performance, life cycle assessment, and economic comparison between date palm waste biochar and activated carbon derived from woody biomass. Heliyon. 8(12): 1-13 **(13 Pages)**.

Shaikh, T.A.; Rasool, T.; Lone, F.R., (2022). Towards leveraging the role of machine learning and artificial intelligence in precision agriculture and smart farming. Comput. Electron. Agric., 107119: 1-29 **(29 Pages)**.

Sharma, H.; Kumar, H.; Mangla, S.K., (2023a). Enablers to computer vision technology for sustainable E-waste management. J. Cleaner Prod., 137396: 1-16 **(16 Pages)**.

Sharma, P.; Bano, A.; Verma, K.; Yadav, M.; Varjani, S.; Singh, S.P.; Tong, Y.W., (2023b). Food waste digestate as biofertilizer and their direct applications in agriculture. Bioresour. Technol. Rep., 101515: 1-12 **(12 Pages)**.

Shokri, A.; Fard, M.S., (2023). Water-energy nexus: Cutting edge water desalination technologies and hybridized renewable-assisted systems; challenges and future roadmaps. Sustainable Energy Technol. Assess., 103173: 1-18 **(18 Pages)**.

Smith, J.; Yeluripati, J.; Smith, P.; Nayak, D.R., (2020). Potential yield challenges to scale-up of zero budget natural farming. Nat. Sustainability. 3(3): 247-252 **(6 Pages)**.

Sparrevik, M.; Lindhjem, H.; Andria, V.; Fet, A.M.; Cornelissen, G., (2014). Environmental and socioeconomic impacts of utilizing waste for biochar in rural areas in Indonesia–a systems perspective. Environ. Sci. Technol., 48(9): 4664-4671 **(5 Pages)**.

Starek-Wójcicka, A.; Stoma, M.; Osmólska, E.; Rydzak, L.; Sobczak, P. 2022. Economic effects of food industry waste management in the context of sustainable development. In: Pascuzzi, S., Santoro, F. (eds) Farm Machinery and Processes Management in Sustainable Agriculture. FMPMSA 2022. Lecture Notes Civil Eng., 289: 97-106 **(10 Pages)**.

Tedesco, D.; de Almeida Moreira, B.R.; Júnior, M.R.B.; Maeda, M.; da Silva, R.P., (2023). Sustainable management of sweet potatoes: A review on practices, strategies, and opportunities in nutrition-sensitive agriculture, energy security, and quality of life. Agric. Syst., 103693: 1-11 **(11 Pages**).

Tong, H.; Shen, Y.; Zhang, J.; Wang, C.-H.; Ge, T.S.; Tong, Y.W., (2018). A comparative life cycle assessment on four waste-to-energy scenarios for food waste generated in eateries. Appl. Energy., 225: 1143-1157 **(15 Pages)**.

Torkayesh, A.E.; Rajaeifar, M.A.; Rostom, M.; Malmir, B.; Yazdani, M.; Suh, S.; Heidrich, O., (2022). Integrating life cycle assessment and multi criteria decision making for sustainable waste management: key issues and recommendations for future studies. Renewable Sustainable Energy Rev., 112819: 1-24 **(24 Pages)**.

Trummer, P.; Ammerer, G.; Scherz, M., (2022). Sustainable consumption and production in the extraction and processing of raw materials—measures sets for achieving SDG target 12.2. Sustainability. 14(17): 1-18 **(18 Pages)**.

Tseng, M.L.; Ha, H.M.; Tran, T.P.T.; Bui, T.D.; Chen, C.C.; Lin, C.W., (2022). Building a data-driven circular supply chain hierarchical structure: Resource recovery implementation drives circular business strategy. Bus Strategy Environ., 31(5): 2082-2106 **(25 Pages)**.

Vasseghian, Y.; Arunkumar, P.; Joo, S.-W.; Gnanasekaran, L.; Kamyab, H.; Rajendran, S.; Balakrishnan, D.; Chelliapan, S.; Klemeš, J.J., (2022). Metal-organic framework-enabled pesticides are an emerging tool for sustainable cleaner production and environmental hazard reduction. J. Cleaner Prod., 133966: 1-13 **(13 Pages)**.

Vu, T.; Vu, D.; Jensen, L.; Sommer, S.; Bruun, S., (2015). Life cycle assessment of biogas production in small-scale household digesters in Vietnam. Asian-Australas. J. Anim. Sci., 28(5): 716-729 **(14 Pages)**.

Wahyono, Y.; Hadiyanto, H.; Gheewala, S.H.; Budihardjo, M.A.; Adiansyah, J.; Widayat, W.; Christwardana, M., (2023). Life cycle assessment for evaluating the energy balance of the multi-feedstock biodiesel production process in Indonesia. Int. J. Ambient Energy. 44(1): 1255-1270 **(15 Pages)**.

Wang, Q.-L.; Li, W.; Gao, X.; Li, S.-J., (2016). Life cycle assessment on biogas production from straw and its sensitivity analysis. Bioresour. Technol., 201: 208-214 **(15 Pages**).

Wang, Y.; Wu, X.; Tong, X.; Li, T.; Wu, F., (2018). Life cycle assessment of large-scale and household biogas plants in northwest China. J. Cleaner Prod., 192: 221-235 **(15 Pages)**.

Wu, L.; Elshorbagy, A.; Pande, S.; Zhuo, L., (2021). Trade-offs and synergies in the water-energy-food nexus: The case of Saskatchewan, Canada. Resour. Conserv. Recycl., 105192: 1-14 **(14 Pages)**.

Yadav, P.; Samadder, S.R., (2018). A critical review of the life cycle assessment studies on solid waste management in Asian countries. J. Cleaner Prod., 185: 492-515 **(24 Pages)**.

Yang, X.; Han, D.; Zhao, Y.; Li, R.; Wu, Y., (2020). Environmental evaluation of a distributed-centralized biomass pyrolysis system: A case study in Shandong, China. Sci. Total Environ., 136915: 1-11 **(11 Pages)**.

Zeug, W.; Bezama, A.; Thrän, D., (2023). Life cycle sustainability assessment for sustainable bioeconomy, societal-ecological transformation and beyond. in: Progress in Life cycle assessment 2021, Springer. 131-159 **(29 Pages)**.

Zhu, X.; Labianca, C.; He, M.; Luo, Z.; Wu, C.; You, S.; Tsang, D.C., (2022). Life-cycle assessment of pyrolysis processes for sustainable production of biochar from agro-residues. Bioresour. Technol., 127601: 1-13 **(13 Pages)**.

Zoppi, G.; Tito, E.; Bianco, I.; Pipitone, G.; Pirone, R.; Bensaid, S., (2023). Life cycle assessment of the biofuel production from lignocellulosic biomass in a hydrothermal liquefaction–aqueous phase reforming integrated biorefinery. Renewable Energy. 206: 375-385 **(11 Pages)**.

AUTHOR (S) BIOSKETCHES

S. Sumiyati, Dr., Assisstant Professor, Department of Environmental Engineering, Universitas Diponegoro, *Jl. Prof. Sudarto SH.,* Semarang, Indonesia.
- Email: m.budihardjo@ft.undip.ac.id
- ORCID: 0000-0002-1256-3076
- Web of Science ResearcherID: NA
- Scopus Author ID: 57194072276
- Homepage: https://kepakaran.apps.undip.ac.id/lecturers/profile/2IYUgEYBSVNj/publications

B.P. Samadikun, Ph.D., Instructor, Department of Environmental Engineering, Universitas Diponegoro, Jl. Prof. Sudarto SH., Semarang, Indonesia.
- Email: budisamadikun@lecturer.undip.ac.id
- ORCID: 0000-0002-0771-0684
- Web of Science ResearcherID: NA
- Scopus Author ID: -
- Homepage: https://kepakaran.apps.undip.ac.id/lecturers/profile/_jLjZME1Kbmh/research

A. Widiyanti, M.T., Instructor, Environmental Engineering Department, Universitas Nahdlatul Ulama Sidoarjo, Sidoarjo 61218, Indonesia.
- Email: astrini.widiyanti@gmail.com
- ORCID: 0009-0001-7681-5260
- Web of Science ResearcherID: NA
- Scopus Author ID: 57763692300
- Homepage: https://sinta.kemdikbud.go.id/authors/profile/6774130

M.A. Budihardjo, Ph.D., Professor, Department of Environmental Engineering, Universitas Diponegoro, *Jl. Prof. Sudarto SH.,* Semarang, Indonesia.
- Email: m.budihardjo@ft.undip.ac.id
- ORCID: 0000-0002-1256-3076
- Web of Science ResearcherID: NA
- Scopus Author ID: 564955416600
- Homepage: https://www.undip.ac.id/?s=arief+budihardjo

S. Al Qadar, M.T., Asisstant Professor, Environmental Science Department, University of Mataram, Jl Majapahit, Mataram, Indonesia.
- Email: syahrulalqadar@gmail.com
- ORCID: 0009-0006-7103-6256
- Web of Science ResearcherID: NA
- Scopus Author ID: NA
- Homepage: https://lingkungan.ft.undip.ac.id/ensi-rg-5/

A.S. Puspita, M.T., Asisstant Professor, Environmental Sustainability Research Group, Universitas Diponegoro, Jl. Prof. Sudarto SH, Semarang, Indonesia.
- Email: annisasila.research@gmail.com
- ORCID: 0000-0002-5207-0735
- Web of Science ResearcherID: NA
- Scopus Author ID: 57361025800
- Homepage: https://lingkungan.ft.undip.ac.id/ensi-rg-5/

HOW TO CITE THIS ARTICLE

Sumiyati, S.; Samadikun, B.P.; Widiyanti, A; Budihardjo, M.A.; Haumahu, S.A.Q.; Puspita, A.S., (2024). Life cycle assessment of agricultural waste recycling for sustainable environmental impact. Global J. Environ. Sci. Manage., 10(2): 907-938.

DOI: 10.22034/gjesm.2024.02.30

URL: https://www.gjesm.net/article_709361.html